Information Systems Reengineering and Integration

Second Edition

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To the memory of my parents Fong Chung Lung and Sun Oil Yuk

Preface

Over the part three decades, there has been a tremendous investment made in information systems. Such systems have evolved from file systems, through database systems, and we are now seeing the emergence of management information systems (MIS) and executive information systems (EIS). With the advent of each new form of technology, there has been a need to redesign and re-implement existing information systems.

In recent years, a great deal of resources have been put into the area of reengineering. Reengineering involves the redesign of existing information systems, while using as much of the existing systems as possible. That is, the approach taken is to transform the existing information systems into the format needed for the new technology, rather than to throw away the old systems. Such an approach has obvious benefits, particularly if it can be automated and/or supported by methods and tools.

Very often, a large company has multiple heterogeneous databases for MIS operations. The company needs to integrate them into a corporate database for its decision support systems. Subsequently, schema integration must be performed to resolve the conflicts between two databases with respect to data name, data type, and data semantics. Schema integration must be done before data integration, which is mainly concerned with the automation of loading data from source databases into an integrated database. Furthermore, in reality, user demands are changing daily. It is essential for companies to enhance and evolve the existing database schemas to meet the new data requirements.

This text will focus upon practical approaches to information systems reengineering and integration, including:

- The conversion and integration of hierarchical or network database systems into relational database technology, or from a relational to an object-oriented database and XML database.

- The integration of multiple databases, and also between a database system and an expert system to produce MIS (management information systems) and EIS (executive information systems).

The text will summarize the concepts, the approach to be taken and the benefits to be gained in these two crucial technological areas. It will focus upon proven methods and tools for:

- Converting hierarchical and network databases to relational technology, or from relational to object-oriented databases, or from relational to XML databases.

- Reengineering existing systems to produce MIS and EIS.

The book will describe in detail:

- Database conversion techniques

- Reverse engineering and forward engineering for data modeling

- A reengineering methodology for information systems

- Techniques of schema and data intergration

From a professional point of view, this book proposes a general solution for the problem of system migration to new database technology. It offers a systematic software engineering approach for reusing existing database systems built with "old" technology by converting them into the new database technology. As a result, investment in the existing information systems can be protected by upgrading database systems and expert systems, rather than phasing them out.

Preface

This book focuses on methodologies for information systems reengineering and integration. It applies many examples, illustrations, and case studies of procedures for reusing existing database systems and information systems. The objective is to make the methodologies very practical for readers to follow. Even though there are many technical terminologies used in the book, the techniques proposed are simple enough for students or computer professionals to follow. The content of the book is divided into nine chapters.

Chapter 1 gives an overview of information systems, and deals with its past history, its evolution to management information systems, its problems encountered in file systems, its solution found in database systems and expert systems, and the need for the reengineering of existing database systems and information systems. It also describes database conversion, the merge of multiple databases, and the integration of the expert systems and the database systems into an expert database system. It show how to apply data transformation for electronic data interchange on the Internet.

Chapter 2 describes basic theories and data structures of various data models, including hierarchical, network, relational, object-oriented, and XML. Their pros and cons are discussed. Expert systems technology is explained. The advanced expert database systems are introduced. The basic concepts discussed include data definition language, data manipulation language, forward chaining, backward chaining, procedural language and non-procedural language, data type definition, and XML schema definition.

Chapter 3 covers various techniques in schema translation from nonrelational (e.g., hierarchical or network) to relational, and from relational to object-oriented and XML databases. Reverse engineering is adopted to recover original schema's semantics into the conceptual model of the Extended Entity Relationship (EER) model. Forward engineering is used to map the EER model into relational or Unified Model Language (UML), a conceptual model for an object-oriented database.

Chapter 4 shows a methodology of converting data from nonrelatonal database to relational database, and from relational database to object-oriented database, and also from relational database into XML database. Unload and upload processing in a logical level approach is adopted to do the task.

Chapter 5 explains a methodology of emulating SQL by using a hierarchical or network database data manipulation language. The methodology can be used in program translation from relational database programs to nonrelational database programs. The objective is to provide a relational interface to the nonrelational database so that the users can use SQL to access a hierarchical or network database. It also presents a methodology of translating SQL query into OSQL (Object SQL or Object Query Language) and XQL (XML Query Language).

Chapter 6 summarizes the database conversion methodology for converting hierarchical or network databases to relational databases. The methodology is in three phases: schema translation, transaction translation, and data conversion. The first and second phases provide a relational interface to a nonrelational database as a temporary solution in the database conversion (migration) process. The third phase provides a permanent solution to convert data from nonrelational database to relational database after nonrelational database programs are phased out or rewritten. A case study of constructing an XML view of a relational database involving schema and data transformation from relational into XML is presented.

Chapter 7 offers a state-of-the-art methodology for integrating two relational database schemas by resolving their name, data type, and data semantics conflicts with user supervision. The relational or object-relational data integration can only be done after relational or object-relational schemas integration for the loading of data into the integrated databases is performed. A Frame model metadata is introduced to store data operation for encapsulation in the object-oriented database.

Chapter 8 lays out the rules in integrating expert systems and database systems for the purpose of reengineering. The technique is to transform both expert systems rules and database systems relations into a common Frame model metadata. This Frame model metadata offers object-oriented-like database functions by treating each frame as an object and a collection of objects as a class. Coupling classes, active classes, static classes, and integrated classes are introduced to implement an expert database system (EDS). The users can then apply EDS to develop new applications.

Chapter 9 summaries the methodologies proposed by the book. The main theme is that knowledge engineering is a requirement for information systems reengineering and integration. We need users' knowledge to assist system developers in reusing existing database systems and expert systems in order to develop new applications. The final result is database systems upgrade, multiple database intergration and expert systems enhancement to knowledge-based systems. As knowledge engineering becomes important in data processing, the resultant knowledge-based system, i.e., the expert database system, will become a very important asset to companies.

Acknowledgments

This book is a tribute to the University of Sunderland in United Kingdom since the author developed most of the methodologies there.

The author thanks Professor Shi-Ming Huang as the original inventor of Frame model metadata used in the book, and also to Dr. Chuk Yau for his joint articles with the author, which contribute the MIS overview in the book. The author appreciates the assistance of the word processing work from Shing-han Li in formatting and drawing the diagrams for the book. Special thanks go to Dr Reggie Kwan and Frances Fong for their review and proofreading of the book. The book is the result of the combined research of the author and his project students over more than a decade.

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Contents

CHAPTER 1

INFORMATION SYSTEMS REENGINEERING AND INTEGRATION

1.1 HISTORY OF INFORMATION SYSTEMS

The primary goal of electronic data processing (EDP) in the 60s and 70s was the automation of existing business operations in organizations. However, except for the quicker availability of more accurate management reporting information, such operations were automated without fundamental changes. During these two decades, data were stored in flat file formats that could be classified into two different forms, namely batch files and on-line files.

Batch Files
Computer applications were initially developed for batch processing where programs would process a specific type of data regularly. Each suite of programs was associated with its own data files. Generally, magnetic tapes were used to hold these files. The sequential nature of the storage medium required the reading and writing of the entire file to reflect any changes to the data stored. Sequential access was simple and effective for batch applications. As more applications were computerized, it became obvious that some of the required data already existed in the data files used by other computer applications.

On-line Files
With the advent of direct access storage devices (DASD) and advances in telecommunications, many batch applications were re-designed for on-line processing. The random sequence of data input by on-line applications requires a monitor that examines each input transaction, and then passes its transaction to the appropriate computer program.

DASD such as magnetic discs made possible the direct retrieval of the required data record for immediate processing. However, the application program had to first calculate the physical location of the data record on disc using an algorithm that operated on an identifying key. When it became necessary to move the data file to another location on the disc, the program that accessed the file had to be modified.

Indexed sequential access method (ISAM) was developed to help isolate the application programs from changes made to the location of the files on the DASD. ISAM uses the record key to reference an intermediate index stored on the DASD to locate the physical location of the record on the DASD; ISAM then retrieves this record from the data file for presentation to the program. In many cases, application programs needed to access the data record by some identifying key other than the existing indexed sequential key. To reduce some of this data file housekeeping by the application program, generalized routines were written for accessing interrelated records via appropriate record pointers, and updating these pointers to reflect changes in the associated record relationships (e.g., insertion or deletion of records). These generalized routines were the precursors of today's database management systems (DBMS).

Problems in Maintaining File Systems

The structures of conventional files restrict the efficiency and effectiveness of information system applications. For example, changes in the types of information recorded in the files, such as to the addition of attributes to its record structure would, at the very least, necessitate the recompilation of all applications accessing the data. The application programs that reference the changed record format may be completely re-written if modifying the program becomes more complex than completely re-writing it.

As more complex applications are developed, the number of data files referenced by these applications increases. Such proliferation of files means that a minor change in either a data file or a program may snowball into a series of major program modifications, and a maintenance nightmare.

Since the same data exists in several different files, programmers must also maintain the data by updating all the files to ensure accuracy and consistency of the stored data. In the event of master file corruption or incomplete processing due to system or operational human errors, data processing practitioners must reprocess the various batches of input data against an earlier version of the corrupted master file for data recovery. Further complexity is added to the system to ensure that sensitive data is accessed only by authorized personnel.

Lastly, such file-based systems do not support the requirements of management. Very often, management need ad hoc reports for decision making, which requires processing on multiple files in a very short time and adds the burden to file processing systems.

Solution in Converting File Systems to Database Systems

As the requirements of the users increased, a more powerful and flexible data processing system was required. This was achieved by abstracting the routines for management of data and combining the data files into a large corpus of structured information solutions, known as the database management system (DBMS) or database. With a database system, data can be shared, and data redundancy can be more easily supported. Security and recovery are also more easily implemented by maintaining a database instead of a set of various files. Even database programming can be easier to support because of the standard utilization of a database among all the production application programs. Once the problems of file management are solved through the introduction of database systems, practitioners are able to consider the information needs of the organization in a new light.

Management Information System

Traditionally, an organization is seen as a three-tiered pyramid, where there is strategic planning and policy-making at the top, management planning and control activities in the middle, and routine operational activities at the bottom. The corporate database is composed of data pertaining to the organization, its operations, its plans, and its environment. Figure 1-1 shows all internal and external components and their relationships in a computerized management information system (MIS) (Yau & Fong, 1989).

Generally, decisions are executed based on information generated from the corporate database and managerial expertise. Higher-level managers set goals to direct operational level activities, and produce plans that form part of the corporate database. Business transactions reflect actual results of operational activities, and the database is updated by these transactions to reflect the current state of the business. Operational level managers query the database to perform daily operations. Tactical level managers receive reports derived from the transaction data stored in the database. They compare the actual results shown in these reports with planned results. For managers at the strategic level, they need information for modeling and forecasting. The corporate database supports all levels of information needs for operations, decision making, and the management process.

When the concept of MIS was first introduced, its supporters envisaged a single system that would integrate all organizational functions. Others doubted the possibility of designing computer-based information systems to support management planning and decision-making functions, particularly at the strategic level. Over the years the concept of a total system proved to be too complex to implement. Now MIS consists of a federation of subsystems, engineered as needed but conforming to the overall organizational plan, standards, and procedures. MIS continues to evolve.

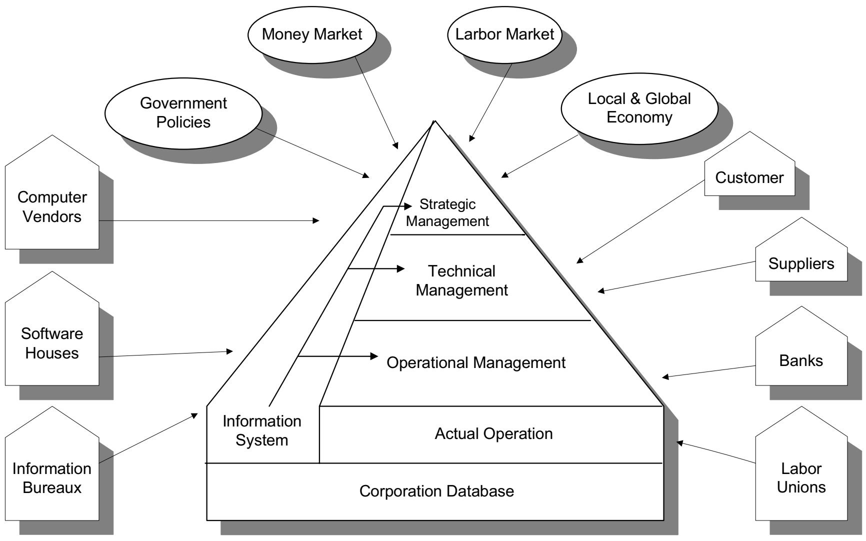

Figure 1-1 The internal and external components of MIS

Knowledge and Information Needs

The most fundamental element of MIS and the management process is knowledge/information about the objectives of the organization, as well as its policies, resources, operations, and environment. In today's complex management environment, no individual manager can have sufficient personal knowledge to serve the diverse needs of the organization. Knowledge and information relating to the organization's management and operations must be stored on the computer file system.

The gathering of data and dissemination of information are complex. Data/information is voluminous, scattered, and often difficult and costly to obtain. The costs and complexities of producing various types of management reports usually cause data duplication and uncoordinated efforts within the organization. Often people and departments prefer to duplicate information rather than share, which results in considerable redundancy within the organization.

Departments fail to recognize the importance of interaction within the company. For example, the production department is concerned with maximizing its production capacity, assuming that goods produced can all be sold by the sales department. In order to achieve good organizational congruence, it is essential that activities of these departments be synchronized via an effective information system that enables the various departments to act on the same database.

The most pressing concern of management is the cost-effective utilization of human and economic resources. In large and complex organizations, this will be difficult to perform without the aid of an MIS to provide information and decision support to managers. For an MIS to be able to satisfy the information requirements of the different levels of management, a DBMS is needed to control and make available data resources of the organization.

Computer-Based/Man-Machine System
The computer-based/man-machine characteristics of MIS affects both system developers and systems users. “Computer-based” means that the information systems must be implemented by computer systems. The developer of an MIS system must also understand the capabilities and behavior of humans as users and define a “good man-machine” interface that does not require users to be computer specialists. Nevertheless, the nature of information and its use in various business functions aids users in specifying their information needs.

Office Automation System
The increasing use of PCs (personal computers) and LANs (local area networks) allow the information processing power of the computer to impact the daily routines and functions of all office workers, including the managers. Intelligent terminals can offer time management, project management, and message management facilities.

Personal terminals aid in project management. A budget and time schedule can be established for each project to allow automatic tracking and status monitoring. Information from monthly status reports on each project can be abstracted, classified, and stored in the database as they are produced, forming a research database. Researchers in the company can interactively search the database by keywords or categories, construct personal databases of relevant research information, and exchange ideas and references with other researchers in the network.

Decision Support Systems

Data ought to be processed and presented so that the result is directed towards the decision at hand. To do this, processing of data items must be based on a decision model. Models are simplified representations of reality. The models of many business problems are widespread and complex, involving operational research and statistical techniques. A decision support system (DSS) provides information through computer-based modeling facilities to help managers make decisions for relatively unstructured problems.

Traditional information systems have essentially been operational in nature, and attempts to structure these systems to provide management information have had little success because of the ill-defined nature of problems at strategic level of management. The emergence of database, PC, 4GL (fourth generation language), and modeling tools have enabled DSS to partially support management planning and decision making. Figure 1-2 shows a fundamental structure of DSS.

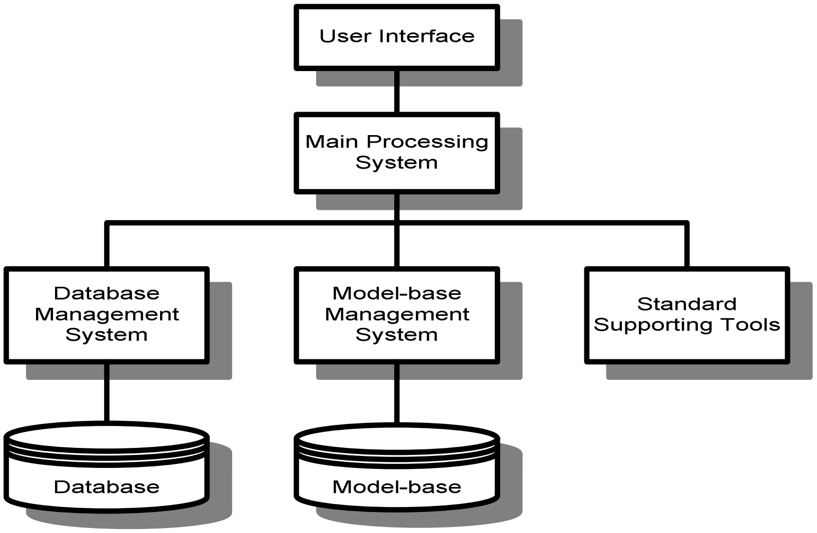
User Interface
Main Processing System
Database Management System
Model-base Management System
Standard Supporting Tools
Database
Model-base

Figure 1-2 Fundamental structure of decision support systenm

Expert Systems

Expert systems (ES) have been widely used in our society from technical and medical to financial, teaching, and administrative applications. They are a general term for special software systems that preserve the knowledge of human experts and reason with it.

The basic differences between ESs and conventional software systems are:

- Conventional software systems are algorithmic. They produce unique and certain answers, e.g., yes or no.

- ESs, by their nature, are heuristic. The results that they produce are not always unique, nor are they necessarily certain and correct, e.g., yes, no, or unknown.

In the recent years, ESs have played an important role in information systems. Their technologies have been used in the more advanced information systems, such as executive information systems (EIS) and executive support systems (ESS). The purpose of EISs is to assist high-level managers with either information or knowledge relating to an organization's decision processing. Most current EISs generate decision knowledge for an organization by integrating expert systems with databases. The technical term for this type of systems is called *expert database systems* (EDS). The ESS often combines DSS and MIS capabilities. ESs usually are the kernel of these types of systems.

1.2 THE NEED

The recent rapid growth in database technology has actually encouraged more installations of database management systems in different kinds of organizations. In addition to new database system installations, there is considerable interest in converting conventional file-oriented systems to database systems and upgrading outdated database systems to a newer database technology. The need to compete, to reduce costs, and to standardize operational procedures make conversions to a new technology a necessity for many organizations. The fact that many large companies still have a large number of sequential file systems indicates a strong need to convert such systems to a database system for better management. The introduction of Internet computing makes XML model a necessity to most companies.

The concept of a relational database was proposed by E.F. Codd in the 70s. It is recognized as a more user friendly model than nonrelational (e.g., hierarchical or network) models. However, it was not adopted by the industry until the 80s because of its poor performance. Thanks to the improvements in their performance, relational databases have gained wider industry acceptance. These improvements have created a need to convert data from a nonrelational to a relational structure.

The object-orientated approach to software engineering has recently become popular, with many manufacturers claiming to have object-oriented systems. Object-oriented modeling is a new way of representing static and dynamic data semantics in the form of objects, links, associations, and methods. Traditional record-based databases (e.g., hierarchical, network, and relational) have been generally used over the past two decades. Organizations with such record-based databases could reengineer their databases into object-oriented databases to capture more semantics of the application domain.

Any medium to large organization that has an independent EDP department typically has a number of databases. Over the last four decades, a number of database systems have come onto the market using these predominant data models: hierarchical, network, relational, object-oriented, and XML. As a result of this proliferation of systems, many large organizations have found that they must support various types of database systems at the same time. However, as the performance of the relational database systems has improved, they have been accepted by the industry and consequently created the need to convert a company's nonrelational database systems to relational.

The hierarchical and network database systems use the concept of currency and require users to navigate through the database from one point to the next. This makes them difficult to use for both end-users and programmers because of the level of skill and experience required to perform this navigation. On the other hand, a relational database is simpler, as it presents to users relations that resemble files in a manual cabinet file system.

In the hierarchical and network models, the connections between sets of data are hard-coded into the data structure and the addition of a new relationship requires a new access path to be added. In relational databases, access paths are not pre-established but are based upon the matching of values in separate tables using a join operation. This makes a relational database a more flexible system for inquiries required. The predefined relationships of the hierarchical or network structures require a complex data definition language (DDL) and data manipulation language (DML). Maintenance of these predefined relationship is difficult. In the relational model, the DDL and DML are simpler and user-oriented, both having relatively simple maintenance and physical storage conditions. Relational databases can provide better flexibility and data independence. Since an organization's need for information changes over time, and because having a relational database encourages new uses, this flexibility of the relational model is highly desirable. Furthermore, with the increasing use of SQL (Structured Query Language), the portability of application programs using SQL as the DML is improved.

As database technologies evolve from hierarchical and network to relational and object-oriented models, companies need guidelines on how to select a new database system, and what to do with their old and obsolete systems. The database approach to information systems is a long-term investment. It requires a large-scale commitment of an organization's resources in compatible hardware and software, skilled personnel and management support. Accompanying costs are the education and training of the personnel, conversion of existing applications and the creation of new documentation. It is essential for an organization to fully appreciate, if not understand, the problems of converting an existing, file-based system to a database system, or upgrading an obsolete database system to a more user-friendly one, and to accept the implications of this operation before they initiate such projects.

Before anything else, the management must decide whether or not the project is a feasible one and if it matches the users' requirements. Costs, timetables, are performance considerations, as well as the availability of expertise are also major concerns.

Management is concerned with a long-term corporate strategy. The database selected must be consistent with the commitments of that corporate strategy. But if the organization does not have a corporate database, then one must be developed before conversion is to take place. Selecting a database must be from the top down. Data flow diagrams, representing the organization's business functions, processes and activities, should be drawn up first. This should be followed by an Entity-Relationship (ER) model (Chan, 1976) detailing the relationships of different business information, and then finally by data modeling. If the ER model has a tree-like structure, then a hierarchical model should be adopted; if the ER model shows a network structure, a network model should be chosen. Otherwise, a relational model should be chosen for a more user-friendly structure, or an object-oriented model should be chosen for a universal structure. For Internet application, an XML model is needed for e-commerce because XML has become the data standard of Internet computing.

Although there are many theories of database design, many databases are found to be unreliable, difficult to modify, and poor in performance. Database designers face a complicated problem: how to arrange the data and programs on different computers to obtain the intended performance, reliability, and availability. Leaving this problem unsolved will restrict the success of database system reengineering. There is a need for a framework for measuring the quality of converted databases. The following criteria are derived from the requirements of software engineering and database technology:

- Integrity - Only syntactically and semantically correct data should be stored in databases to enforce domain integrity. Referential integrity is another type of semantic integrity such that data cannot exist or be modified unless some precursor data values exist or some actions are taken.

- Trace-ability - A good database design should support trace-ability from the requirements down to the physical design stage back through documentation. So trace-ability is necessary for different phases of database development. Simplification and overload errors can occur in any phase and will affect the degree of trace-ability.

- Consistency - In distributed database systems, data are often replicated to improve performance and availability. All copies of the same logical data item must agree on exactly one "current value" for the data item. All users within the environment should have a uniform view of the system. If the data are inconsistent, the users cannot share the same information. It is particularly important for parallel applications that partition data into different parts to increase their processing speed. If the partitions are stored in different sites, consistency is a key factor to ensure correctness of the application.

- Correctness - A database is correct if it correctly describes the external objects and processes that it is intended to model. They use a set of static constraints on objects and their attributes, and a set of dynamic constraints on how objects can interact and evolve. A database is said to be syntactically correct if the concepts are properly defined in the schema at each stage; it is said to be semantically correct if the concepts are used according to their definition at each stage.

- Completeness - A database schema can be defined as complete when the schema represents all relevant features of the application domain. Two major principles can be used to check completeness of the design: (a) checking all the requirements of the application domain and ensuring that each of them is represented somewhere in the final system; (b) checking to see whether each concept is mentioned in the requirements.

- Efficiency - A database schema can be regarded as an efficient design if the schema (a) can support any processes on the component schema; (b) provides both timely and accurate data access for a given set of queries and transactions.

Information technologists have moved from data processing to information processing and are now moving into the field of knowledge processing. The new term expert database system (EDS) has emerged to refer to an important area in this field. An EDS is a system that results from the integration of expert systems and database management system technology.

Consider the following problem taken from a real application: A personnel manager must find the best person for a particular job, or the best group of people for a particular project (i.e., a project that includes different types of jobs) by considering the total departmental manpower. A common way to solve this problem is to send the employee information and the job vacancy information to a human resource management consultant agency. The experts in this agency will then use their expertise to produce a human resource plan and hence give the manager some suggestions. Figure 1-3 shows the relationship between these components. Taking a system view, the manager is the end-user, the human resource consultant is the expert system, and the personnel information and job vacancy information are stored into the database (for detailed information, see Section 8.4, which contains a description of a human resource management expert database system).

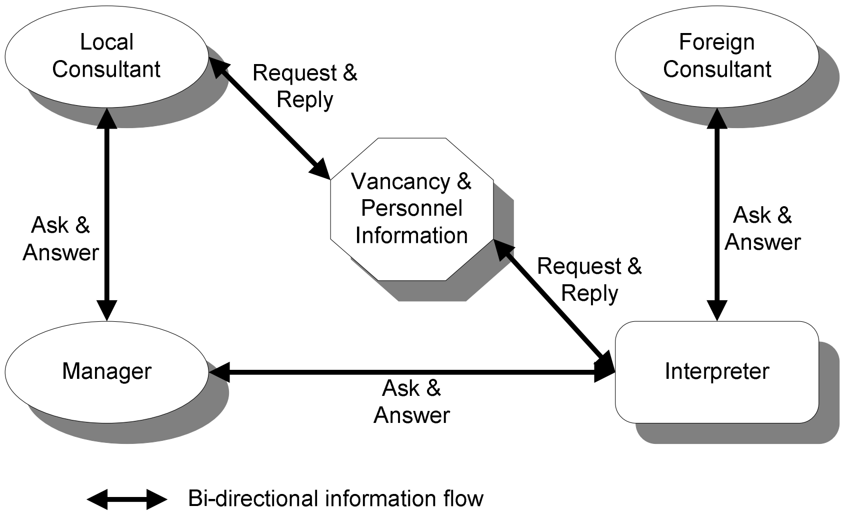

Figure 1-3 A job vacancy problem application model

An easy way to model this application situation is to view each component as an independent module. The system's performance will depend on the performance of each module and on communication (i.e., message passing). The normal way for information passing is as follows: The manager (end-user) asks the consultant (expert system (ES)) to do a job, then the consultant (ES) analyses this particular job and asks the company (database (DB)) to supply the necessary information that is needed for this particular job. The company (DB) then sends this information to the consultant (ES) and the consultant (ES) uses his/her expertise to generate a result that is sent back to the manager (end-user). The consultant may be a foreigner and may not know the local language. Thus sometimes an interpreter (interface) is needed at the same time. It is also necessary to support an open structure to allow any new subsystem to join the system.

EDS are widely used in the current information systems. Further examples can be found in the areas of business, industry, banking, and retail. For example, a business plan is necessary when planning for future events. A planning manager (end-user) asks experts (ES) to analyze the plan and give suggestions by using the company information, market information (DB), and so on.

Current EDS technology still has a long way to go in order to achieve the full requirements of EDSs from the two different view points, i.e. DB users and ES users. The main reasons are that information systems are complex systems that require multiple environments to deal with different situations. In general, there are four different situations that system developers will meet when designing an EDS.

- Case 1: Building a new EDS. The system developer must create new database(s) and expert system(s) for the EDS. No usable systems exist.
- Case 2: Reusing expert system(s). The system developer reuses existing expert system(s) and builds new database(s) for the EDS.
- Case 3: Reusing database(s). The system developer reuses existing database(s) and builds new expert system(s) for the EDS.
- Case 4: Reusing both database(s) and expert system(s). The system developer reuses both existing database(s) and expert system(s) in the EDS.

The last three cases use the concept of reengineering to save the cost of implementation. A recent EDS empirical survey conducted in the United Kingdom has shown that a large number (59%) of the respondents thought that enhancing existing systems to couple both technologies is the most feasible approach. The main reason behind this result is the concept of reengineering.

1.3 THE PROBLEMS

Database system reengineering is not an easy task. The acquisition and running of a new system is both a longterm commitment and a long term investment for an organization. This being the case, it is important that the top management understand the objectives of committing to a new environment, as well as some of the problems that may lead to the collapse of such a project.

The following are the major strategic issues that must be considered in the early stage of the reengineering process.

Selecting a Database Model

Advocates of network and hierarchical models argue that the two models correspond more closely to the real world, and that there is less redundancy of data. Since the connections among the data are built into the database structure, access time is shorter, therefore making the two systems very suitable for fairly stable databases with uses that can be precisely predetermined.

Supporters of the relational model argue that the relational concept is simple and that the model can provide flexibility and data independence. Since an organization's need for information changes over time, and because having a database encourages new uses, this flexibility is highly desirable.

One might wonder with these comparative advantages why all databases are not relational in nature. The answer is that for many applications the relational model is simply unsuitable. The pointer approach is much more efficient than general table operations if relationships between sets of data can be predetermined. So, if the database contains a large number of records or performance requirements, or both, or if the transaction volume is high and the ad-hoc queries are not common, then the hierarchical or network models are more efficient than the relational model.

Relational databases have over the last decade become an accepted solution to the issue of storing and retrieving data. Based upon the mathematical concept of a relation, these systems use tables (relations) and fixed size field (domains) to represent the information and its inter-relationships. The mathematical rigor and simplicity of these systems have been their major attraction. However, there are many drawbacks to such database systems. For one thing, the semantics of relational databases are often hidden within the many relationships and cannot be extracted without users' help. Also, relations stored in the database must first at least be in normal form, preventing the representation of multiple or set attributes. Furthermore, relational data models accept entities in a certain form, and structural changes to an entity require changes to all the instances of that entity in the database. Thus, it is not possible to change a single instance without affecting the whole database.

Object-oriented databases offer solutions to many of these problems. Based on the notions of abstraction and generalization, object-oriented models capture the semantics and complexity of the data. Fundamentals to the object-oriented approach are the concepts of class, instance, and inheritance. An instance is an occurrence of a class, where a class is a description of an entity. Classes may inherit the attributes of one or more superclass(es) and thus capture some of the semantics of an entity. Also object-oriented database supports complex data types. An object-oriented model is thus more reusable and flexible in schema evolution and data storage.

Database Conversion
The complexity of converting an existing system to a new database system may cause a project to become unmanageable. Most people assume that there is an application system ready to be converted to the new environment. The assumption presumes that most application systems are technically up to date, logically sound, and properly organized. A careful review of the majority of application systems, however, will prove otherwise. A successful system conversion depends on a good understanding of management requirements and technical requirements.

A systems manager should consider redesigning the application system if it becomes unmaintainable. The redesign should be based on the database concept rather than wasting precious resources by wandering round a conversion process. There is no absolute certainty about planning and controlling reengineering projects because there are no foolproof methods to abide by. However, there are three conventional approaches to system conversion (Yau & Fong, 1989).

- Parallel Conversion: This approach converts application programs and other data for the new system while the existing system is still in operation. This is a very safe approach permitting the old system to return to operation when problems crop up in the new system. However, handling two systems at the same time requires extra effort.

- Direct Cut-Over: This approach converts application programs and other data to replace the old one in a specified period of time. It is less costly than the parallel approach and is well suited to conversion projects involving a small system.

- Phase-In: This approach is employed when the system is a very large one and one cannot be completely converted in one go. It divides the whole conversion process into several phases.

To successfully convert an information system, people such as software engineers, users, managers, and operations personnel must have a common ground to discuss with one another their individual needs, goals, expectations and constraints, and the goals of the organization. A common ground can be established by holding regular meetings for the related parties. The result of the meetings should be management commitment, transportable documentation that is understandable by appropriate parties, and a jointly owned, user-oriented set of structured models of the systems design. These models should contain why, what, where, and how the conversion will affect the organization. In brief, users' involvement is an essential factor in all phases of the conversion: planning, requirements, design, construction, implementation, and operations.

On the technical side, system conversion can be separated into two main parts: program conversion and data conversion. Converting programs will be less of a problem if the installation has good software quality standards. Problems arise when such quality standards do not exist or when they are loosely enforced.

Many software vendors supply software utility tools to help clients convert their databases. For example, Computer Associates International Ltd. has a software tool called ESCAPE DL/1, which translates the input-output statements in IMS to that in IDMS so that IMS programs can access IDMS databases without converting the data. (IMS and IDMS are database management systems supplied by IBM Corp.) Computer Associates also supplies programs to convert specification blocks in IMS into corresponding IDMS schemas and subschemas, including those that help unload IMS databases to sequential files and reload them into IDMS databases. Figure 1-4 describes the function of ESCAPE DL/1 (CA, 1992).

Data conversion can be very complicated if the existing data organization is very different from the new database model. Similar to program conversion, some software vendors also provide utilities for data conversion. One example is converting sequential files to a database system called ADABAS.

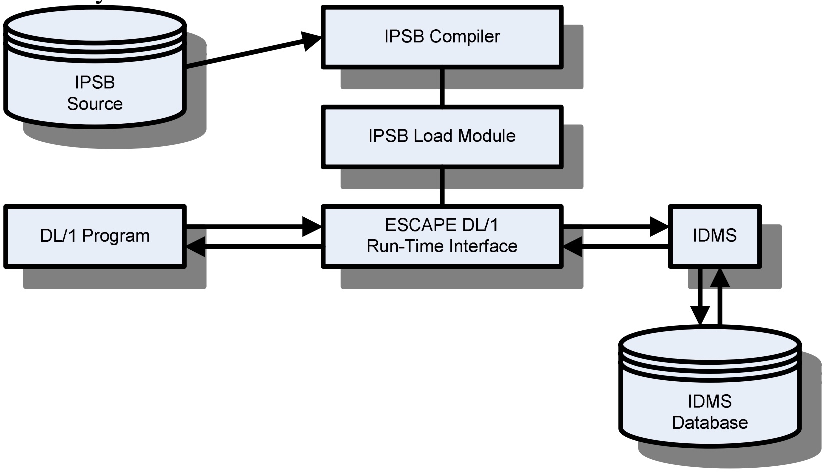

Figure 1-4 A practical database conversion approach

The use of customer-made programs is the more common approach to converting existing files, but this has several serious shortcomings. Each translation required is handled by a specially written program that is used only once, hence, a costly solution. Such programs may be unreliable for restructuring complex databases because of possible program error or data misinterpretation. This process becomes even more complex if the conversions of software and hardware are going on at the same time. Although the use of the generalized program can overcome such problems, the disadvantage is that it may not be able to be executed efficiently (because the program is generalized), meaning it cannot convert all the data from the source to the target. Reconstructing data files is time-consuming, and some data files may not be reconstructed because of drastic changes to the database semantics. Furthermore, this approach depends on one language to describe the data structure (at both the source and the target) and another to describe the restructuring specifications; these languages may be cumbersome to use. With the Bridge Program Technique, some redundant data may have to be retained in the database so that the files needed by the existing programs can be created again.

Very often, in order to maximize the benefits of a database, it is better to redesign the existing application, and the design of the new database model from scratch. In this case, bridge programs must be written for unloading the existing database to sequential files or serial files, and to upload them into the new database structures. In this process, the redundancy of existing files should be removed and standards should be strictly adhered to. Errors in current files must be detected and removed. Also file inconsistencies must be found before the conversion, rather than later when they may cause system malfunction.

The problem of totally automatic translation from a nonrelational DML to SQL remains a classical problem in the area of databases. Algorithms have been developed to translate some primitive nonrelational DML to SQL, but not all DMLs can be translated. Decompilation of lower level nonrelational DML to the higher level SQL statements cannot therefore be used in production systems. Furthermore, the effort of rewriting the un-decompiled part of the nonrelational DML to SQL is similar to a rewrite of the whole nonrelational database program, as the time for program analysis in both approaches is about the same.

Integration of Multiple Databases

There has been a proliferation of databases in most organizations. These databases are created and managed by the various units of the organization for their own localized applications. Thus the global view of all the data that is being stored and managed by the organization is missing. Schema integration is a technique to present such a global view of an organization's databases. There has been a lot of work done on schema integration. Özsu amd Valduriez (1991) presented surveys of work in this area. But all these techniques concentrate on integrating database schemas without taking into consideration new database applications. We need a practical approach to schema integration to support new database applications by comparing the existing databases against data requirements of the new applications. If the existing databases are inadequate to support new applications, they must then be evolved to support them.

Since the relational databases emerged, they have been widely used in commercial organizations. However, in an organization, different departments or sections would have probably developed their own relational database systems according to their own requirements at various times. Thus, large quantities of data are fragmented across a variety of databases. Data could then be redundant and inconsistent. A global view on all data is not there. This will affect the effectiveness of decision making in an organization, as these disparate data do not adequately support the information needs of an organization operating in a dynamic business environment. It is vital that a data resource should provide current data for development of up-to-date information to support just-in-time decision making in an organization. There is a great need to create a global view on all existing disparate data by integrating them in a global database so as to support dynamic and complex business activities.

Data integration is to implement a global database by integrating various *source* databases into a global *target* database. To accomplish the task of data integration, the first step is schema integration. This process involves many steps including solving conflicts between source databases, capturing the semantics of entity, weak entity, cardinality, isa, generalization, categorization and aggregation of the relations, and merging to a new integrated schema for each pair of the existing relational schemas in the source databases.

The next process is data integration. Its objective is to merge data from source databases to the new global database without any loss of information. It must transform the data structure from the sources to the target integrated global database whilst preserving its semantics. It also uses the data structure of the integrated schema derived from schema integration.

The integrated global database can be verified by confirming the recaptured semantics from examining its data occurrence. If the recovered semantics matches the semantics of the integrated schema, then the original semantics have been preserved in the integrated databases and there is no loss of information after integration. Figure 1-5 shows the data flow of data integration after schema integration of source relational schemas.

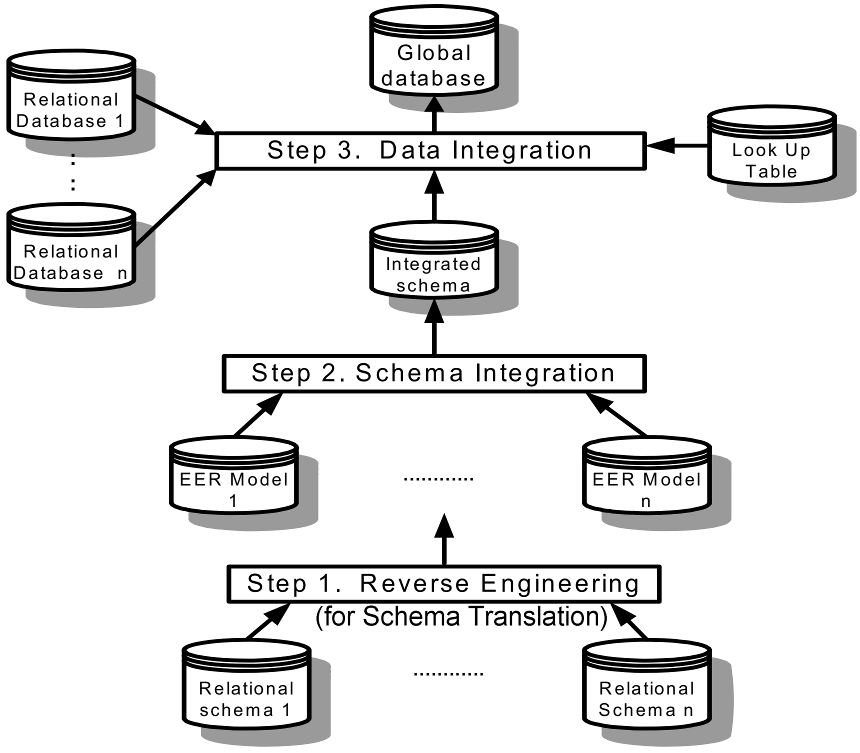

Figure 1-5 Architecture of multiple databases integration

Integration of Database and Expert Systems

Integration of existing databases with a new updated computing technology is another issue of database reengineering. The integration will update the existing systems to meet a new requirement. Our main theme, in this subsection, is to describe the problem of integrating expert systems (ES) with database systems (DBS), i.e., EDS.

The short term and probably most straightforward strategy for developing an EDS is to extend existing systems. This approach treats DBSs and/or ESs as starting points and moves in an evolutionary fashion towards the goal of a knowledge based management system. An example of this is enhancing existing relational databases to include ES technology (an enhanced DBS), or adding an efficient use of secondary storage to an existing ES (an enhanced ES).

However, some people believe that allowing a DBS and ES to communicate down a common data channel will be a far better approach. An example of this is using a data dictionary to connect a database to a knowledge base. This kind of peer-to-peer coupled EDS allows the DBS and the ES to exist as independent systems.

The EDSs described above are heterogeneous systems. Schematic and operation heterogeneity are a crucial problem in building and using a heterogeneous system. This is because the different systems operate independently and the data or knowledge may include structural and representational discrepancies (i.e., conflicts). Schematic heterogeneity concerns knowledge representation aspects. It can take these form:

- Naming conflicts: Different systems use different names to represent the same concepts.

- Domain conflicts: Different systems use different values to represent the same concepts.

- Meta-data conflicts: The same concepts are represented at the schema level in one system and at the instance level in another.

- Structural conflicts: Different data models of hierarchical, network, relational, object-oriented, and XML are used together, representing different structures for the same concepts.

In most ESs, facts are realized according to the constraints imposed by the characteristics of the inference engine and by the properties of the problem at hand. Most of these systems mention nothing of the ad hoc ways of structuring a database of facts. That is why this type of problem becomes a major task in enhanced ESs. On the other hand, the relational model is not really compatible with logic, rules, frames, and semantic networks, which are typical of ES systems. Several performance problems arise from this mismatch, especially those requiring data to be exchanged by using redundant data descriptions to form the interface between the coupled systems.

An ES reasoning mechanism makes use of data through its variables instantly; therefore, it requires some data during each inference and in an atomic form (individual tuples of data values). However, a relational DBMS answers a query by returning results as sets of tuples. Accordingly, when the front-end breaks down a query into a sequence of queries on tuples, each of them incurs a heavy back-end performance overhead. We lose, therefore, the benefits of the set-oriented optimization that is characteristic of the back-end relational database.

The third criticism concerns the limited functionality and general information provided by the integrating system. Ideally, the integrated system should support the full functionality of both systems plus some additional functionality arising from the integration. Unfortunately, most current systems either do not support all of the functions of both systems, or support only a very limited set of additional functions. Also the general resource information (i.e., the data dictionary), is poor in current EDSs. Most systems do not support this resource information. This makes programming expert database systems extremely difficult.

The fourth criticism concerns the development lifecycle of re-using the existing systems to create a new information system. Currently there are no formal methodologies to implement this type of system. How can the developer know the existing data is sufficient for the new system requirements? If it is not sufficient, what will be the remedial action? How can the existing system join the system analysis and design phase? How do we test this type of system during the development lifecycle?

1.4 APPROACHES TO REENGINEERING

Reengineering information systems involves reusing the existing outdated database systems and expert systems by upgrading or integrating them to new technology systems to meet the new users' requirements. Database upgrading, in a logical sense, is to upgrade an old database technologies, i.e., one using a hierarchical or network model, to a new database technology, i.e., a relational, object-oriented, or XML model. Reusing an expert system can be accomplished by integrating it with a database system.

Database Reengineering

Database reengineering consists of three parts: schema translation, data conversion, and program translation. It can be described as follows:

In schema translation, there are two approaches:

- Direct translation - One can directly translate a nonrelational schema to a relational schema. However, such translations may result in the loss of information because of their primitive mode of operation that cannot recover or identify all the original nonrelational schema's semantics. Certain advanced semantics are lost once they are mapped from a conceptual schema (e.g., ER model) to a logical schema (e.g., Hierarchical or Network schema). Thus, users' input is needed to recover the lost semantics.

- Indirect translation - Indirect translations can be accomplished by mapping a logical hierarchical or network schema into a conceptual ER model schema in reverse engineering. The translated conceptual schema must have all the original logical schema's semantics. User input can be used to recapture the semantics of the conceptual schema. A knowledge base can be used to support the process of recovering such semantics. Then the conceptual schema can be automatically mapped to a relational schema. Similarly, in order to translate a relational schema to an object-oriented schema, we can map the relational schema first into the ER model, then into a UML (Unified Modeling Language) (Booch et al, 1999), a conceptual model for object-oriented model, and finally translate the UML model onto the object-oriented model of the target database. Similarly, we can map relational to XML model through DTD graph and XSD graph.

Chapter 3 will describe in detail methods for schema translation.

In data conversion, there are three approaches:

- Physical conversion - The physical data of the nonrelational database is directly converted to the physical data of the relational database. This can be done using an interpreter approach or a generator approach. The former is a direct translation from one data item to another. The latter is to provide a generator that generates a program to accomplish the physical data conversion.

- Logical conversion - The logical approach is to unload the nonrelational database to sequential files in the logical sequence, similar to the relational model. The sequential files can then be uploaded back to a target relational database. This approach is concerned with the logical sequence of the data rather the physical attributes of each data item.

- Bridge program - Each nonrelational file requires a bridge program to convert it to the relational model.

Chapter 4 will describe in detail the methods for data conversion.

In program conversion, the five approaches to translating nonrelational database programs to relational database programs are as follows:

- Rewrite - One can translate the nonrelational schema into a relational schema, map a nonrelational database into a relational database, and rewrite all the application programs to run on the relational database.

- Bridge program - One can map the nonrelational schema into a relational schema, then add a relational interface software layer on the top of the nonrelational DBMS. The relational interface layer translates the relational program DML into nonrelational program DML statements to access the existing nonrelational database. The user can then view the nonrelational database as a relational database, and use relational DML commands to extract and manipulate the underlying nonrelational database system.

- Emulation - This is the technique of providing software or firmware in the target system that maps source program commands into functionally equivalent commands in the target system. Each nonrelational DML is substituted by relational DML statements to access the converted relational database.

- Decompilation - Decompilation is the process of transforming a program written in a low level language into an equivalent but more abstract version and the implementation of the new programs to meet the new environment, database files, and DBMS requirements.

- Co-existence - One can continue to support a nonrelational database while developing an information capacity equivalent relational database for the same application.

Chapter 5 will describe in detail the methods for program translation.

Adding a Relational Interface to Nonrelational Database
Even though a lot of problems have been resolved in database

conversion, the difficulty arises in the translation of semantics. Not only do we not know whether there is a 1:1 or a 1:n relationship between the parent (owner) and the child (member) segments (records) in the hierarchical (network) schema, but we also cannot obtain unique key transformation. The complication in semantic analysis appears not only in the DDL of the schema, but also in the database programs. The automation of the direct translation from procedural (with database navigation) nonrelational DML statement to non-procedural (without database navigation) relational DML statement is still a challenge to database researchers.

In order to resolve the above problems, an alternative approach for database reengineering is endorsed in a methodology of RELIKEDB (Relational-like-database) (Fong, 1993), which is similar to the relational interface approach in that both provide a relational interface to make the hierarchical or network DBMS a relational-like DBMS.

RELIKEDB provides schema translation in which user input contributes to the process. Direct schema translation from a hierarchical model or network model into a relational cannot guarantee the capture of all the original conceptual schema semantics. With user input, we can at least provide a relational schema that is closer to the user's expectations and which preserves the existing schema's constraints such as record key, relationships, and attributes.

As to data conversion, RELIKEDB provides algorithms to unload a hierarchical or a network database into sequential files directly and efficiently, which can then be uploaded into a relational database.

In program translation, RELIKEDB provides an "open" data structure by adding secondary indices in the existing hierarchical or network database. This eliminates the navigation access path required to retrieve a target record from a system record. Instead, each target record type can be accessed directly without database navigation. The database access time is thus reduced and the program conversion effort simplified. RELIKEDB provides algorithms to translate SQL statements into hierarchical or network DML statements. These are sound solutions to the program conversion problem.

Chapter 6 will describe in detail the proposed three-phased methodology of RELIKEDB to add a relational interface atop of nonrelational database.

As to the program translation from a relational to object-oriented form, the difficulty is that there is no standard object-oriented database DML at present.

Integrated Expert Systems and Database Systems
There are fundamentally different opinions coming from the current ES and DB communities for EDS. The use of ES functions in DB products is to achieve “deductive data", retrieve the semantics of data, and create an intelligent interface, integrity constraints, etc. The use of DB functions in ES products is to represent factual knowledge in the original knowledge base. These differences mean that current EDSs have very different working environments.

Different approaches have been taken by various research projects and commercial products to achieve the requirements of an EDS. They can be classified into two different groups (see Figure 1-6):

- Based on existing systems: There are four different architectures in this area, i.e., enhancing existing database systems, enhancing existing expert systems, master-slaver coupling of ES-DB, and peer-to-peer coupling of ES-DB. Most current products can be categorized into one of these four architectures.

- A new knowledge base management system: This architecture involves searching for a new model to represent knowledge. One example of this type of system is Generis (Deductive System Ltd., 1988).

Reengineering functions and a high level synthesis model are two main requirements for the future EDS (Huang, 1994). These two functions cannot be traded off against one another. They can combine together to become a very powerful and sophisticated EDS. Another interesting result is that both ES and DB researchers are using object-oriented technology. It seems that most people currently believe that object-oriented technology will become the future for EDS.

Chapter 8 describes in detail EDS technology. It presents a case study that illustrates one EDS scenario, where existing DBs and ESs have been used to build an EDS application. The consequent lessons are then addressed and some problems of current techniques for the integration of ESs and DBs are explored. The “ideal” future for EDSs using object-oriented technology are also discussed.

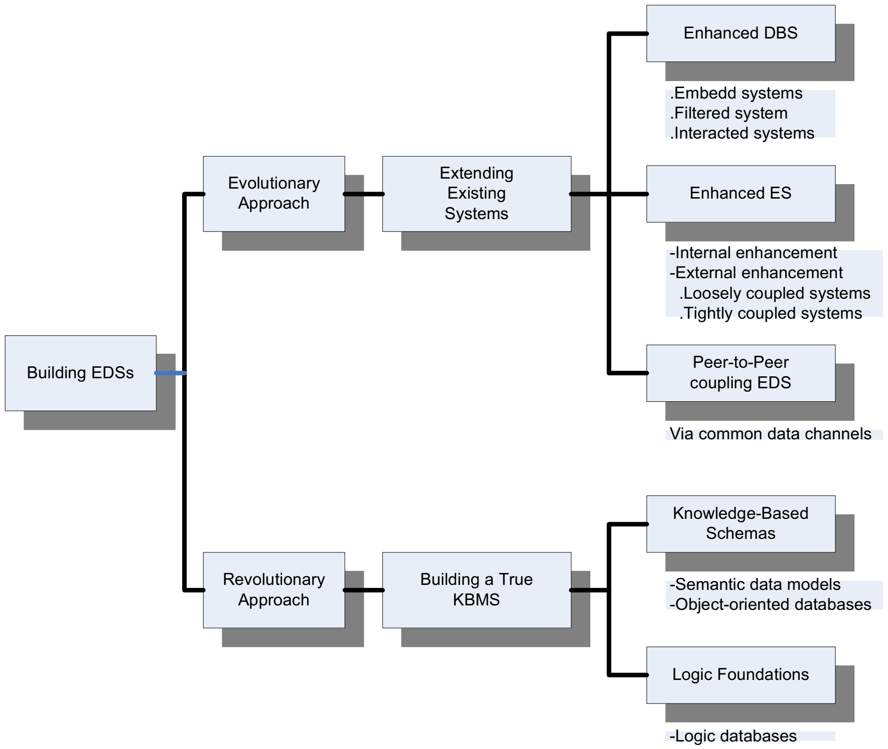

Figure 1-6 EDS typology

Chapter 9 concludes with a discussion of a suggested overarching framework for future information system reengineering. It first discusses the application of database conversion methodologies. It, then describes the concepts of the multiple databases integration, and also the database system and expert system integration application. The final part of this chapter explores the issues of the future trends for information systems reengineering and integration.

User Interface to Knowledge-Based Systems

To recover the advance semantics such as generalization, categorization and n-ary relationship from the relational schema, user input is needed during the process of reverse engineering. To support this process we need an expert system shell. This consists of an inference engine, a factbase, and one or more rule bases. The database schema is automatically converted by a preprocessor into a factbase for the expert system. Each record name is translated into a fact statement. For example, derive facts from the given DDL. (Fong and Ho, 1993).

<u>DDL</u>	<u>FACTS</u>

```
RECORD department                  department is a record
    dept PIC 999                   dept is contained in department
    dept-name PIC CHAR(30)         dept-name is contained in
                                   department
RECORD instructor                  instructor is a record
    name PIC CHAR(30)              name is contained in instructor
    instr-addr CHAR(50)            instr-addr is contained in instructor
RECORD section                     section is a record
    section-name                   section-name is contained in section
    SET dept-instr                 dept-instr is a set
        OWNER dept                 dept is contained in dept-instr
        MEMBER instructor          dept owns instructor
    SET instr-sect                 inst-sect is a set
        OWNER instr                instr is contained in instr-sect
        MEMBER section             instr owns section
                                   section owns none
```

The following backward rule transforms the records into entities and 'R’ represents variables to be instantiated:

```
        'R’ is a entity     /* known facts if the condition is met */
If
        'R’ is a record     /* the condition */
```

The expert system shell provides a mechanism to obtain facts from users in the form of “askable facts”, such as ‘E’ identified fully? When ‘E’ is bound to department, for example, will generate

Is the statement: department identified fully, true? Please enter (Y)es, (N)o or (W)hy.

Typing “why” will generate an explanation of why the system asked the question, by showing the rules that may help the user to respond better. If the answer is “yes,” the entity is tagged as fully internally identified and the premise succeeds. If the answer is “No,” this premise fails. In order for the conclusion to fire, the premises must succeed, otherwise, the system will try the next rule.

The whole rule base is shown below, illustrating how the “askable fact” is used within a rule:

```
                read key-attribute ‘K’
        IF
                ‘E’ is a entity and
```

```
            'E' identified fully?

            Read partial-key-attribute 'K'
    IF
            'E' is a entity and
            NOT 'E' identified partially?

            Introduce sequence 'K'
    IF
            'E' is a entity and
            NOT 'E' identified fully and
            NOT 'E' identified partially
```

There are three kinds of record identifiers as follows:

- Fully internally identified - The existing record key can uniquely identify the record as an entity. For example, 'a dept' can be a record identifier that uniquely identifities a department in the same record.

- Partial internally identified - The concatenation of owner record keys with the existing record keys can uniquely identify the record as an entity. For example, the record identifier of instructor record is the concatenation of its parent record department identifier: dept with its own record key: instructor-name. That is, dept, instructor-name can uniquely identify instructor-address of the instructor working in the department.

- Internally unidentified - The concatenation of owner record keys with a sequence# can uniquely identify the record as an entity. For example, the record identifier of book-shelf is the concatenation of the identifier of its parent record instructor (instructor-name) with a sequence#. That is, instructor-name, sequence# can uniquely identify book-shelf record. A computer generated sequence# is necessary because there is no unique identifier in the book-shelf record (i.e. an instructor may have n book-shelves where n varies from 1 to many).

1.5 THE APPLICATIONS

The Internet has opened up a multitude of opportunities for many businesses to improve customer relationships and operations efficiency. The Internet is adopted by most companies because the cost of having Internet access via an Internet Services Provider can be as low as less than one hundred Hong Kong dollars per month.

Electronic Data Interchange (EDI) is the electronic transfer of structured business information between trading partners. The idea behind it is simple: Companies have to exchange an enormous amount of paperwork to conduct business. We replace the paperwork with electronic files. EDI reduces administrative costs and improves relationships between trading partners. Figure 1-7 shows the data flow diagram of a traditional EDI operation on the Internet.

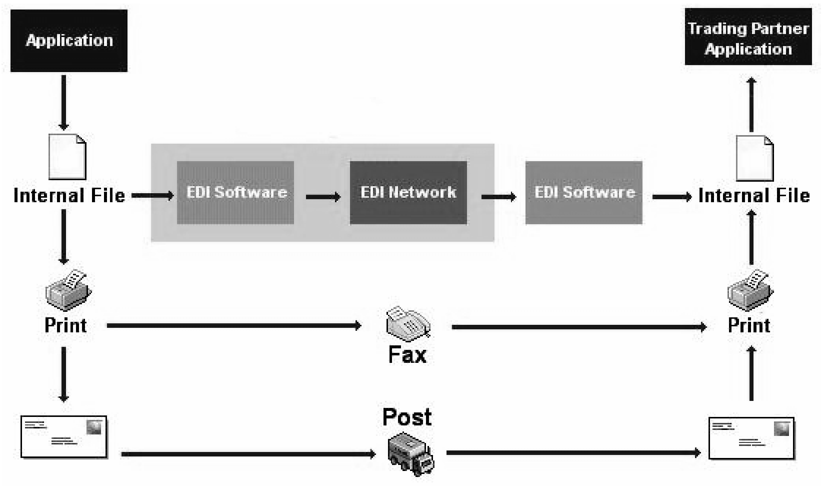

Figure 1-7 Traditional EDI exchange

However, EDI systems are very expensive and time consuming to implement and maintain; they are inflexible and limited to integration between trading partners. The traditional EDI systems are seven to ten times more expensive than Internet-based options. Besides, the Internet offers broad connectivity that links networks around the world and offers a platform-independent means of exchanging information. Internet technology can extend the capabilities of existing EDI systems. It is easier to implement and maintain. This has led a growing number of companies to look for alternative to the EDI formats. XML (Extensible Markup Language) (W3C, 2004) is the most attractive alternative because it offers superior conversion features.

XML is defined as EXtensible Markup Language as developed by the World Wide Web Consortium (W3C) recommendation Version 1.0 as of 10/02/1998 as a Meta-Markup Language with a set of rules for creating semantic tags used to describe data.

To apply XML in EDI on the Internet, in Figure 1-8, an XML Receiver Transmitter (XMLRT) system can automate the translation of relational schema and data into the topological XML documents based on their data semantics. They are integrated into an XML document. The translated XML document is mapped and stored into the receiver's relational database for computing. The contribution of XMLRT architecture is to automate the translation of schema and data through the topological data structures of an XML document.

Using an XMLRT system with XML document, we can enrich data portability and application access on the Internet more efficiently than ever before. XMLRT and XML documents allow a company to realize long term benefits via improved feasibility in the market. We also bring information into any Web browser anywhere in the world. By providing an information highway on the Internet, an XML document is made to suit a company's inter-company and self-defined requirements for data exchange The tasks involved are: (1) Select and map a view of sender's relational database into different topological XML documents. (2) Integrate the translated topological XML documents into one. (3) Translate the XML document to receiver's relational database for storage.

To make relational tables compatible with the XML document, we join the former into a single relation, and transfer the joined relational schema into XML schema. We load tuples of the joined relation into object instances of elements or attributes in the XML document according to the XML schema, and preserve their data dependencies.

To receive an XML document from the Internet, we need an XML-to-Relational Connectivity Machine. This machine maps an XML schema into a relational schema. By traversing the XML document from Root to all element instances, it loads XML instances into tuples in relations with *OID* (object identity). The Data Map schemas consist of relational schemas and their corresponding XML schemas. The company relational database consists of seller and buyer databases (Fong and Wong, 2004).

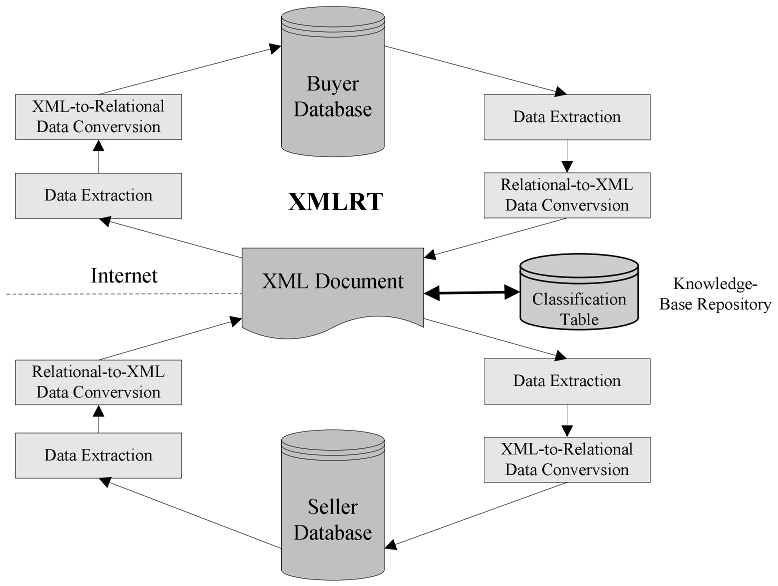
Buyer Database
XML-to-Relational Data Convervsion
Data Extraction
Data Extraction
Relational-to-XML Data Convervsion
XMLRT
Internet
XML Document
Classification Table
Knowledge-Base Repository
Relational-to-XML Data Convervsion
Data Extraction
Data Extraction
XML-to-Relational Data Convervsion
Seller Database

Figure 1-8 Architecture of XML receiver transmitter

To convert a relational database into an XML document and vice versa, we apply a Relational XML Connectivity Machine using an XML document for information exchange standard on the Internet for B2B (business-to-business) applications. The Data Map schema files consist of relational schema and corresponding XML schema. The company relational database consists of seller/buyer databases. The XML document is for the information exchange on the Internet in Figure 1-9.

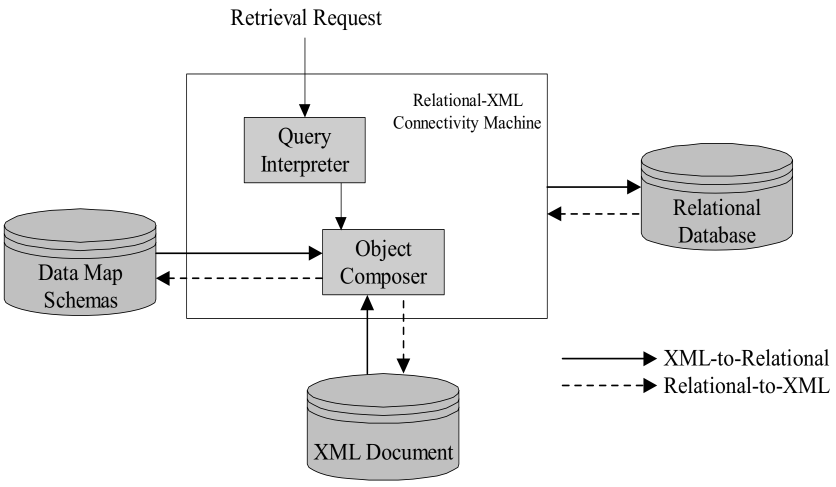

Figure 1-9 Relational-XML connectivity machine

1.6 SUMMARY

The evolution of information system technologies started with file systems in the 60s, database system in the 70s, and expert systems in the 80s. The need to upgrade a company's information system is vital to its success. Database technologies offer a solution for a company's organization to share information efficiently and effectively. Expert systems provide important information for management decision making. To protect a company's huge investment in the information system, reengineering rather than rewriting seems to be more cost effective. Information engineering includes database reengineering and expert system reengineering. The former can be accomplished by upgrading an obsolete record-based hierarchical or network database into a relation-based relational, or reengineering a relational database into an object-based object-oriented, or Internet-based XML. The upgrade (conversion) process includes schema translation, data conversion, and program translation. The aspect of reengineering an existing database system into an object-oriented or XML system is also very attractive due to the increase of productivity and user friendliness of object-oriented systems, and the importance of Internet application of

XML systems. Data integration must be done after schema integration and schema translation. An expert system can be reused by integrating it with a new or existing database system. The resultant expert database system is the core information resource system for a company for future reengineering purposes. The problems in database reengineering are in the handling of different data structures of various data models. Also, the existing expert systems can become obsolete due to changes of user requirements and production databases. The suggested solution is to upgrade record-based data models of hierarchical or network databases to table oriented relational databases, object-oriented databases, and XML databases. We can also reuse expert systems by integrating them with the database into an expert database system. An example of the application of reengineering can be seen in the electronic data interchange on the Internet. The EDI system can help trading companies exchange information for their business. However, EDI needs programming solutions that are too expensive and not promptly developed. The alternative is to use XMLRT and XML document as a medium for data transmission on the Internet. Since XML is the default data standard on the Internet, which can be browsed through Internet Explorer without programming, the XMLRT and XML document solution can perform better with less cost than EDI. We will show how to perform data transformation between relational data and an XML document in the later chapters.

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QUESTIONS

Question 1-1

What is an expert system, an expert database system and a knowledge-based system? What are their major differences?

Question 1-2

How can one validate and measure the quality of a converted database?

CHAPTER 2

DATABASE AND EXPERT SYSTEM TECHNOLOGY

2.1 HIERARCHICAL MODEL

The hierarchical data model is a logical schema and can be viewed as a subset of a network model because it imposes a further restriction on the relationship types in the form of an inverted tree structure. The linkage between record types is in an automatic fixed set membership. The database access path of a hierarchical database follows the hierarchical path from a parent to child record. The default path is a hierarchical sequence of top-to-bottom, left-to-right, and front-to-back.

It is common that many real life data can be structured in hierarchical form. For example, enrollment in a university can be ordered according to the department organizations. Because hierarchies are so familiar in nature and in human society, it seems natural to represent data in a hierarchical structure. Data represent ideas about the real world that people conceive in terms of entities. Based on the characteristics of entities, entity type can be defined. Figure 2-1 shows a generic hierarchical tree that represents entity types where entities refer to record types and record. In the tree, the record type at the top is usually known as the "root." Record types are groups of entities or records that can be described by the same set of attributes. In general, the root may have any number of dependents, each of these may have any number of lower-level dependents, and so on, to any number of levels. Individual records are the actual occurrences of data. The righthand side is the hierarchical sequence.

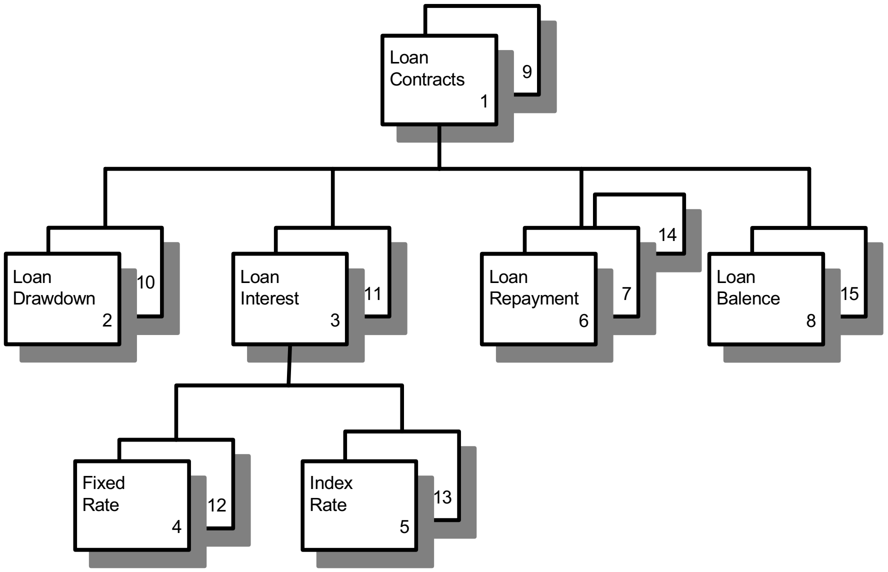


Figure 2-1 Hierarchical database of a loan system

There are some important properties of the hierarchical database model.

There is a set of record types (R_1, R_2,.... R_N). It is possible to designate a field of record type as an identifier of a record occurrence of this type. This may provide either a unique or a non-unique identification. This identifier is called a key.

- There is a set of relationships connecting all record types in one data structure diagram.
- There is no more than one relationship between any two record types R_i and R_j. Hence, relationships need not be labeled.
- The relationships expressed in the data structure diagram form a tree with all edges pointing towards the leaves.
- Each relationship is 1:n and it is total. That is, if R_i is the parent of R_j in the hierarchy, then for every record occurrence of R_j there is exactly one R_i record connected to it.

To construct a hierarchical model, it is natural to build an ER model and map it to a hierarchical model because an ER model carries more semantics. Once an ER model is built, if relationships are all binary, we can map a 1:n or 1:1 relationship from A to B as a binary tree. To map a m:n relationship from A to B, we can use virtual record types (pointer to actual records) which are distinguished by an ID field in a physical address as shown in Figure 2-2 (McElreath, 1981).

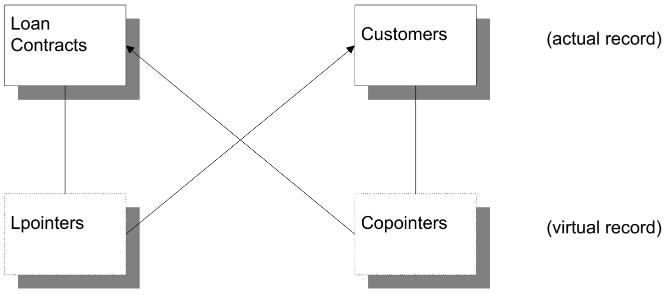


Figure 2-2 m:n relationship of a hierarchical model in a loan system

Hierarchical Data Definition Language

Two types of structures are used to implement the inverted tree structure of a hierarchical model: namely data definition trees and data occurrence trees. The role of a data definition tree is to describe the data types and their relationships. For example, Figure 2-1 shows seven data types, in a parent (the top one)-child (the bottom one) relationship with respect to each other. Data occurrence tree represents the actual data in the database. Figure 2-1 shows fifteen data occurrences in hierarchical sequence, the default read sequence in hierarchical model.

Due to the limitation of an inverted tree structure, the hierarchical model cannot be used to implement the followings:

- m:n relationship between two record types
- A child record type with more than one parent record type
- n-ary relationships with more than two participating record types

But with virtual pointers architecture, each record type can be in an m:n relationship with another record type through the pointers. The record type with the source pointers is called the logical child.

Its target record type is called the logical parent. For example, Figure 2-2 shows that the record types of Cpointers and Lpointers are logical child record types. Their corresponding logical parent record types are Customers and Loan Contracts. As a result of these pointers, Record type Customers and Loan Contracts are in an m:n relationship such that each customer can sign many loan contracts, and each loan contract can be signed by many customers.

Hierarchical Data Manipulation Language

Hierarchical data manipulation language (HDML) is a record-at-a-time language for manipulating hierarchical databases. The commands of a HDML must be embedded in a general-purpose programming language, called a host language. Following each HDML command, the last record accessed by the command is called the current database record. The system maintains a pointer to the current record. Subsequent database commands proceed from the current record and move to a new current record depending on the operation of the command. The traversal of the database access follows the inverted tree structure, i.e., each database navigation path according to the hierarchical sequence. For example, Figure 2-1 has five access paths as follows:

Path 1	**Path 2**	**Path 3**	**Path 4**	**Path 5**
Loan Cont	Loan Cont.	Loan Cont.	Loan Cont.	Loan Cont.
Loan Drawdown	Loan Interest	Loan Interest	Loan Repayment	Loan balance
	Fixed Rate	Indexed Rate		

The commands in any DML, can be divided into two sets: retrieval commands and modification commands. The following are the syntax of the hierarchical DML of IMS (IBM's Information Management System, a hierarchical DBMS). There are four parameters in IMS DML. They are:

- Function Code, which defines the database access function

- Program Control Block, which defines the external subschema access path

- I-O-Area, which is a target segment address

- Segment Search Argument, which defines the target segment selection criteria as follows:

```
    CALL "CBLTDLI" USING FUNCTION-CODE
```

```
                  PCB-MASK
                  I-O-AREA
                  SSA-1
                  ...
                  SSA-n.
```

Note: CBLTDLI is a call by a Cobol program to access the DL/1 database.

Retrieval Command:

- Get Unique (GU)

  This command retrieves the leftmost segment that satisfies the specified condition. For example, the following Get unique command is to retrieve a Loan Balance segment of a loan with the loan contract number 277988 and loan balance date of July 22, 1996.

```
CALL "CBLTDLI" USING GU
                     PCB-MASK
                     I-O-AREA
                      LOAN_CONTRACT# = 277988
                      BALANCE_DATE = '960722'
```

- Get Next (GN)

  This command retrieves the next segment based on the pre-order traversal algorithm from the current location. The clause for the record identifier and retrieval conditions is optional. If the clause is not given, GET NEXT would retrieve the next sequential segment from the current location. For example, the following command is to retrieve the next Loan Contract record after the current Loan Contract record occurrence.

```
CALL "CBLTDLI" USING GN
                                  PCB-MASK
                                  LOAN_CONTRACT.
```

- Get Next WITHIN PARENT(GNP)

  This command retrieves segments from the set of children sharing the same parent as the current segment of the given type. The parent segment is visited by a previous GET command, i.e., it establishes parentage of a segment type according to the current pointer of its parent segment type. For example, the following command retrieves the next in a hierarchical sequence of a Loan_interest segment under the loan_contract segment type with a loan_contract# of "277988".

```
CALL "CBLTDLI" USING GNP
                     PCB-MASK
                     LOAN_INTEREST
                     LOAN_CONTRACT# = 277988.
```

Hierarchical Modification Commands:

- INSERT(ISRT)

  This command stores a new segment and connects it to a parent segment. The parent segment must be selected by the previous GET command. For example, the following commands is to insert a balance segment of $1,000,000 under the Loan_contract number 277988 on July 22, 1996.

```
CALL "CBLTDLI" USING GU
                     PCB-MASK
                     I-O-AREA
                     LOAN_CONTRACT# = 277988.
MOVE "19960722" TO BALANCE_DATE.
MOVE 1000000 TO BALANCE_AMOUNT.
CALL "CBLTDLI" USING ISRT
                     PCB-MASK
                     LOAN_BALANCE.
```

- REPLACE(REPL)

  This command replaces the current segment with the new segment. It can be used to alter the detail of the current segment. For example, the following commands are to update the loan balance of loan contract# 277988 from 1,000,000 to 2,000,000 on July 22, 1996. The GHU function is a get hold unique call to apply a record lock on a segment before an update.

```
CALL "CBLTDLI" USING GHU
                     PCB-MASK
                     I-O-AREA
                     LOAN_CONTRACT# = 277988
                     BALANCE_DATE = '960722'
```

```
    MOVE 2000000 TO BALANCE_AMOUNT.
     CALL "CBLTDLI" USING REPL.
```

- DELETE (DELT)

  This command physically deletes the current segment and all of its child segments. For example, the following command deletes a balance segment of a loan contract# 277988 on July 22, 1996.

```
CALL "CBLTDLI" USING GHU
                     PCB-MASK
                     I-O-AREA
                     LOAN_CONTRACT# = 277988
                     BALANCE_DATE = '960722'
CALL "CBLTDLI" USING DELT.
```

2.2 NETWORK (CODASYL) MODEL

The Network model is a logical schema and is based on tables and graphs (CODASYL, 1971). The nodes of a graph (segment types) usually correspond to the entity types, which are represented as connections (sets) between tables in the form of network. The insertion and retention of segment types depend on the set membership constraints that exist between the owner and member segments, with automatic or manual insertion, and fixed, mandatory, or optional retention.

A network database model is similar to a hierarchical database model that represents data and a data relationship in a graphical form. The network model differs from the hierarchical model as:

- There can be more than one edge between a given pair of entities

- There is no concept of root and

- A segment can have more than one parent segment

For example, Figure 2-3 is a network model for the university enrollment system.

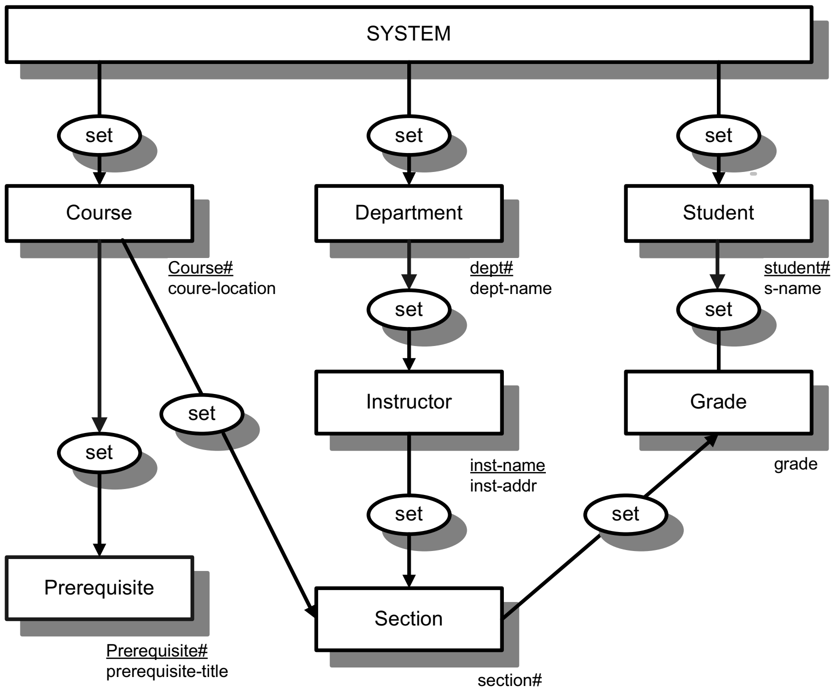


Figure 2-3 A Network model for university enrollment

The CODASYL (Network) model is composed of two basic data constructs: the record and the set respectively. These two data constructs are built up from simpler data elements which are discussed in the following:

- Data Item - An occurrence of the smallest unit of named data. It is represented in the database by a value. A data item may be used to build other more complicated data constructs. This corresponds to an attribute in the ER data model.

- Data Aggregation - An occurrence of a named collection of data items within a record.

- Record - An occurrence of a named collection of data items or data aggregates. This collection is in conformity with the record type definition specified in the database schema.

- Set - An occurrence of a named collection of records. A set occurrence is in direct correspondence with the set type definition specified in the database schema. Each set type consists of one owner record type and at least one member record type.

- Area - The notion of an area used to identify the partition of record occurrences. An area is a named collection of records that need not preserve owner-member relationships. An area may contain occurrences of one or more record types and a record type may have occurrences in more than one area.

When designing a network database, the following rules must be followed to ensure the integrity of the definitions:

- An area is a named subdivision of the database.
- An arbitrary number of areas may be defined in a system.
- Records may be independently assigned to areas of their set associations.
- A record occurrence is stored within one area only.
- A single occurrence of a set type may span several areas.
- Each set type must be uniquely named and must have an owner record type. A special type of set which has exactly one occurrence and for which the system is the owner may be declared as a singular set.
- Any record type may be defined as the owner of one or more set types.
- If a set has an owner record which has no member record, the set is known as empty or null.
- A record cannot be used as an owner record in more than one occurrence of the same set type.
- A record cannot be participated as a member record in more than one occurrence of the same type.
- A set contains exactly one occurrence of its owner.
- A set may have any number of member occurrences.

The followings shows some record entries and set entries of the university enrollment system.

```
RECORD NAME IS DEPARTMENT WITHIN ANY AREA
    KEY DEPARTMENTID IS DEPARTMENT#
    DUPLICATES ARE NOT ALLOWED
    CALL CHECK-AUTHORIZATION BEFORE DELETE
    DEPARTMENT# TYPE IS NUMERIC INTEGER
    DEPARTMENT-NAME TYPE IS CHARACTER 30

RECORD NAME IS INSTRUCTOR WITHIN ANY AREA
    KEY INSTRUCTORID IS INSTRUCTOR-NAME
    DUPLICATES ARE ALLOWED
    CALL CHECK-AUTHORIZATION BEFORE DELETE
    INSTRUCTOR-NAME TYPE IS CHARACTER 30
    INSTRUCTOR-ADDRESS TYPE IS CHARACTER 40

SET NAME IS HIRE
    OWNER IS DEPARTMENT
    ORDER IS PERMANENT INSERTION IS FIRST
    MEMBER IS INSTRUCTOR
    INSERTION IS AUTOMATIC RETENTION IS MANDATORY
    SET SELECTION IS THRU HIRE OWNER IS IDENTIFIED
           BY APPLICATION
```

The INSERTION clause specifies the class of membership of a member record in a set type. There are two options in this clause: AUTOMATIC and MANUAL. For the AUTOMATIC option, the system ensures the status of the member record in the occurrences of the set type. For the MANUAL option, the application must handle the record as a member of some set occurrence in the database. The RETENTION is concerned with the ways in which records retain their membership in the database. There are three ways: FIXED, MANDATORY and OPTIONAL, for handling set membership. For the FIXED option, if a record occurrence is made a member in a set, then that record must exist as a member of the set in which it associates. For MANDATORY, if a record is made a member in some set, then it must exist as a member of some occurrence of this set type. Therefore, it is possible to transfer the record from one set occurrence to another. For OPTIONAL, a record is allowed to be moved from a set occurrence without requiring that the record be placed in a different occurrence.

Network Data Definition Language

As shown in Figure 2-4, the DBTG (database task group) specification proposeS three levels of data organization. There are two pairs of DDL and DML for the schema level and sub-schema level respectively. The four languages are:

- The schema Data Definition Language, schema DDL
- The sub-schema Data Definition Language, sub-schema DDL
- The Data Manipulation Language, DML and
- The Data Storage Description Language, DSDL

The schema is the logical description of the global database and is made up of a description of all the areas, set types, and record types as well as associated data items and data aggregates. A database is defined as consisting of all areas, records and sets that are controlled by a specific schema. A schema definition consists of the following elements:

- A schema entry
- One or more area entries
- One or more record entities and
- One or more set entries

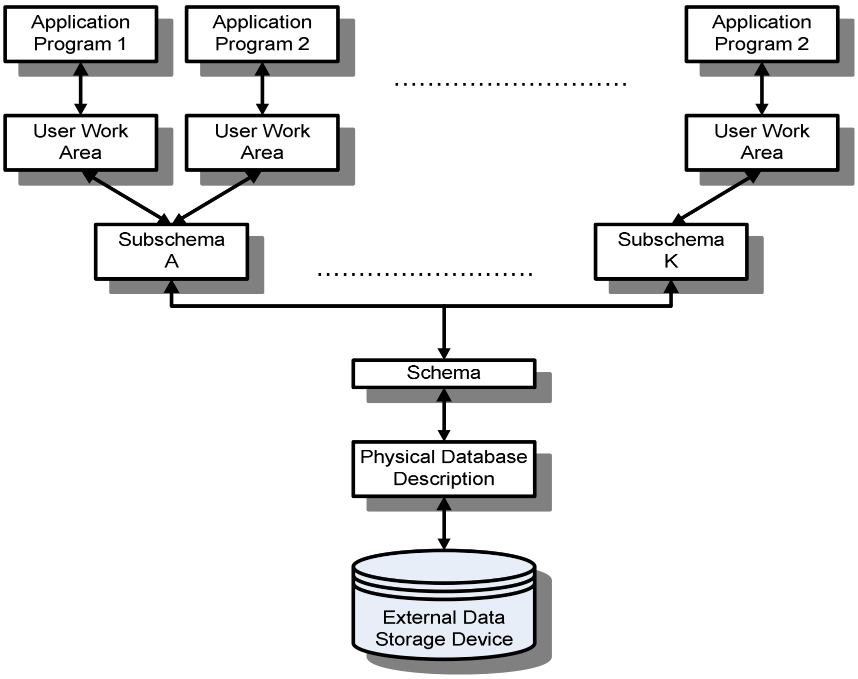


Figure 2-4 Architecture of a Codasyl DBTG system

The schema must be mapped to the physical storage device. This transformation is achieved by declaring the physical properties of the schema in the DSDL. The use of the DDL and DSDL provide the DBMS with a certain degree of data independence. In the DDL, the schema and area entries are more simple than the record and set entries. When declaring records and sets, database procedures must be defined by the database designer. Database procedures are specific to a particular database and are stored in the system. These procedures include validation of access, computation of data items values, and sorting sequence.

Network Data Manipulation Language

The language for operating a network database is called the network data DML. These DML commands can be embedded in a third-generation programming language called a host language. The DML commands can be divided into three groups: Navigation, Retrieval, and Updating. Navigation commands are used to set the currency indicators to specific records, and set occurrences in the database. Retrieval commands extract the current record of the run unit. Updating commands are used to update, store, and delete record and set occurrences.

Several currency indicators are maintained by the database network system to enable the programmer to navigate through the database. The following currency indicators are useful when a DML is used.

- Current of run unit - A run unit currency indicator refers to the record most recently accessed by the run unit; there is only one currency indicator of this kind.
- Current of a set type - A set type currency indicator refers to the record within a given set type that was most recently accessed. There are as many currency indicators of this kind as the number of set types defined in the sub-schema referenced by this run unit.
- Current of record type - A record currency indicator refers to the record within a given type that was most recently accessed.

The following are the major network DML statements:

a) OBTAIN First/Next record-name-i [USING {identifier-j}]

The OBTAIN statement is used to establish a specific record occurrence in the database. The target record of the OBTAIN statement becomes the current record. A number of different record selection expressions can be used in the OBTAIN statement. For example, the following statements are to obtain an occurrence of STUDENT record with student# = 1234 (Martin, 1990).

```
MOVE     1234 TO STUDENT#.
OBTAIN ANY STUDENT USING STUDENT#.
```

b) CONNECT record-name-i to set-name-j/all

The CONNECT statement makes a record of members of one or more set types. If these set type are enumerated, then the type of the current record must be either an OPTIONAL AUTOMATIC or a MANUAL member in these types. If ALL is selected, then this record type must be specified as an OPTIONAL AUTOMATIC or a MANUAL member in at least one set type declared in the sub-schema. For example, the following commands are to assign the student with student# = 1234 to the Computer Science Department.

```
MOVE              “Computer Science” TO name.
```

```
OBTAIN          Department USING name.
MOVE            1234 TO student#.
OBTAIN          Student USING student#
CONNECT         Student TO Department.
```

c) DISCONNECT [record-name-i] from set-name-j/all

The DISCONNECT statement removes the current member record from all specified set types. If set types are enumerated, then the record type of the current record must be an OPTIONAL member in each of the enumerated types. In the case when ALL is selected, the record type must be an OPTIONAL member in at least one set type of the subschema. For example, the following commands disconnect a student record from the department of computer science.

```
MOVE            "Computer Science" TO name.
OBTAIN          Department USING name.
MOVE            1234 TO student#.
OBTAIN          Student USING student#.
DISCONNECT      Student FROM Department.
```

d) STORE record-name-i

The STORE statement actually writes the record created in the record area of the UWA (user working area) to the database. For example, the following commands store a student record of John Doe with student# = 1234.

```
MOVE      "John Doe" TO Name.
MOVE      1234 TO student#.
STORE     Student.
```

e) MODIFY record-name-i

The modify statement is issued to change the contents of one or more data items in a record. It can also change the set membership of a record. For example, the following command changes a student's name from John Doe to John W. Doe.

```
MOVE      1234 TO student#.
OBTAIN    Student USING student#.
MOVE      "John W. Doe" TO Name.
MODIFY    Student.
```

f) ERASE [ALL] [record-name-i]

To delete a record by the ERSAE statement, the record must be located as the current record of the run unit. The current record of the run unit is removed provided that all affected sets are null sets. If ALL is specified and the current of the run unit is the owner of a non-null set, then all members of the set are removed. If the ALL option is not specified, then an affected set with member records can be removed only if its member records have FIXED or OPTIONAL membership in the set. For example, the following is the command to erase the student record with student# of 1234.

```
MOVE  1234 TO student#.
ERASE Student.
```

2.3 RELATIONAL MODEL

The relational model is a logical schema in the form of tables (relations) corresponding to the representation of an entity type. A column (attribute) of the tables represents the extension of attributes in the entity. The row (tuple) of the tables represents instances of the entity. Such tables are commonly called record types and consist of a non-null primary key that can uniquely identify a tuple. The parent-child relationship of relations is represented in the foreign key residing in the child relation referencing the primary key of parent relation.

The following are fundamental properties of a relational database:

- Column Homogeneous: For any given column of a relation, all items must be of the same kind whereas items in different columns may not be of the same kind.

- Indivisible Items: Each item is a simple number or a character string. It should represent a data element with the simplest form.

- Uniqueness of Records: All rows (records) of a relation are distinct. This implies that there must be a primary key for each record.

- Row Ordering: The ordering of rows within a relation is immaterial.
- Column Ordering: The columns of a relation are assigned distinct names and the ordering of the columns is immaterial.

For example, the following represents a relational model for university enrollment, where each table is a relation.

Relation Course

Course	Course-title	Location
CS101	Introduction to Computer Science	Lecture Theater 1
IS201	System Analysis	Lecture Theater 2
IS301	Decision Support System	Room P7818

Relation Prerequisite

*Course#	Prerequisite	Prereq-title
IS301	IS201	System Analysis

Relation Instructor

Inst-name	SS#	Inst-addr
A.B. Adams	415223614	White Plains
J.S. Fink	613557642	Brooklyn
A.M. Jones	452113641	Long Island

Relation Section

SS#	*Course	Section#	Lecture-hour
415223614	CS101	1	30
613557642	CS101	2	30

Relation Graduate Student

Student#	Degree-to-be
012888	M.Sc.
120008	Ph.D.

Relation Student

Student	Student-name	Sex
012888	Paul Chitson	M
120008	Irene Kwan	F
117402	John Lee	M

Relation Enrollment

*Student#	*Course	SS#	Section#	Year	Grade
012888	CS101	415223614	1	1995	A
120008	CS101	613557642	2	1996	B

Normalization

The primary problem of relational database design is how the data item types should be combined to form record types that naturally and completely describe entities and the relationships between entities. E.F. Codd developed the theory of normalization in the 1970s to overcome this problem. The purpose of normalization is to reduce complex user-views to a set of manageable and stable data structures.

Normalization theory is built around the concept of normal forms. A relation is said to be a particular normal form if it satisfies a certain specified set of constraints. Numerous normal forms have been defined. All normalized relations are in first normal form (1NF). Some 1NF relations are also in second normal form (2NF). Some 2NF are also in third normal form (3NF) (Elmasri & Navathe, 1989).

A 1NF relates to the structure of relations such that the field of a relation should have simple and atomic values, and relations should have no repeating groups.

A 2NF is one where all partial dependencies have been removed from its 1NF. That is, no non-key field depends on a subset of a composite key.

A 3NF is one where all transitive dependencies have been removed from its 2NF. That is, no non-key field depends on another non-key field.

The normalization applies functional dependencies in its normal forms. Functional dependencies is a relationship that exists between any two fields. We say that field A determines field B if each value of A has precisely one value of B. In other words, field B is functionally dependent on field A. This can be written as
FD:A $\rightarrow$ B where A is a determinant and B is a dependent field.

The following is an example to illustrate normalization where student details forms a repeating group.

Class#____________	Begin_date_____________
Lecturer_name_________________	End_date______________
Lecturer_address_______________	
_______________	

Student#	Student_name	Grade
.....	.....	....

The data in the above table is in unnormalized form because there are repeating groups of Student#, Student_name, and Grade. To normalize it into 1NF, we must eliminate the repeating groups by making them single data items in each tuple as follows:

Class (Class#, Lecturer_name, Lecturer_address,Begin_date,

End_date)
Enrolled_Student (Class#, Student#, Student_name, Grade)

To normalize it into 2NF, we must eliminate the partial dependencies by making dependent field Student_name fully functionally dependent on Student# as follows:

Class (Class#, Lecturer_name, Lecturer_address, Begin_date, End_date)
Enrolled_Student (Class#, Student#, Grade)
Student (Student#, Student_name)

Finally, to normalize the relations into 3NF, we eliminate the transitive dependencies by making Lecturer_address dependent on Lecturer_name, not transitively dependent on class# as follows:

Class (Class#, Lecturer_name, Begin_date, End_date)
Lecturer (Lecturer_name, Lecturer_address)
Enrolled_Student (Class#, Student#, Grade)
Student (Student#, Student_name)

Structured Query Language (SQL)
SQL was introduced as the standard query language for relational DBMS. The basic structure of an SQL retrieval command, a Select statement, is as follows:

Select A_1, A_2, ... A_n
from r_1, r_2.... r_n
[where P]
[order by O]
[group by G]
[having H]

All classes contained within the square brackets are optional. The A_i represents attributes, the r_i represent relations, and P is a predicate, and is default to be true. The attribute A_is may be replaced with a star (*) to select all attributes of all relations appearing in the form clause. O is the sort order of the target tuples based upon attribute values. G is the display group of the target attributes. H is the selection criteria of the display groups.

For example, if we use the normalized relations as source, we can issue the following select statements:

- To retrieve the student# of all students

```
Select Student# from Student
```

- To retrieve the student# of all students who are taking CS101

```
Select Student# from Enroled-Student
      where Class# = CS101
```

- To retrieve the student# of all students who are taking CS101 and whose grade is A.

```
Select Student# from Enroled-Student
      where Class# = CS101 and Grade = A
```

- To retrieve the address of all lecturers who teach CS101

```
 Select Lecturer_address from Enroled_Student, Lecturer
         where Enroled_Student.Lecturer_name =
                 Lecturer.Lecturer_name
            and Class# = CS101
```

- List all student_name and student# of all students ordered by student_name. The default ordering is ascending lexiographic.

```
 Select Student# from Student
      order by  Student_name
```

- List the class#, student#, and student_name of all students for each class.

```
Select Class#, Student#, Student_name from
     Student,Enroled_Student
     where Student.Student# = Enroled_student.Student#
     group by Class#
```

- List all class#, student#, and student_name of all students for each class and whose grade is A.

```
Select Class#, Student#, Student_name from
      Student,Enrolled_Student
      where Student.Student# = Enrolled_student.Student#
      group by Class#
      having Grade = ’A’
```

The database modification statements of SQL are as follows:

- Insertion
    The syntax of Insert statement of SQL is:

```
Insert into R
attributes ($A_1$, $A_{2...}$ $A_n$)
values ($V_1$, $V_2$ ,....$V_n$)
```

For example, insert a student with student# = 1234 and student name =“John Doe”.

```
Insert into Student
attributes (Student#, Student_name)
values (1234, “John Doe”)
```

- Updating
  The syntax of the update statement of SQL is:
  ```
  Update R
  Set $A_i$ = $V_i$
  [where P]
  ```

  For example, modify the grade of all students enrolled into CS101 to ’B’.

  ```
  Update Enrolled_Student
  Set Grade = ’B’
  where class# = ‘CS101’
  ```

- Delete
  The syntax of delete statement of SQL is:
  ```
  Delete R
  [where P]
  ```

  For example, delete the grade of student whose student# is 1234 and who is taking CS101.

  ```
  Delete Enrolled_student
  where Student# = 1234 and Class# = ‘CS101’
  ```

Extended Entity Relationship Model

The Entity Relationship (ER) Model (Chen, 1976) is a special diagram technique used as a tool for logical database design. It serves as an informal representation to model the real world by adopting the more natural view such that the real world consists of entities and relationships; it also incorporates some important semantic information into the model. The model can achieve a high degree of data independence and is based on set theory and relation theory. It can be used as a basis for a unified view of data and a prelude to designing a conceptual database.

The components of an ER model are:

1. Entity set – An entity set (i.e. entity type) or an entity (i.e., entity instance) is an important, distinguishable object for an application, e.g., a regular entity, a weak entity.

2. Entity key – An entity attribute that can uniquely identify an entity instance.

3. Entity attribute – Fields that describe an entity (i.e., properties of an entity).

4. Degree of relationship – The number of entity sets that are related to each other. For example, unary means one entity, binary means two entities, ternary means three entities, and n-ary means n entities related to each other.

5. Cardinality – The connectivity of two entities, that is, one-to-one, one-to-many, and many-to-many.

6. Relationship membership – The insertion rules of relationship. For example, mandatory means compulsory relationship, optional means not compulsory relationship.

7. (Minimum, maximum) occurrence – The minimum and maximum instances of cardinality. (For example, zero minimum occurrence means partial participation in an optional relationship.)

The Entity Relationship (ER) model has been widely used but does have some shortcomings. It is difficult to represent cases where an entity may have varying attributes dependant upon some property. For example, one might want to store different information for different employees dependent upon their role, although there will still be certain data such as name, job title, and department that remain common to all employees. Employees who are engineers may require professional qualifications to be stored. We may need to know the typing speed of typist employees and would need to store the language spoken by each translator employee.

Because of these limitations, the Extended Entity Relationship Model (EER) has been proposed by several authors (Kozacynski, 1988), although there is no general agreement on what constitutes such a model. Here, we will include in our model the following additions to the ER model:

- Generalization (Elmasri, 1989) – More than one isa relationship can form data abstraction (superclass/subclass) among entities. A subclass entity is a subset of its superclass entity. There are two kinds of generalization. The first is disjoint generalization such that subclass entities are mutually exclusive, which can be differentiated by a field in the superclass entity. The second is overlap generalization in which subclass entities can overlap each other and can be differentiated by fields in the superclass entity.

- Categorization – More than one isa relationship form data abstraction among entities such that the union of entities form a superclass entity to a subclass entity.

- Aggregation – The relationship between entities and relationships can be aggregated (grouped) as an entity.

In summary, an Extended Entity Relationship model consists of eight data semantics as shown in Figure 2-5 (Teorey, 1986).

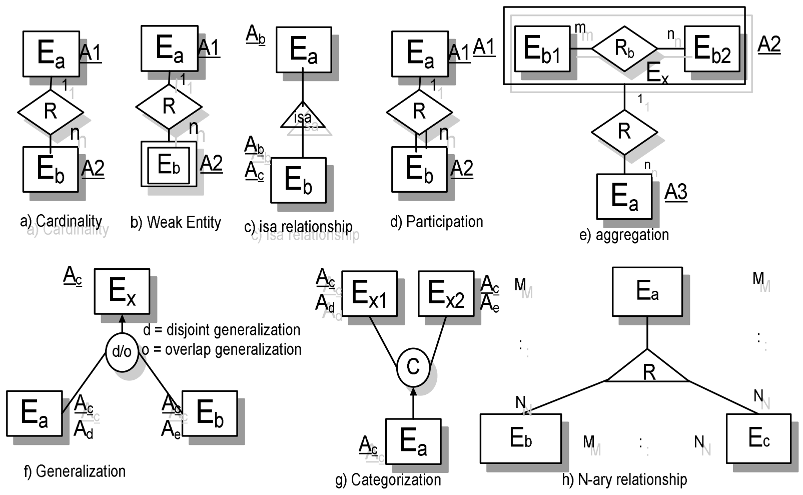


Figure 2-5 Eight data semantics in Extended Entity Relationship model

Figure 2-5 illustrates different data semantics including:

(a) One-to-many cardinality between entities E_a and E_b

(b) Weak entity E_b concatenates the key of A1 from E_a

(c) Subclass entity E_b is a subset of entity E_a with the same key A_b A_c

(d) Entity E_b is in total participation with Entity E_a

(e) Binary relationship R_b of entity E_{b1} relating with entity E_{b2} is an aggregate entity

(f) Subclass entity E_a and E_b can be generalized into superclass entity $E_{x.}$

(g) Subclass E_a is a subset of the union of superclass entity E_{x1} and E_{x2}.

(h) Entities E_a, E_b and E_c are in many-to-many ternary relationship

A sample of an Extended Entity Relationship model for a hospital patient record system is in Figure 2-6. A patient is insured by many insurance coverage. A patient belongs to many record folders. Each record folder contains many medical records. An AE record, a ward record, and an outpatient record can be generalized as medical record.

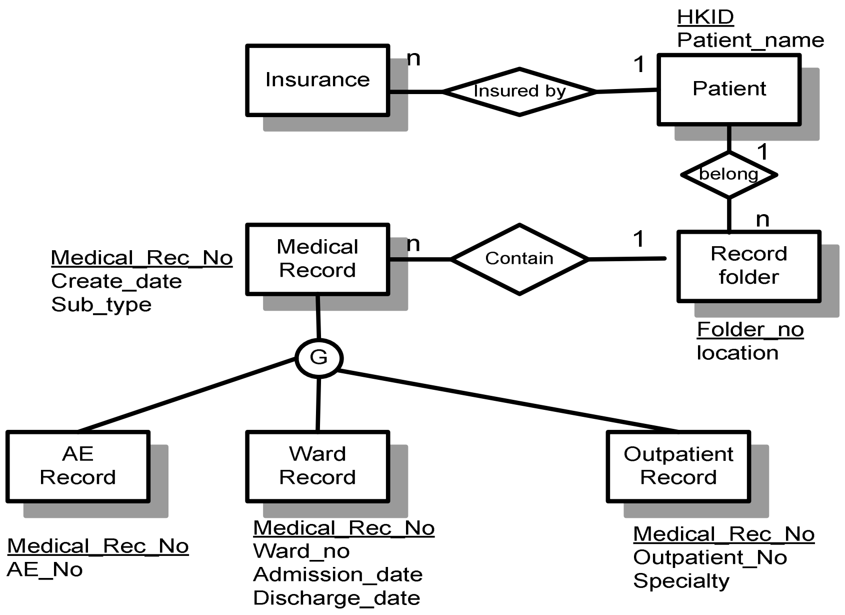


Figure 2-6 An Extended Entity Relationship model for hospital patient record

2.4 OBJECT-ORIENTED MODEL

To date, numerous object-oriented data models have been proposed. In an object-oriented data model (Hughes, 1991), the world is viewed as a set of objects that communicate with each other by exchanging messages, and can be described as follows.

Object-oriented model is a logical schema in the form of objects with name, properties, and behavior. An object represents "a thing" that is important to users in the portion of reality that the users want to model. Each object belongs to a family, or class, of similar objects. A class is a template (containing code and data) that describes the common characteristics of a set of objects. Object-oriented database systems simplify programming database updates and provide faster access to stored data by blurring the distinction between programming language and database.

Objects that have similar properties are grouped together into a class. Each class has an ID that is called the object ID (i.e., OID). The object IDs are unique. The IDs need not necessarily be the same as the primary key values used to identify the tuples in the relational model.

A class has properties that describe the objects of the class.

These properties are called instance variables (i.e., attributes). A link is a physical or conceptual connection between object instances (i.e., classes). A link is an instance of an association.

Classes have methods associated with them. Methods are procedures that are executed when they are invoked. Methods are invoked when appropriate messages are received. An instance variable (i.e., attribute) could be either a non-composite instance variable or it could be a composite variable. Non-composite instance variables are divided further into simple instance variables and complex instance variables. Simple instance variables take individual objects as their values. An individual object could be a basic system object such as integer, string, or Boolean, or a user defined object. Complex instance variables (i.e., complex objects) take a set or a list of individual objects as their values. For example, a complex instance variable HOBBY can have multiple values (SWIMMING, TENNIS, MUSIC).

Any class that has a composite instance variable is a composite class. The instances belonging to such a class are composite objects. A composite object together with its components forms a IS-PART-OF hierarchy. The link from a composite object to its component is called a composite link. For example, a composite class CAR can have attributes (BODY, ENGINE, TIER) and each one of them is a class itself.

A second hierarchy that may be formed is the ISA hierarchy, where subclasses are associated with a class. The subclasses inherit all the methods and instance variables defined for the class. A subclass could also have some additional instance variables and methods. For example, a subclass GRADUATE_STUDENT can inherit all the attributes and methods of its superclass STUDENT.

An object-oriented data model has the following properties:

- An object is an instance value of a class. A class can have many instances. A class has attributes and methods. The attributes of a class describe its properties. The methods of a class describe its operations.

- A class must support encapsulation (i.e., hiding operations from the users) such that
  object = data + program
  data = values of attributes
  program = methods that operates on the state

- Object attributes can be either simple or complex. The value of a complex attribute is a reference to the instance of another class. In other words, an object can be a nested object such that the value of an object is another object.

- Polymorphism allows a program entity to refer at run-time to instances of a variety of types.

- Object attributes can be single-valued or multi-valued.

- Objects are uniquely identified by object identifier (OID) that are assigned by the system.

- In a class hierarchy, a subclass inherits attributes and methods from one or more superclasses.

An example of a class Department and a class Instructor is shown below:

```
Class Department
 attribute Dept#: integer
 attribute Dept-name: string
 association attribute hire ref set(Instructor)
 Method
  Create Department
end Department

Class Instructor
 attribute Inst-name: string
 attribute Inst-addr: string
 association attribute hired-by ref Department
 Method
  Create Instructor
end Instructor.
```

In this example, class Department has a complex attribute Instructor such that the attributes and the methods of an independent class Instructor is contained in the class Department. The data structure of the Object-oriented schema can be illustrated in Figure 2-7 where the class defining and object is used to find the code for the method that is applied to the object (Date, 1995).

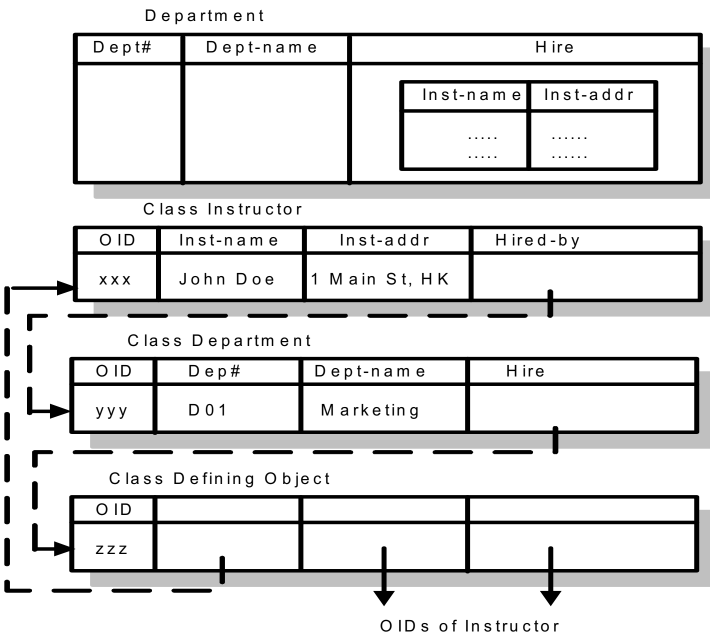


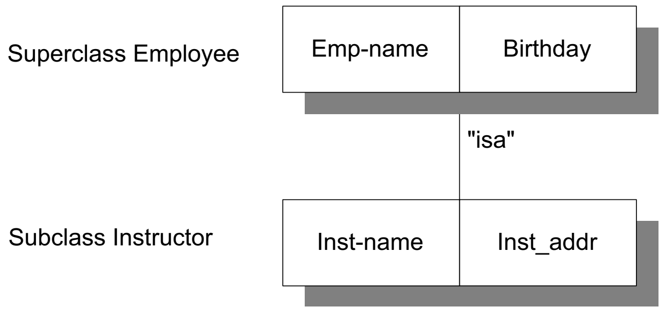
Figure 2-7 A containment hierarchy data structure in object-oriented schema

In an object-oriented schema, a special relationship between an instance of a subclass and the instances of the deep extent of a class exists. Such a relationship can be represented by a "class instance inclusion dependence" indicating that the class instances of a subclass is a subset of the class instances of its superclass. In other words, every instance value of a subclass, is also an instance value of its superclass. However, for every instance value of a superclass, there may not be any subclass object. Thus, the isa relationship can be described as an ID (inclusion dependency) in an object-oriented schema as follows:

ID: subclass object OID $\subseteq$ All superclass object OID

(Note: "All" refers to the deep extent of the class.)

This can be illustrated in Figure 2-8.



ID: Instructor OID $\subseteq$ All Employee OID

Figure 2-8 Data structure of superclass object and subclass object

Unified Model Language

To describe the semantic of the object-oriented database, we use an object-oriented conceptual model such as Unified Model Language, which is popular in object-oriented system design. In general, UML is more powerful than the EER model because UML includes not only static data, but also dynamic data behavior in its method. The syntax of Unified Model Language can be described as follows (Booch, 1994):

● Class - Each rectangular box is a class. For example, in Figure 2-9 Patient is a class.

● Each class consists of three components: class name, attributes, and methods. For example, Class Patient has attributes HKID and Patient_name, and a method Create Patient.

● Links - The association between two classes are called links. The dot sign at the end of the link indicates the cardinality of the association. A dot sign means that more than one occurrence of the entity exist at that end. A straight line without a dot sign means one occurrence of the entity exists at that end. For example, in Figure 2-9, there is a link between class Patient and class Insurance. The solid dot sign where the link attaches to the class Insurance side means each Patient can link with more than one Insurance.

- Aggregation - A diamond sign that links classes is called aggregation. Aggregation represents "part-of" semantics. The bottom part(s) are the component(s) of the top part (the aggregated class). The existence of the component(s) part depends on its aggregated class. If the aggregated class is deleted, then the component parts are also deleted. The components of an aggregation must exist before the aggregate can be created.

- Inheritance - An triangular symbol that links classes is called the inheritance symbol. The apex of the triangle is linked to the superclass with the subclasses being linked to the base of the triangle. Figure 2-9 shows that class AE_Record is a subclass that inherits the attributes and methods of its superclass Medical_Record.

- Navigation – Given an association between two classes, it is possible to navigate from objects of one kind to objects of the other kind. Unless otherwise specified, navigation across an association is bidirectional.

In Unified Model Language, a class diagram is a collection of declarative model elements, such as classes, their contents and relationships. It is a graphical view of the static structural model. It shows the relationship between classes and the attributes and operations of a class.

A class is a description of a set of objects that share the same data structure (attributes), behaviours (operations), methods, and relationships. Objects are instances of classes. An attribute is a class property that specifies the data structure that instances of the class may contain. An operation is a class interface that is invoked on an object to manipulate attributes. A method is the implementation of an operation. It specifies a program or procedure associated with an operation. Relationship is a connection among model elements.

Association and generalization are useful relationships specified in Unified Model Language. Association is the semantic relationship between two or more classes that specifies connections among their instances. It consists of at least two ends, each specifying a connected class and a set of properties such as navigability and multiplicity that must be fulfilled for the relationship to be valid. Association class is a model element that has both association and class properties. It allows the additions of attributes and operations to an association.

In summary, there are basically five major data semantics in

Unified Model Language class diagram as shown in Figure 2-9 in the following semantics:

(a) One-to-many association between classes Patient and class Record folder
(b) Subclass AE record, subclass Ward record, and subclass Outpatient record is a subset of superclass Medical record.

.

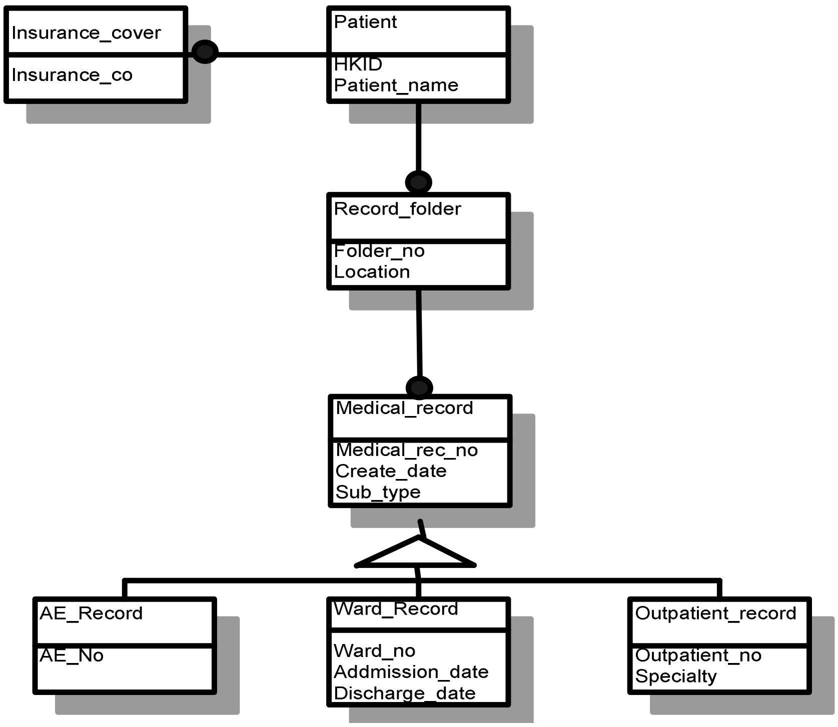


Figure 2-9 An object-oriented model for hospital patient record

Object-Oriented Data Definition Language

There are many commercial object-object databases in the industry. In this book, we choose UniSQL (UniSQL, 1992) as a representative for illustration purposes. In order to implement the abstract data type, we must first define each class. A class is a collection of many objects with similar properties. Each object is an instance of a class. A class consists of a class name, attributes, and methods, and can be defined as follows:

Class <class-name>
Attributes

```
        [inherit<class-name>]
        <attribute-name>: [set] <primitive data type>/<class>
Method
        [operations]
```

A class must have a unique name and can inherit from any other class that is not a descendant of itself. The attribute describes the properties of a class. Its data type can be a primitive one such as integer, numeric, and character. It can be another class. If it is another class, it is called a complex object, which means a class is within another class, or a nested class. If an object associates many other objects, then we must use Set in describing the associated attributes. This is similar to 1:m cardinality in the ER model and in a relational model.

The inherit statement is to indicate that the subclass inherits attributes and methods from its superclass. The class with the inherit statement is the subclass. The target class after the inherit key word is the superclass. The methods are the defined/stored operation(s) of a class.

The object-oriented data definition language of UniSQL consists of Create class statement, as follows:

Create - Use a create statement to define a class. For example,

```
Create class Department          Create class Instructor
     (Dept#: integer,                 (Inst-name: char(30),
     Dept-name: char(30),             Inst-addr: char(50),
     Hire: set-of Instructors)        Hired-by: Department)
Procedure                         Procedure
     Display Department.              Display Instructor.
```

2.5 EXTENSIBLE MARKUP LANGUAGE

XML is defined as EXtensible Markup Language (XML). Its development can be traced up to World Wide Web Consortium (W3C, 2004) recommendation Version 1.0 as of 10/02/1998. It describes data, rather than instructing a system on how to process it, and provides powerful capabilities for data integration and data-driven styling, introduces new processing paradigms and requires new ways of thinking about Web development. It is a Meta-Markup Language with a set of rules for creating semantic tags used to describe data.

XML is a supplement to HTML such that it is not a replacement for

HTML. It will be used to structure and describe the Web data while HTML will be used to format and display the same data. XML can keep data separated from an HTML document. XML can also store data inside HTML documents (Data Islands). XML can be used to exchange and store data.

With the development of Internet, the third generation of post relational database may be an XML database, which uses an XML document as its fundamental unit, defines a model such as elements, attributes, PCDATA, etc. for an XML instance, and is stored as either binary code or text file. XML has been widely used on the Internet for business transaction in both B2B and B2C. We can expect a strong need to migrate relational databases into XML documents for the reengineering and the interoperability of the relational and XML databases.

The XML schema can be described in the form of Data Type Declaration (DTD) which is a mechanism (set of rules) to describe the structure, syntax and vocabulary of XML documents. DTD defines the legal building blocks of an XML document. It has a set of rules to define document structure with a list of legal elements, and declared inline in the XML document or as an external reference. All names are user defined. One DTD can be used for multiple documents.

An XML element is made up of a *start tag*, an *end tag*, and data in between. The name of the element is enclosed by the less than and greater than characters, and these are called tags. The start and end tags describe the data within the tags, which is considered the *value* of the element. For example, the following XML element is a <Hospital> element with the value "Queen's"

```
<Hospital>Queen's</Hospital>
```

XML has three kinds of tags as follows:

– **Start-Tag**

In the example <Patient> is the start tag. It defines type of the element and possible *attribute specifications*

```
<Patient HKID="E376684" Patient_name="John Doe"></Patient>
```

All XML documents must have a root (start) tag.
Documents must contain a single tag pair to define the root element.
All other elements must be nested within the root element.
All elements can have sub (children) elements.

Sub-elements must be in pairs and correctly nested within their parent element:

```
<root>
  <child>
    <subchild>
   </subchild>
  </child>
</root>
```

– **End-Tag**

In the example </Patient> is the end tag. It identifies the type of element that tag is ending. Unlike start tag, an end tag cannot contain *attribute specifications.*

All XML elements must have a closing tag. In XML, all elements must have a closing tag like this:

```
<p>This is a paragraph</p>
<p>This is another paragraph</p>
```

– **Empty Element Tag**

Like start tag, this has *attribute specifications* but it does not need an end tag. It denotes that the element is empty (does not have any other elements). Note that the symbol is for ending tag '/' before '> '

```
<Patient HKID="E376684" Patient_name="John Doe"/>
```

Attributes are always contained within the start tag of an element. Here is an example:

```
<Patient HKID="E376684" patient_name="John Doe" />
```

Patient	-	Element Name
HKID	-	Attribute Name
E376684	-	Attribute Value

Attribute values must always be quoted. XML elements can have attributes in name/value pairs just like in HTML. An element can optionally contain one or more *attributes*. In XML, the attribute value must always be quoted. An attribute is a name-value pair separated by an equal sign (=). An example of XML document is:

```
<?xml version="1.0"?>
<note>
```

```
<to>Tan Siew Teng</to>
<from>Lee Sim Wee</from>
<heading>Reminder</heading>
<body>Don't forget the Golf Championship this weekend!</body>
</note>
```

The first line in the document: *The XML declaration* must be included. It defines the XML version of the document. In this case the document conforms to the 1.0 specification of XML. <?xml version="1.0"?> The next line defines the first element of the document (the root element): <note>.

The next lines defines four child elements of the root (to, from, heading, and body):

```
<to>Tan Siew Teng</to>
<from>Lee Sim Wee</from>
<heading>Reminder</heading>
<body>Don't forget the Golf Championship this weekend!
</body>
```

The last line defines the end of the root element:

```
</note>
```

A typical XML system is as shown in Figure 2-10.

1. XML Document (content)
2. XML Document Type Definition - DTD (structure definition; this is an operational part)
3. XML Parser (conformity checker)
4. XML Application (uses the output of the Parser to achieve your unique objectives)

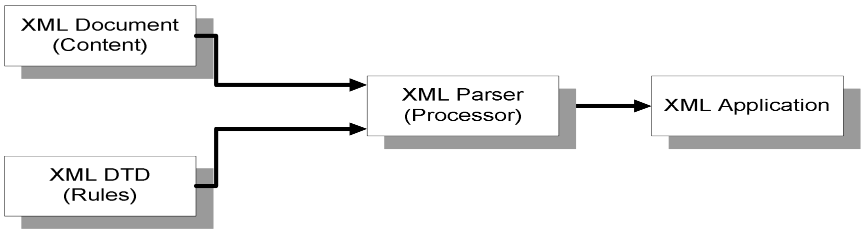


Figure 2-10 Architecture of XML database system

A sample XML DTD schema for Hospital patient record in DTD is:

```
<?xml version-“1.0”
<!ELEMENT Patient_Records (Patient+)>
<!ELEMENT Patient (Record_Folder+)>
<!ATTLIST Patient
        HKID CDATA #REQUIRED
        Patient_Name CDATA #REQUIRED
        Country_Code CDATA #REQUIRED>
<!ELEMENT Record_Folder (Medical_Record+, Borrow*)>
<!ATTLIST Record_Folder
        Folder_No ID #REQUIRED
        Location CDATA #REQUIRED>
<!ELEMENT Medical_Record (AE | Ward | Outpatient)>
<!ATTLIST Medical_Record
        Medical_Rec_No CDATA #REQUIRED
        Create_Date CDATA #REQUIRED
        Sub_Type CDATA #REQUIRED>
<!ELEMENT AE EMPTY>
<!ATTLIST AE
        AE_No CDATA #REQUIRED>
<!ELEMENT Ward EMPTY>
<!ATTLIST Ward
        Ward_No CDATA #REQUIRED
        Admission_Date CDATA #REQUIRED
        Discharge_Date CDATA #REQUIRED>
<!ELEMENT Outpatient EMPTY>
<!ATTLIST Outpatient
        Outpatient_No CDATA #REQUIRED
        Specialty CDATA #REQUIRED>
,!ELEMENT Borrow(Loan_History)>
<!ATTLIST Borrow Borrow_no CDATA #REQUIRED>
<!ELEMENT Loan_History EMPTY>
<!ATTLIST Loan_History Loan_date CDATA REQUIRED>
```

Data Type Definition Graph

XML started in 1998 as a new data standard on the Internet. XML documents can be stored in a native XML database or an XML enabled database. The former is an XML oriented database management system. The latter is relational database with an XML Application Program Interface (API).

To design an XML database, one needs to construct an XSD Graph in the form of a hierarchical containment, starting with a root element on top of other elements. An XML schema can be stored in a Data Type Definition (DTD) or an XML schema Definition Language (XSD).

Given the DTD information of the XML to be stored, we can create a structure called the Data Type Definition Graph (Funderburks, 2002) that mirrors the structure of the DTD. Each node in the Data Type Definition graph represents an XML element in rectangle, an XML attribute in semi-cycle, and an operator in cycle. They are put together in a hierarchical containment under a root element node, with element nodes under a parent element node.

Facilities are available to link elements together with an Identifier (ID) and Identifier Reference (IDREF). An element with IDREF refers to an element with ID. Each ID must have a unique address. Nodes can refer to each other by using ID and IDREF such that nodes with IDREF referring to nodes with ID.

An XML document is in a hierarchical tree structure. Every XML document must have one root element. The root element is in the highest hierarchical level. The root element contains all the other elements and attributes inside of it. Other elements are in hierarchical order such that they are in relative parent or child node. That is, the relative higher level is the parent node and the relative lower level is the child node.

An element is the basic building block of an XML document. An element name must start with a letter or underscore character. An element can have sub-element under it. An empty element does not have a sub-element. Between element and sub-element, there are declarations that control the occurrences of sub-elements. For example, one can define element instances in a Document Type Definition (DTD) with an Occurrence indicator. For example, the "*" operator identifies "set" sub-elements that can occur from zero to many times under a parent element. The "+" occurrence indicator specifies one to many times occurrence under a parent element. The "?" occurrence indicator specifies zero to one time occurrence under a parent element.

Attributes give more information about an element and reside inside of the element. Attributes can further define the behaviour of an element and allow it to have extended links through giving it an identifier.

For example, the following is a Data Type Definition Graph with root element Patient_Record. In Figure 2-11, the Data Type Definition Graph has a root element Patient record. Under the root element Patient Record, there is an element of Patient. Element Patient has a sub-element Record folder. The Element Record folder has one sub-element, Medical record. Element Medical record has the sub-element AE record, sub-element Ward record, or sub-element Outpatient record.

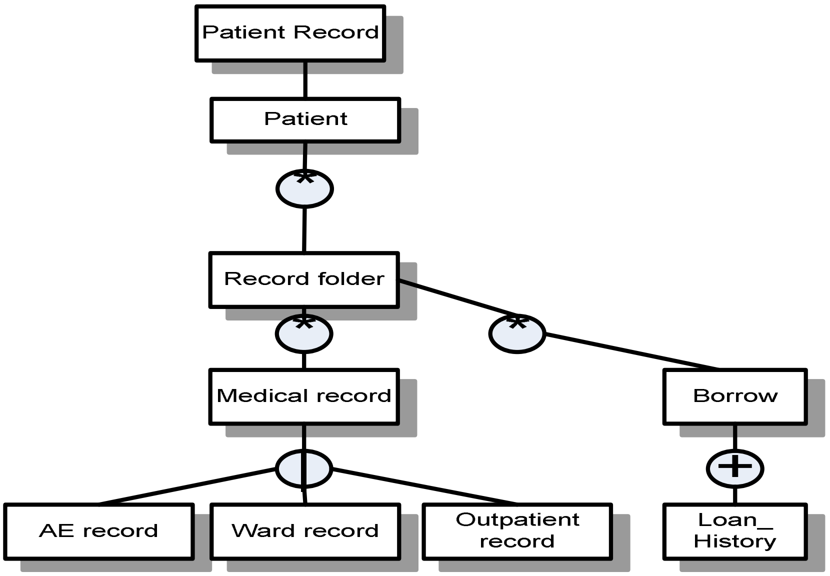


Figure 2-11 A data type definition graph for patient record

XML SCHEMA DEFINITION and XSD Graph

XML Schema Definition (XSD) (Fong, 2005) is in the logical level of the XML model and is used in most Web applications. At present, there is no standard format for the conceptual level of the XML model. Therefore, we introduce an XSD Graph as an XML conceptual schema for representing and confirming the data semantics according to the user requirements in a diagram. The XSD Graph consists of nodes representing all elements within the XSD, and can capture the data semantics of root element, weak elements, participation, cardinality, aggregation, generalization, categorization, and n-ary association. These data semantics can be implemented by the structural constraints of XSD such as key, keyref, minOccurs, maxOccurs, Choice, Sequence, and extension. They can be shown as follows:

Element

Element are tags with texts between them

- Proper nesting
  <account> … <balance> …. </balance> </account>
- Improper nesting
  <account> … <balance> …. </account> </balance>

Sub-element

Sub-element is an element inside another element.

- <account> <balance> …. </balance> </account>
- <balance>…</balance> is a sub-element of <account>…</account>

Attribute

An element may have several attributes, but each attribute name can only occur once

<account type = "checking" charge = "5">

Name Space

XML data is to be exchanged and appended by regions

Same tags may be used by multiple regions.

- Can't avoid using the same names

Solution: "name_space : element_name"

<bank xmlns:FB='http://www.HKBank.com'>

Complex Element

A complex element is an XML element that contains other elements and/or attributes.

There are four kinds of complex elements:

- Empty elements
- Elements that contain only other elements
- Elements that contain only text
- Elements that contain both other elements and text

Element Groups

Element groups are defined with the group declaration, like this:

```
<xs:group name="persongroup">
<xs:sequence>
        <xs:element name="firstname" type="xs:string"/>
        <xs:element name="lastname" type="xs:string"/>
        <xs:element name="birthday" type="xs:date"/>
</xs:sequence>
</xs:group>
```

User-defined Data Type
User can define their own data type by definion <type: “xxx”>; xxx is not a primitive data type. The following is an example.

```
<xs:element name=“staff">
<xs:complexType>
          <xs:sequence>
            <xs:element name=“staff_name" type=“name"/>
            <xs:element name=“post" type=“xs:string"/>
          </xs:sequence>
</xs:complexType>
</xs:element>

<xs:complexType name=“name">
<xs:sequence>
            <xs:element name="firstname" type="xs:string"/>
            <xs:element name="lastname" type="xs:string"/>
</xs:sequence>
</xs:complexType>
```

Extension
Extension can be used for defining Generalization or Isa constraint.
The following is an example.

```
<xs:element name=“b" type=“b_type"/>
<xs:complexType name=“b_type">
<xs:complexContent>
          <xs:extension base="a"/>
</xs:complexContent>
</xs:complexType>
<xs:complexType name="a">
<xs:sequence>
          <xs:element name="a_name" type="xs:string"/>
</xs:sequence>
</xs:complexType>
```

Choice
The <choice> indicator specifies that either one
child element or another can occur:

```
<xs:element name="person">
```

```
<xs:complexType>
        <xs:choice>
                <xs:element name="employee“ type="employee"/>
                <xs:element name="member" type="member"/>
        </xs:choice>
</xs:complexType>
</xs:element>
```

We can also apply an XML Schema Definition Graph (XSD Graph) (Fong, 2005), as shown in Figure 2-12, as an XML conceptual schema to model and analyze the structure of an XML database. The benefit of using the XSD Graph is being able to visualize, specify, and document structural constraints in a visible diagram, and also to construct executable systems. The model can be used to represent the inter-relationship of elements inside a logical schema, such as XSD, DTD, Schematron, XDR. SOX, DSD, and so on, together with various data semantics specifications.

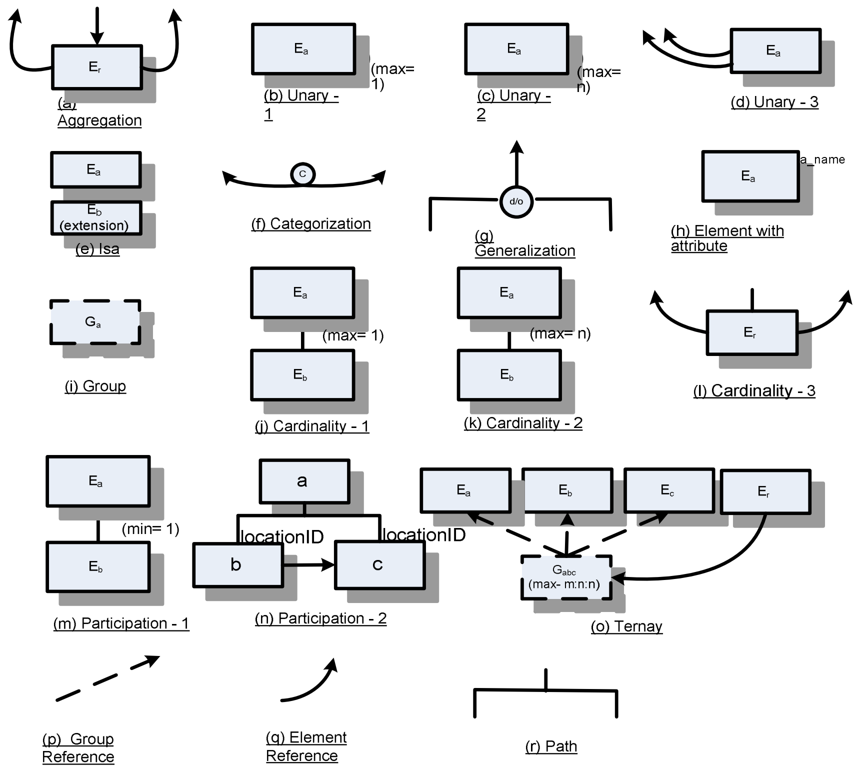


Figure 2-12 Legends for XSD graph

where

(a) Sub-element E_r that is an aggregate element addresses to two elements for creating a binary relationship in "m:n" cardinality.

(b) E_a that is in "1:1" cardinality addresses to itself for creating u-ary relationship.

(c) E_a that is in "1:n" cardinality addresses to itself for creating u-ary relationship.

(d) E_a that is in "m:n" cardinality constructs two links addressing to the same element for creating u-ary relationship.

(e) E_b with "extension" keyword inherits all properties of E_a for showing the "isa" relationship.

(e) Sub-element with "c" circle that is a subset in union operation of relational algebra links up with two group elements by using "choice" keyword.

(f) Two or more sub-elements with "d" or "o" circle can be generalized from element for showing disjoint or overlap generalization..

(h) E_a represents an element with an attribute declaration.

(i) G_a represents a group declaration.

(j) E_b is a sub-element belonging to an element E_a. E_b is in a "1:1" cardinality relationship in connection with E_a.

(k) E_b is a sub-element belonging to an element E_a. E_b is in a "1:n" cardinality relationship in connection with E_a.

(l) E_r that is a sub-element addresses to two elements for creating a "m:n" cardinality relationship.

(m) E_b with "min=1" keyword that is a sub-element links up with an element E_a for showing total participation relationship.

(n) E_a links up with an element E_b by a concrete line with arrow for showing partial participation relationship.

(o) Three elements named E_a, E_b, and E_c are pointed by a group named G_{abc} with "m:n:n" keyword pointed by an element E_r for showing "m:n:n" ternary relationship.

(p) Broken line with arrow represents a "ref" keyword within a group declaration.

(q) Concrete Line with arrow represents a "ref" keyword within an element declaration.

(r) Hierarchy path shows one top element with two sub-elements.

In general, an XSD Graph can be used to represent the structural constraints of an XML schema and an XML document with the following specifications:

Rule 1: Root element – An XML schema must be in a hierarchical tree structure starting with a root element. Other relevant elements must be under the root element.
Rule 2: Parent-child positions – Elements are in a relative parent-child position. A parent element is above a child element and a grandchild element. The child element is a parent element to the grandchild element relatively.
Rule 3: A curved line represents a reference while a straight line represents hierarchical links between two elements.
Rule 4: minOccurs and maxOccurs are the minimum and the maximum data volume (cardinality) of a child element under a parent element. There are one-to-one, one-to-many, and many-to-many cardinality.
Rule 5: An extension element and a base element are in an isa relationship such that they are in one-to-one cardinality and the extension subclass element is a part of the base superclass element.
Rule 6: A group element consists of multiple mandatory component elements under it.
Rule 7: A circle with a letter "d" means disjoint generalization with mutually exclusive subclass elements' instances under a superclass element. A circle with a letter "o" means overlap generalization with mutually inclusive subclass elements' instances.
Rule 8: A circle with a letter "c" means categorization such that each subclass element instance is in an isa relationship with one of the multiple superclasses elements' instances.

For example, the following is an XSD for a disjoint generalization such that a staff can either be a contract staff or a permanent staff:

```
<xsd:complexType name="Librarian" abstract="true">
        <xsd:choice>
        <xsd:element    name="contract"    type="lib:ContractStaff"/>
        <xsd:element name="permanent" type="lib:PermanentStaff"/>
        </xsd:choice>
</xsd:complexType>
```

Its corresponding XSD graph is shown in Figure 2-13.

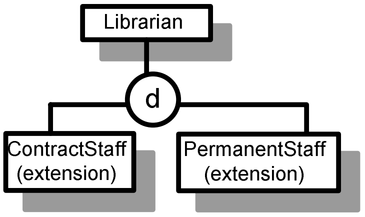


Figure 2-13 An XSD graph for a disjoint generalization

2.6 EXPERT SYSTEM

An expert system (ES) has been seen as an important information system for organizations in recent years. It is a piece of software that seeks to model the expertise of a human expert within a specific narrow problem domain. It has a comparatively short history under the aegis of Artificial Intelligence (AI). The early period of AI was dominated by the brief that a few general problem-solving strategies implemented on a computer could produce expert level performance in a particular domain. As AI was developed, it was soon realized that such general-purpose mechanisms were too weak to solve the most complex problems. In reaction to these limitations, users began to concentrate on more narrowly defined problems, and expert systems were developed.

An ES generally consists of five parts (see Figure 2-14):

- Inference engine: The component of the system that uses the knowledge base to respond to queries posed by users.
- Knowledge base: The repository of domain-specific knowledge.
- Working memory: A data area used for storing the intermediate or partial results of problem solving.
- User interface: An interface that allows end-users to interact with the ES.
- Explanation subsystem: A set of facilities that enable the user to ask questions of the system, about how, for instance, the system came to a particular conclusion.

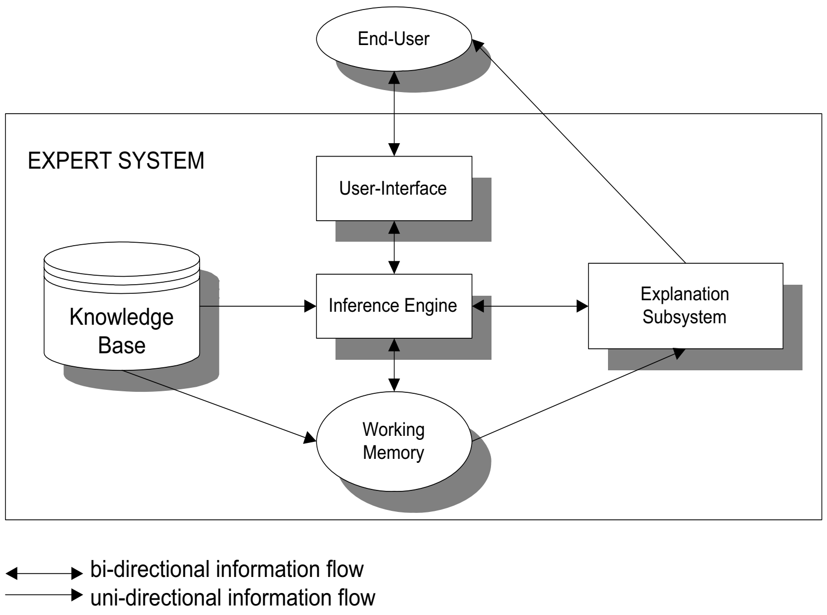


Figure 2-14 An expert system architecture

Knowledge Representation
A general model for knowledge representation is to form the basis of a system exhibiting human intelligence. Such a model is likely to require a wide variety of knowledge representation formalisms to represent different types of knowledge such as current facts, past and future knowledge, meaning of words, certain and uncertain situations, negative situations, etc. There are several schemes for representing knowledge in an ES. The most common methods of knowledge representation are semantic networks, rule-based systems, and frame-based systems.

1. Semantic Networks

The most general representational scheme, and also one of the oldest in AI, is the semantic network (or semantic net). A semantic network is an explicit taxonomic hierarchical structure for categorizing classes of real world objects (see Figure 2-15). An object in the semantic network is called a node. Nodes are connected by arcs or links. Ordinarily, both the nodes and the links are labeled.

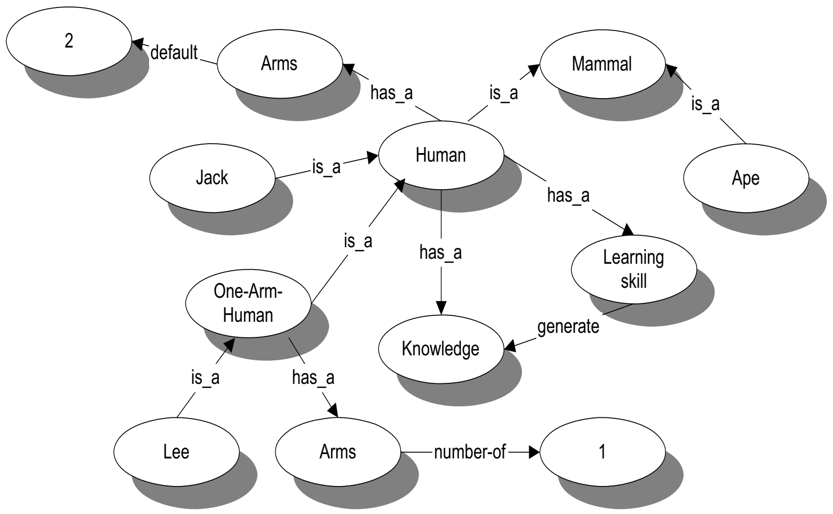


Figure 2-15 A semantic network

Nodes are used to represent physical objects, conceptual entities, or descriptors. Physical objects can be seen or touched (e.g., human, ape, etc.). Conceptual entities are objects such as acts, events, or abstract categories, like mammal, 2, and so on. Descriptors provide additional information about objects (e.g., 'knowledge' stores information about 'human').

Links are used to represent the relationships between nodes. Examples of relationships include IS_A, HAS_A, and human-defined relationships. The IS_A link is often used to represent the class/instance relationship. For example, 'Jack IS_A Human' or 'Human IS_A Mammal'. The IS_A link is, also, used for the purpose of generalization. It is used to provide inference using property inheritance deduction and organization in a generalization hierarchy. Inheritance has become an important feature of semantic networks. It refers to the ability of one node to "inherit" characteristics from other related nodes. Property inheritance means that instances of a class are assumed to have all of the properties of the more general classes of which they are members.

HAS_A links identify nodes that are properties of other nodes. For example, 'Human HAS_A Knowledge.' or 'Human HAS_A two Legs.' The HAS_A link has thus often been used for aggregation. It is the same as the A_PART_OF relationship that represents a situation where one class is an assembly (or aggregate) of component objects in a database application. Aggregation is one important feature of the semantic network by which the relevant facts about objects or concepts can be inferred from the nodes to which they are directly linked, without the need for a search through a large database.

Human-defined links are used to capture heuristic knowledge such as 'Learning Skill GENERATEs Knowledge' (see Figure 2.13). Relationships like these enrich the network by providing additional paths.

Flexibility is a major advantage of this representational scheme. New nodes and links can be defined as needed. The lack of any formal semantics and difficulties handling exceptions are the major disadvantages. A system that was built using semantic networks cannot generally distinguish between instances and classes. For example, 'Jack is a human' represents an instance, while 'Human is a Mammal' represents a class. This disadvantage has meant that semantic networks have limited success for large knowledge representation systems.

2. Production Rule Systems

Production rules were previously used in automata theory, formal grammars, and the design of programming languages, before being used in psychological modeling and expert systems. In the expert system literature, they are sometimes called 'condition-action rules', 'situation-action rules', 'premise-conclusion rules', or 'if-then rules'. The syntax of production rules include two parts: the IF-part and the THEN-part. For example:

Production Rule:

$$\begin{array}{c}\text{condition}\\ \text{situation}\\ \text{premise}\\ \text{if}\end{array}\left\{\begin{array}{c}\text{If C1 and}\\ \text{..... and}\\ \text{Cn}\\ \end{array}\qquad\qquad \begin{array}{c}\text{Then A1 and}\\ \text{..... and}\\ \text{Cn}\\ \end{array}\right\}\begin{array}{l}\text{actions}\\ \text{conclusion}\\ \text{then}\\ \end{array}$$

When the IF-part is true (i.e., conditions C1 and ... and Cn are true), the THEN-part (i.e., perform actions A1 and .... and An) is executed.

A production rule system is a system to effectively manage production rules. Roughly speaking, a production rule system consists of:

- A set of rules called production rules

- A working memory that can hold data, goals or intermediate results

- A rule interpreter that decides how and when to apply the rules, and which rules to apply

The working memory holds a number of facts relevant to the particular problem to which the production system is being applied. These facts are used by the interpreter to drive the production rules, in the sense that the presence or absence of data elements in the working memory will "trigger" some rules, by satisfying their activation patterns.

The "rule interpreter" is a program that identifies applicable rules (i.e., rules whose condition part is satisfied), and determines the order in which applicable rules should be applied. It follows the "recognize-act cycle" (see Figure 2-16).

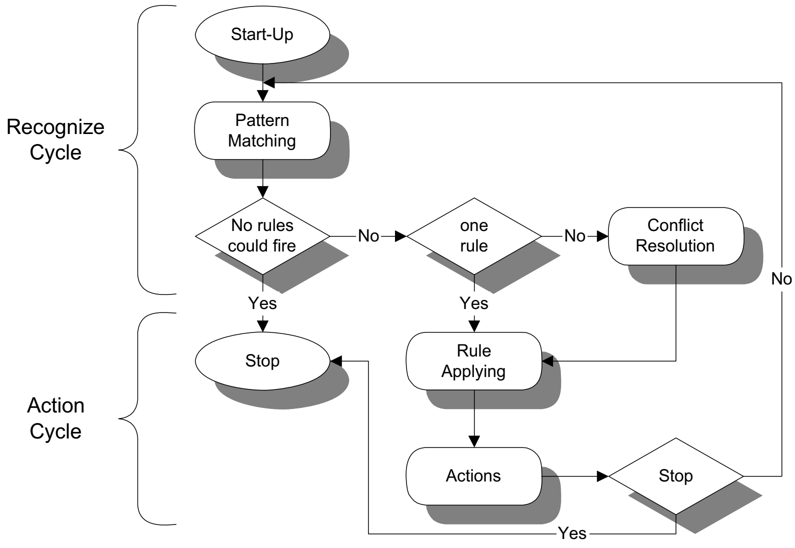


Figure 2-16 Recognize-act cycle

Working memory supplies the data for pattern matching and its structure may be modified during the application of rules. Usually, a 'start-up' element is inserted into the working memory at the start of the computation to get the cycle going. The computation halts if there is a cycle in which no rules become active, or if the action of a fired rule contains an explicit command to stop.

Pattern matching identifies which rules could be fired. The interpreter matches the calling patterns of rules against elements in working memory. Two major control strategies used for pattern matching are forward chaining and backward chaining. We can chain forward from those conditions that we know to be true, towards conclusions that the facts allow us to establish, by matching data in working memory against the IF-part of rules. However, we can also chain backward from a conclusion that we wish to establish, towards the conditions necessary for its truth, to see if they are supported by the facts.

Conflict resolution determines which rule to fire. There is no conflict resolution problem in deterministic rule sets, because we can always determine the right rule to fire at any point in the computation. The problem we need to solve is in the case of non-deterministic rules. Good performance conflict resolution is dependent on both sensitivity and stability from an expert system point of view. Sensitivity means responding quickly to changes in the environment reflected in the working memory, while stability means showing some kind of continuity in the line of reasoning (Jackson, 1990).

Finally, we summarize the advantages and disadvantages of using production rules through the work of Reichgelt (1991). The advantages are:

- Naturalness of expression: Production rules have proved particularly successful in building expert systems. One of the main reasons for this has been the naturalness with which expert knowledge can be expressed in the terms of production rules.

- Modularity: The architecture of a production system supports a very structured knowledge base. First, "permanent" knowledge is separated from "temporary" knowledge. Production rule systems contain both a rule base, in which the more permanent knowledge resides, and a working memory, which contains the temporary knowledge describing the problem the system is currently working on. Second, the different rules are structurally independent. Third, the interpreter is independent from the knowledge that is encoded in the rule base and working memory. The advantages gained from this modularity are that it is easy to construct, maintain, and debug the knowledge base.

- Restricted syntax: Production rules have a very restricted syntax. The main advantage is that it becomes feasible to write a program that can read and/or modify a set of production rules. It is also useful in generating natural language explanations.

- The problem-solving process: Production rules determine what to do next by examining the representation of the present state of the problem solving process in working memory. This particular feature gives important advantages for the overall problem-solving process. The system can quickly focus on a hypothesis that looks particularly promising without being forced to do so at a premature stage.

- Explanation: Production rules have been claimed to facilitate the construction of programs that can explain their reasoning.

The disadvantages of the production system are:

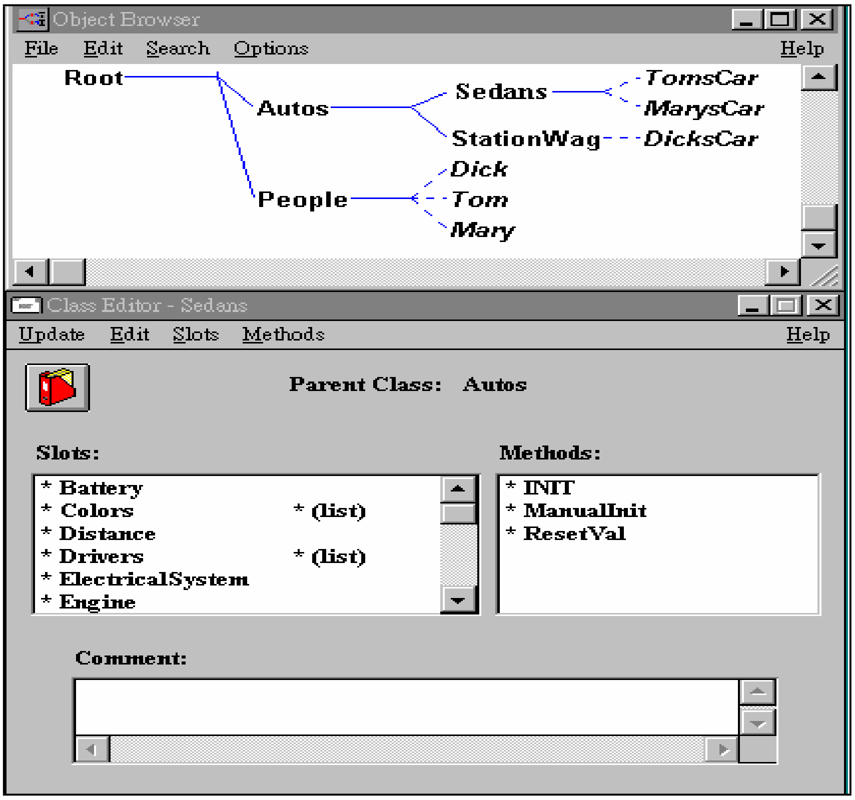
- Inefficiency in the case of large rule bases: There are two possible sources of inefficiency for large rule bases. First, determining the conflict set for a large rule base might become a very time-consuming process. Second, once the conflict set is determined, and turns out to contain a lot of rules, conflict resolution can require a lot of computational power. Some work has been done in this area, such as the RETE matching algorithm (Forgy, 1982), and the use of meta-rules (Davis, 1980).

- Limited express ability: The expression of negative and disjunctive knowledge is difficult in the THEN-part of rules.

- Lack of formality: There is a lack of formality in the descriptions of production rules and of the reasoning processes that they use. It is not, therefore, clear whether one can sustain the claim that rule bases can be constructed incrementally. Without this capability, a lot of the attractive features of production rules would disappear.

3. Frame-Based Systems

The main idea of a frame is to collect all information related to one concept in one place. It attempts to reason about classes of objects by using "prototypical" representations of knowledge that hold for the majority of cases. The intuition behind the theory was that conceptual encoding in the human brain is less concerned with defining strictly and exhaustively the properties that entities must possess in order to be considered exemplars of some category, and more concerned with the salient properties associated with objects that are somehow typical of their class (Jackson, 1990). Figure 2-17 shows an example of a frame-based system based on the KAPPA system (IntelliCorp, 1994).



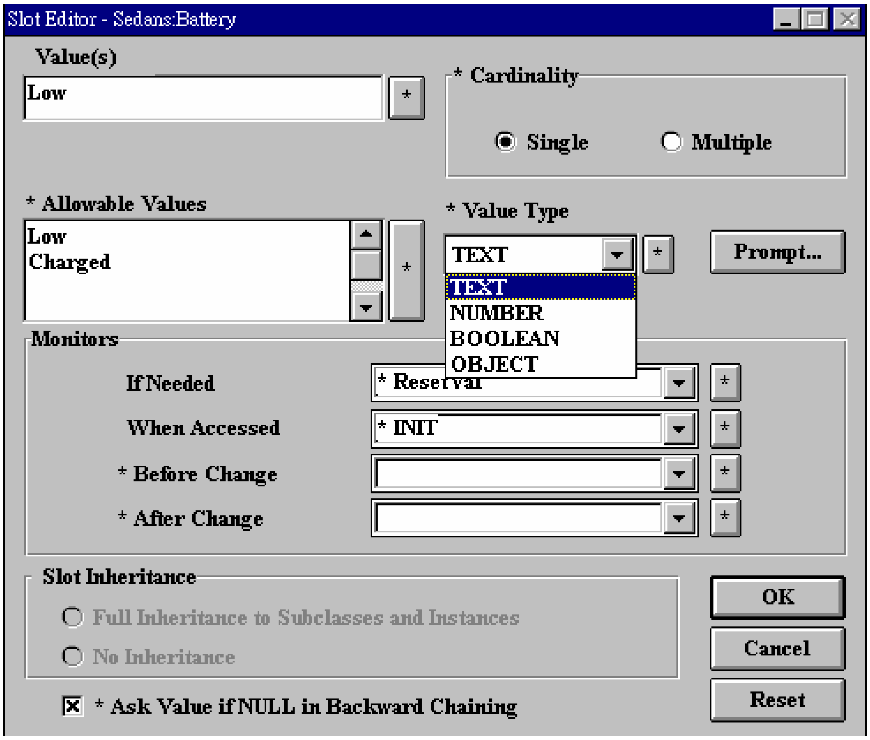
Slots:		Methods:
* Battery		* INIT
* Colors	* (list)	* ManualInit
* Distance		* ResetVal
* Drivers	* (list)	
* ElectricalSystem		
* Engine		

Figure 2-17 An example of frame-based system: Kappa

A frame is a complex structure that can store and represent knowledge by using the 'Slot and Filler' formalisms, as termed in (Forst, 1987). A slot is an attribute that describes a frame. A frame usually consists of a number of slots. A filler describes values of a slot. A slot has only one filler. There are two types of frames in most frame systems: a class frame and an instance frame. A class frame is a description of a class of entities in the world. An instance frame is an intention description of an individual entity in the world. For example, 'Jack is a Human'. In this knowledge, 'Human' is generic knowledge and can be a class frame. 'Jack' is an individual object and can be an instance frame.

Frames are always linked into taxonomies by using two types of links: subclass links and member links. A subclass link represents the generalization relationship between class frames. Class frames can have subclass links to one or more other class frames. For example (see Figure 2-17), Sedans is a subclass of Autos. The member link represents the class membership between instance frame and class frame. Any instance frame can have a member link to one or more class frames. For example, Tomscar is a member of Sedans. These links provide two standard interpretations of the meaning of 'is-a' links, such as 'Jack is a Human' and 'Human is a Mammal' (see Figure 2-15. The 'is_a' link supports inheritance for frame-based systems. Most current frame-based systems support multiple inheritance. There are two main problems that must be solved here. First, there is a need for the system to distinguish between its own slots and those it has inherited, and to decide the priority of the two types of slot. The systems own slots will usually get higher priority than inherited slots. For example (see Figure 2-15): A human has two arms, but one-arm-human is a human who only has one arm. The own slot property will overwrite the inheritable property. Another example is 'Bird is an animal'. 'The locomotion mode of animal is walking' but 'Bird can not only walk but also fly'. The own slot property and inheritable property must exist together. Second is a need to solve any conflict problems between inherited slots. If inherited slots from different frames have the same slot name there is a conflict. The general solution for this problem is to keep only one slot from the highest priority inheritance frame, or to keep these slots at different levels. The situation is similar to the first problem.

An important source of the expressive power of frame-based languages are the facilities that they provide for describing object attributes, called slots (Minsky, 1975). These facilities allow frames to include partial descriptions of attribute values, and help preserve the semantic integrity of a system's knowledge base by constraining the number and range of allowable attribute values. A slot usually consists of two parts: a slot-name, which describes an attribute, and a slot-filler, which describes the character of the slot values. The slot-filler supports very powerful features (see Figure 2-18). It allows the filler to be represented as single/multiple values, instance frames, or procedures. The single or multiple value situation is dependent on the “cardinality”. A slot-filler usually has an attribute type, such as Text, Number, or Boolean, to represent the values. Frame-based systems also allow users to define the object type in their slot-filler. This creates a new relationship called aggregation, i.e., 'a_part_of' link. Aggregation is an abstraction in which a relationship between objects is represented by a higher level, aggregate object. Most current systems only allow a single instance frame. Procedural attachment is also found in most frame-based systems. This allows users to define the attribute type as a procedure so as to represent procedural information. The procedure is a normal routine that is called whenever a value for a slot is required.


Slot Editor - Sedans:Battery

Value(s): Low

* Cardinality: [✓ Single] Multiple

* Allowable Values: Low, Charged

* Value Type: TEXT (TEXT, NUMBER, BOOLEAN, OBJECT)

Monitors

If Needed	* Reserval
When Accessed	* INIT
* Before Change	
* After Change	

Slot Inheritance: Full Inheritance to Subclasses and Instances / No Inheritance

[✓] * Ask Value if NULL in Backward Chaining

Figure 2-18 A slot-filler in KAPPA frame based system

Restriction and Default functions are also important features of frame-based systems. Many frame-based systems allow the use of the logical connectives NOT, OR, and AND in the formulation of restrictions on slots. For example, you can put the following restriction on the gender slot associated with the member frame to represent a school for girls. Members of school are students and staff. Most of them are female.

(gender (default female) (restrict (OR male female)))

Procedural attachment may also be used here for constraints or monitors. There is one type of procedure called a 'demon' which is a restriction (constraint) or integrity function that is called whenever the slot in question receives a value or is updated.

Implementing reasoning is a complex process in frame-based systems. Most frame-based inference mechanisms are based on the structural properties of frames and taxonomies. There are five major mechanisms that can be used for reasoning in frame-based systems (Reichgelt, 1991).

- Matching
  This mechanism concerns taking a decision as to which of the many frames in the knowledge base is applicable to the current situation. The system must compare descriptions of incoming stimuli with frames in the knowledge base, and retrieve the class frame that best matches the situation.

- Inheritance
  The matching retrieves the relevant frame that contains general information for the reasoning process and applies inherited information to specific information. The basic inheritance mechanism uses member links, sub-class links, and prototype descriptions of class members to assert and retrieve the specific information.

- Instance Frame Reasoning
  The inheritance reasoning infers the frame by using the 'is_a' link and the instance frame reasoning infers the frame through their 'a_part_of' link. It is a mechanism to retrieve specific information for a slot with instance frame values.

- Procedural Reasoning
  This is a mechanism to retrieve specific information for a slot with procedure values or to perform constraint and integrity checking by the use of demons. The technique includes sending a message to an object-oriented method or performing an external call in order to run a normal routine (e.g., calling standard functions in LISP).

- Cardinality and Constraint Checking
  A frame-based system considers cardinality, default, and restriction specifications as constraints on the legal values of a slot. The system provides constraint checking procedures for determining whether a slot's value is valid.

Currently most frame-based representation facilities also provide a convenient rule-based management facility. There are usually two ways to combine rules and frames. One is to attach a production rule language to the frame-based system, such as in GoldWorks (Casey, 1989), The frame facility supplies an expressively powerful language for describing the objects being reasoned about and automatically performs a useful set of inferences on those descriptions. The other involves representing a rule as a frame, such as in KEE (Fikes and Kehler, 1985). KEE allows production rules to be represented by frames so that they can easily be classified into taxonomies, created, analyzed, and modified as necessary.

Several advantages have been claimed for frame-based knowledge representation schemes. Many of these advantages involve the representation of stereotypes and assertion clustering, which improves access to knowledge by storing associated representations together. It is expected that this technique will become common in the future, particularly in large and sophisticated expert systems.

2.7 SUMMARY

Database systems and expert systems are the major components of information systems. The legacy data models include hierarchical, network, relational, object-oriented, and XML. The hierarchical model has an inverted tree structure data structure, which makes it most suitable for top-down applications. Its main DBMS is IMS by IBM Corp. It is a record-based database and the users follow a hierarchical sequence to access the database by default. However, the users can also access the database directly by specifying the segment keys along the access paths. Its main disadvantage is its implementation of m:n relationships in the conceptual model. Data redundancy occurs as a result of the implementation.

The network database has a graphic data structure (i.e., a record can have multiple input and multiple output). It has Set data structure that is used as pointer to link the owner record and member records. It has the best performance among the other data models, but is also the less user-friendly model. Its main advantage is to implement an m:n relationship among the records. IDMS is a main legacy network DBMS by Computer Associates International Ltd.

The relational database is the most popular data model in the industry now. It is very user friendly among all the other models. Its data structure is tables that link to each other through foreign keys or composite keys. However, these keys may cause data redundancy. Normalization is needed to eliminate anormalies. At present, SQL is the standard DDL and DML for relational databases, and is also the most used database language.

The object-oriented database is based on grouping related instances (i.e., objects) into class. Its data structure is based on OID, an object identity that is generated as a unique number by the system. OID is used as a pointer to link class objects together. Its major advantages are increased productivity by inheritance and encapsulation. Its major attraction is its ability in reengineering existing object-oriented database systems for future enhancements, i.e., it is more flexible than the other data models. It seems to take a more important role in the future to replace relational as the dominant model. An example of object-oriented data model can be found in UniSQL.

As Internet computing becomes part of everyday life, the Extensible Markup Language defined by W3C committee has also been adopted as the data standard on the Internet. The XML is an extension to HTML, and is programmable with XML schema and XML document. The XML schema can be in the form of Document Type Definition (DTD) or XML Schema Definition (XSD). It has a hierarchical tree structure that focuses on the root element with other elements under it. The DTD can also be visualized in the form of DTD Graph. Each element represents a node in the graph, and the attributes describe the properties of the element. The ID and IDREF must exist in pair with IDREF addressing to ID in the XML document. The DTD Graph and XSD Graph can be used as an XML conceptual schema for the design of an XML database.

The expert system is the core software for decision support system and information systems. It plays the role of the experts by transferring expert knowledge into a computer system. Technically, it can perform forward and backward chaining to derive condition to conclusion, or conclusion from condition. As the information age evolves to the knowledge age, so does information systems evolve to knowledge based systems. The role of expert systems becomes more important since knowledge-based systems and knowledge engineering becomes more popular in the industry.

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QUESTIONS

Question 2-1

What is data modeling? What are the relationships between conceptual schema, logical schema, and internal (physical file) schema in the Anxi-X3 architecture of data modeling?

Question 2-2

(a) How can one show the process of reengineering in terms of the processes of forward engineering and reverse engineering?
(b)What is an entity-relationship model and what are its components?
(c) What is the relationship between DTD and Data Type Definition graph? Describe the application of Data Type Definition graph?

Question 2-3

Can multiple Relational Schemas be integrated into one Relational Schema? Give the rational of your answer. How can the integration of Relational Schemas be compared with the integration of extended entity relationship Models with respect to meeting users' requirements?

CHAPTER 3

Schema Translation

A database system consists of three components: schemas, data, and programs. Database reengineering starts with the schema, which defines the meaning of data and their relationship in different models. Only after a schema has been redefined can data and programs then be reengineered into a new database system, which makes use of the translated schema. Schema translation is the process of changing a schema expressed in one data model into an equivalent schema expressed in a different data model.

This chapter describes the techniques of translating the hierarchical model or the network model into the relational model. It also outlines a methodology for transforming a relational schema into an object-oriented database schema, and an XML database schema.

Some work has been done to translate directly from a hierarchical model or network model to a relational model. Others translate a logical hierarchical schema or a logical network schema into a conceptual schema based on the extended entity relationship (EER) model. The EER model is then translated into a logical relational schema (Elmasri & Navathe, 1988).

The object-oriented model is becoming very popular; however, there is no such thing as a standard object-oriented model. Nevertheless, many conceptual models for object-oriented database systems exist and have been adopted by the industry. For example, UML, Booch (Booch, 1994), and Yourdon are some of conceptual object-oriented models used to design object-oriented databases. We consider it premature to address direct translation from a relational to object-oriented database. Instead we present a method to translate a relational model to a UML model. We choose UML model because of its similarity with the EER model. One can translate from a relational model to a EER model in a reverse engineering step and then from EER model to UML model in forward engineering step, which can then be mapped to a proprietary object-oriented schema.

Record-based relational databases built by using top-down modeling techniques such as the EER model have been generally used over the past two decades. Organizations with such record-based databases could seek to reengineer their databases into object-oriented databases to capture more of the semantics of the application domain. The UML model can be regarded as an extension of the EER model with complete object-oriented features, a comprehensive object-oriented database model enhanced with advanced semantic features. UML model improves EER model in the areas of expressiveness and readability. It is thus reasonable to follow the traditional method to design a database starting with the EER model for its richness in static semantic data modeling techniques, and then map it to a UML model as part of an object-oriented database design.

3.1 DIRECT TRANSLATING A NETWORK MODEL TO A RELATIONAL MODEL

Translation from a network schema to a relational schema involves a one-to-one mapping between the record type and the relation. The set structure of the network schema is translated into the referential relationship between parent and child relations. For example, Zaniolo (1979) designed a set of relations that recast the logical network schema in terms of a relational model as shown in the following procedure:

Step 1- Derive relations.

Map each network record type to a relation in a one-to-one manner.

Step 2 - Derive relation keys.

Map each record key of a network schema to a primary key in a relational table. However, if the existing network record key is not unique, then it is concatenated with its owner record key in order to create a unique a primary key. The owner record key is also mapped to a foreign key in the relational table to link the parent and child records. If the set membership in the logical network schema is manual, then the record key of member record will be mapped as a candidate key in the relational table. For instance, Figure 3-1 is the network schema for a US President.

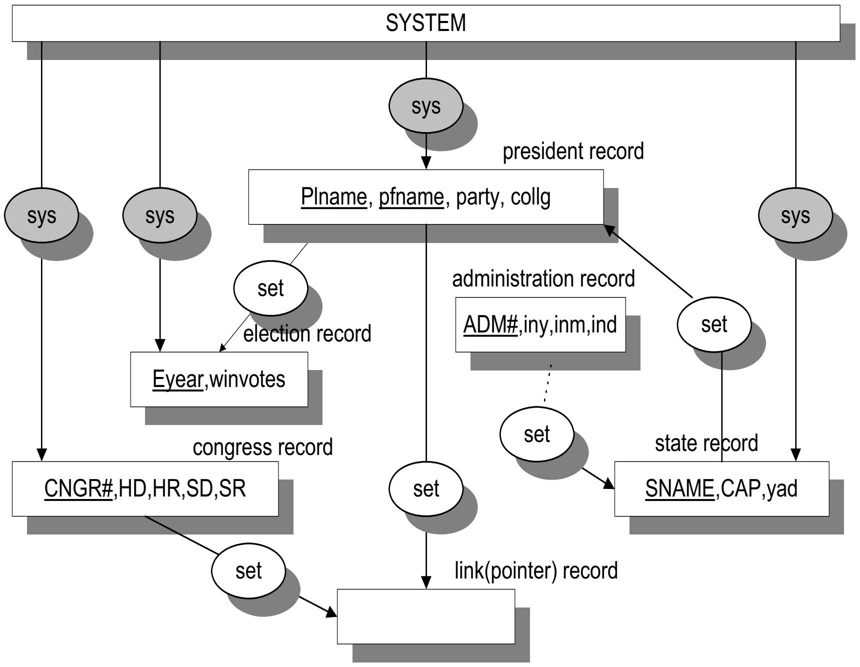


Figure 3-1 Network schema on US president

Applying the above steps, we can map the network schema in Figure 3-1 to the following relations:

PRESIDENT (Plname, Pfname, Party, Collg, *Sname)
ADMINISTRATION (Adm#, Iny, Inm, Ind, *Plname, *Pfname)
STATE (Sname, Cap, *Pln, Pfn, Adm#, Yad*)
ELECTION (Eyear, Winvotes, *Plname, *Pfname)
LINK (*Plname, *Pfname, Cngr#)
CONGRESS (Cngr#, Hd, Hr, Sd, Sr)

Note: italic are candidate keys, underlined words are primary keys, and words with '*' prefixes are foreign keys.

3.2 DIRECT TRANSLATING A HIERARCHICAL MODEL TO A RELATIONAL MODEL

Mapping between hierarchical and relational schema is similar to the one between network and relational. It can be considered as a subset of a network schema because the inverted tree structure of its data structure can be modeled directly in a network data model.

However, it does not have as many set memberships types and constraints as in the network schema. All parent child relationships in the hierarchical schema are "fixed", i.e., not changeable once it is inserted. A relational schema can be derived using the following steps:

Step 1- Derive relations.
Map each record type into a relation.

Step 2 - Derive relation keys
The record key of a hierarchical schema is mapped as a primary key of a relation. However, if the record type of the hierarchical schema is a child record, then the primary key is derived by concatenating it with its parent record key. The parent record key is also mapped as a foreign key in the child relation (Quizon, 1990).

An example of mapping a hierarchical database for an accounts system is shown in Figure 3-2.

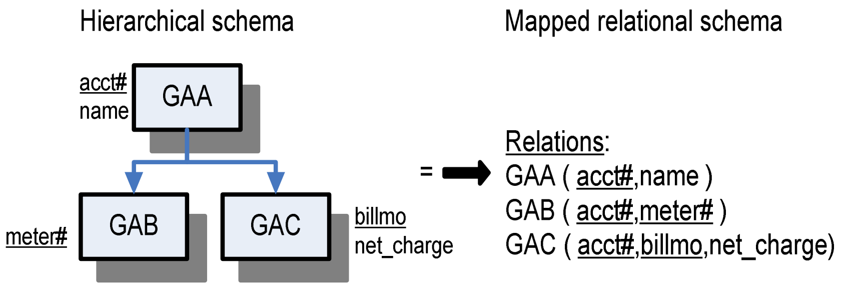


Figure 3-2 A hierarchical schema mapped to a relational schema

3.3 *INDIRECT TRANSLATING A NETWORK MODEL TO A RELATIONAL MODEL*

In much of the published literature on schema translation by direct translation assumptions have generally been made on the semantics of the database. There is always the chance that the translated schema may not encapsulate the original designer's idea. This problem occurs because there are so many possible relational schema that can be derived from a known hierarchical schema or a network schema and the translation analyst makes many very primitive assumptions (for example, the direct translation hierarchical schema or a network schema into a composite key of a hierarchical schema or a network schema into a composite key of the relational model by concatenating its parent record key with its own key). However, there are exceptions such that the child record is fully internally identified, which can be transformed directly to a primary key of a logical relational schema. As a result, the translated relational model may be incorrect.

When a company's existing database system needs to be upgraded into a new model such as relational, object-oriented, or XML, the current nonrelational data models must be translated into the new models. To translate from one model to another involves not just data structure transformation, but also the transfer of semantics. Very often, semantics are lost once a conceptual model has been mapped into a logical model because the former is more rich in semantics than the latter. Thus, schema translations between logical schema such as hierarchical, network, relational, object-oriented, and XML are done by mapping them back to a higher semantic model of the EER model.

To solve the problem in a logical manner, we need users as the domain and relation integrity experts for the nonrelational schema. They can provide information on the semantics of the data; that is, their domain values and constraints in the database. A knowledge acquisition system can assist the user to confirm the translated EER model by enforcing the database integrity heuristic rules such as FDs (functional dependencies) and IDs (inclusion dependencies) in the translation. The resultant conceptual model can meet the heuristic rule requirements in the existing nonrelational schema. Even though there are many possible EER models that can be constructed from a known logical schema, the translated EER model should be the one closest to the user's expectation.

A conceptual schema based on the EER model carries richer semantics than a hierarchical schema or a network schema. Since it is dangerous to make assumptions on how to recover the semantics lost in the logical schema, our strategy is to capture these semantics from the users' knowledge of the database and rebuild the conceptual schema in an EER model. We can then map directly from the EER model to a logical relational schema; refer to Figure 3-3 (Fong, 1992).

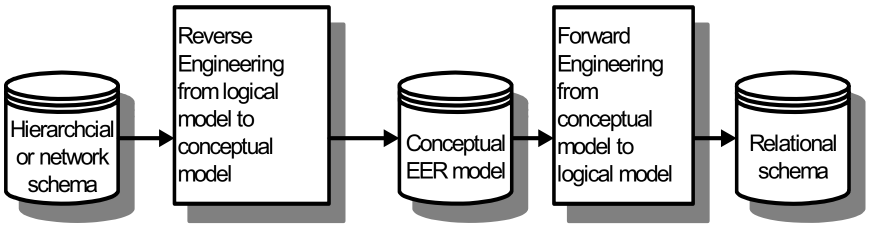

Hierarchcial or network schema
Reverse Engineering from logical model to conceptual model
Conceptual EER model
Forward Engineering from conceptual model to logical model
Relational schema

Figure 3-3 Indirect schema translation data flow diagram

This section describes the step-by-step mapping process.

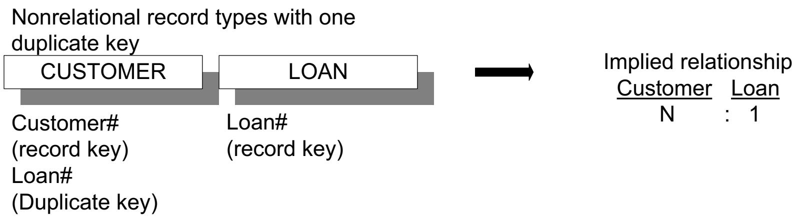
Step 1 - Reverse engineering from network schema to conceptual EER model.

Since the EER structure is built upon other lower level structures, we must normalize existing network schema, followed by translating the primitive semantics such as existence and navigational semantics into cardinalities, entity keys and relationships, and lastly we need to add the higher level semantics of aggregation, generalization, and categorization.

Substep 1 - Derive implied relationships.

The network schema to be translated may not be normalized. Modifications may have been made to the schema for performance or other reasons. Generally, modifications are made to improve performance. The explicit semantic implies a 1:n relationship if there is one duplicate key in one record type, or 1:1 if there is a duplicate key found in the record on both sides of the relationships. User input is sought to confirm the existence of such semantics.

For example, in the loan system in Figure 3-4, one duplicate key of Loan# implies a 1:n relationship between Loan and Customer records such that a loan can be participated by many customers whose records can be found by matching the loan#. In some cases, you may have two duplicate keys imply a 1:1 relationship between Customer and Loan records such that a customer books a particular loan.



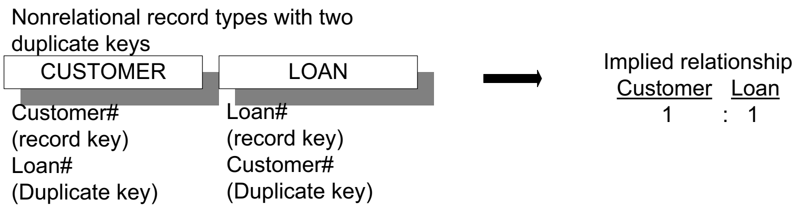


Figure 3-4 Derive implied relationship

Substep 2 - Derive multiple (alternative) relationships.

In a network schema, a circuit of record types may carry different navigational semantics. For example, Figure 3-5 is a circuit or loopy network schema:

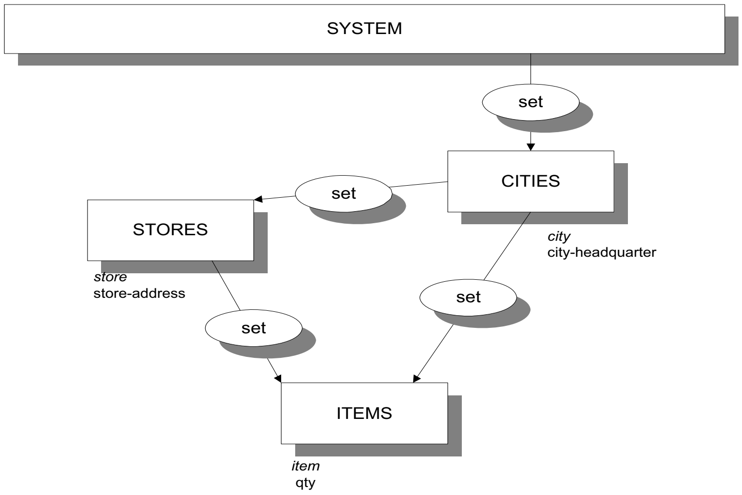


Figure 3-5 A circuit loop network schema

Here the relationship between Cities and Items is in a loop because the same relationship can be derived by joining the relationship between Cities and Stores, and between Stores and Items. The former may carry the semantics of manufactured items in cities and the latter may carry the semantics of available items in stores under cities. They thus carry different semantics.

On the other hand, the default assumption is that the alternative access path may be for better performance because it takes a shorter access path by alternative path from record Cities to record Items directly.

It is up to the user to confirm the original database designer's idea on the function of the alternative path. If the user confirms the existence of a navigational semantic, then the record types and Sets in the alternative path are mapped to different network subschema (one subschema for each path) before translating to the relational schema.

Substep 3 - Derive unary relationships.

We map link (dummy) records of network schema into unary relationships. These dummy records are either without any attributes, or contain key attributes only as shown in Figure 3-6. The default is a 1:n relationship between owner and member for each Set record type, but user input is sought to confirm or modify this relationship into a 1:1 or an isa relationship.

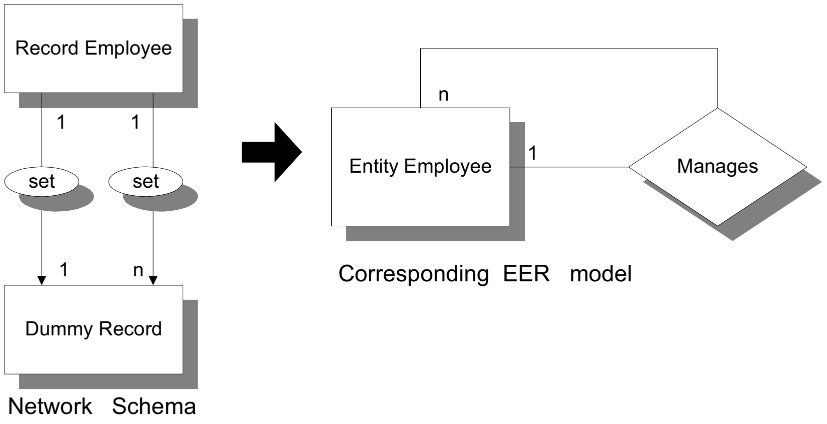


Figure 3-6 Map unary 1:n relationship from network to EER model

Substep 4 - Derive binary relationships.

Next we map each SET into a relationship between the owner and member records, assuming a default 1:n cardinality. However, one record type can be a member of more than one SET. Multiple membership logically intersects the owner records of two (or more) SETs. A member record type with two owner record types implies a m:n relationship between the two owner record types. The member record type becomes a relationship relation between the two owners records as shown in Figure 3-7. The default is 1:n relationship between owner and member for each Set record type, but user input is sought to confirm or modify this relationship into a 1:1 or an isa relationship.

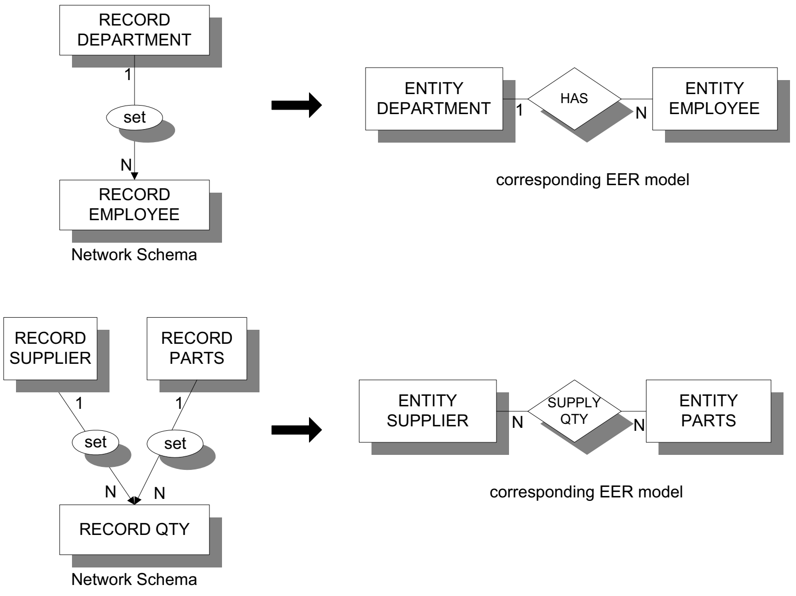


Figure 3-7 Map 1:n and m:n relationship from network to EER model

Substep 5 - Derive entities of n-ary relationships.

For multiple record types linking together through Sets, if there is a semantic to associate them in a relationship, then they are mapped as an n-ary relationship in the EER model. Two examples are shown in Figure 3-8.

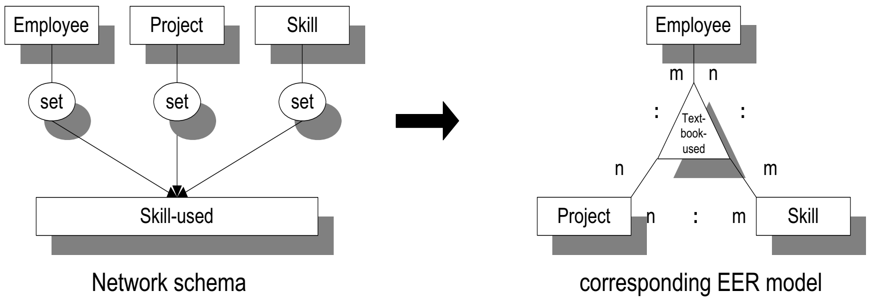


Figure 3-8 Map n-ary relationship to EER model

In Figure 3-8, each skill-used relationship is associated with n employee(s), n project(s) and n skill(s), which implies that employees use a wide range of different skills on each project with which they are associated.

The default is a binary relationship as described in step 3. A knowledge acquisition system should be able to detect a possible n-ary relationship from the DDL of the network schema. Again, user input is sought to confirm or modify this relationship. The user must be aware that a mandatory binary relationship can be grouped as an m:n or n-ary relationship depending on the semantics. Above all, any optional relationship must stay as a binary relationship.

Substep 6 - Derive aggregation, generalization, and categorization.

An aggregation is derived if an m:n relationship from step 4 further relates to another entity. The knowledge acquisition system should be able to detect a possible aggregation if there is a potential m:n relationship relation record type that is further linked to another record type. In the network schema, such a relationship can be represented by the record type shown in Figure 3-9.

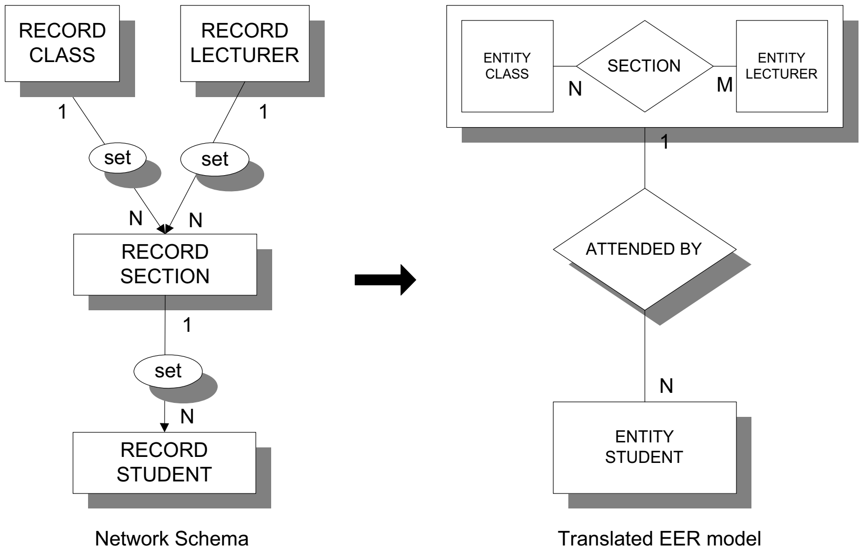


Figure 3-9 Map set of relationships to aggregation in EER model

A disjoint generalization is derived by mapping isa relationships and their record types to a superclass/subclass entities relationship such that a superclass entity (mapped from an owner record type) is a generalized class for the subclass entities (mapped from member record types) which are mutually exclusive. Again, the knowledge acquisition system should be able to detect such potential generalization by locating isa relationship linkages with one owner and more than one member record type. However, user input is needed to confirm this. Figure 3-10 is an example with Paid-scale used as an attribute in Employee entity to determine of which subclass (salaried-employee, hourly-employee) the superclass (Employee) is a member.

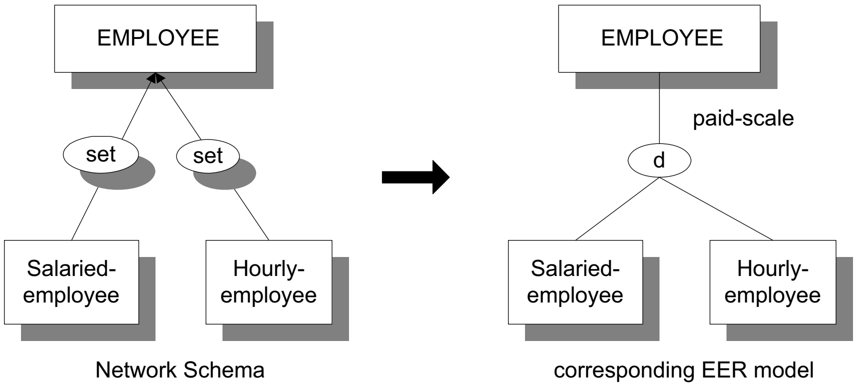


Figure 3-10 Map isa relationships to disjoint generalization

An overlap generalization is derived by mapping isa relationships and their record types to a superclass/subclass relationship such that a superclass entity (mapped from an owner record type) is a generalized class for the subclass entities (mapped from member record types) that overlap each other. Again, the knowledge acquisition system should be able to detect such a potential generalization by locating isa relationships with one owner and more than one member record type. However, user input is needed to confirm these semantics. Figure 3-11 is an example with Employee-flag, Alumnus-flag, and Student-flag being used to indicate the membership of the subclass entities (Employee, Alumnus, Student). An employee can be both a student and a person. The difference between disjoint and overlap generalization is that the former needs only one predicate field while the latter needs one predicate field for each subclass entity.

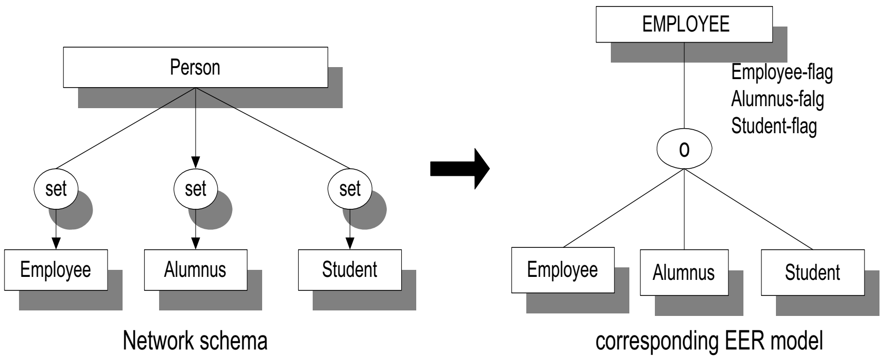


Figure 3-11 Map isa relationship to overlap generalization

A categorization is derived by mapping isa relationships and their record types to superclass/subclass entities relationships such that a set of class entities (mapped from a set of owner record types) can be united to form the superclass entity of a subclass entity (mapped from a member record type). Again, the knowledge acquisition system should be able to detect a potential categorization by locating isa relationships with more than one owner and one member record type. However, user input is needed to confirm such a semantic. Figure 3-12 is an example.

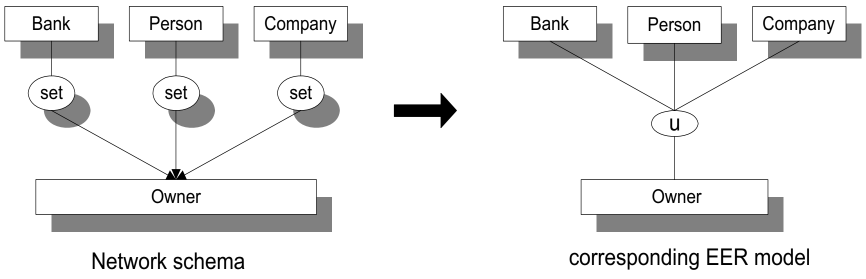


Figure 3-12 Map isa relationships to categorization in EER model

Substep 7 - Derive entity keys and other constraints.

There are three forms of identifiers. They can be described as follows:

- Fully internally identified - The record key uniquely identifies the record. For example, in a loan system records can be identified as in Figure 3-13. Here Loan# and Collateral# are unique in the whole loan system.

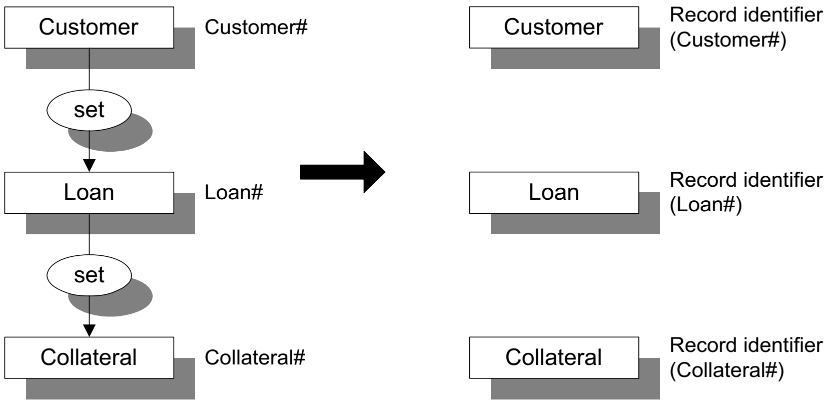

Customer
Customer#
set
Loan
Loan#
set
Collateral
Collateral#
Customer
Record identifier (Customer#)
Loan
Record identifier (Loan#)
Collateral
Record identifier (Collateral#)

Figure 3-13 Map network schema with fully internally identifier to relational

- Partially internally identified - Concatenation of owner record(s) key(s) with the member record key can uniquely identify the member record (i.e., identifier dependency). For example, the same loan system records could be identified as in Figure 3-14. Here Loan# is only unique within a customer and Collateral# is only unique within a loan.

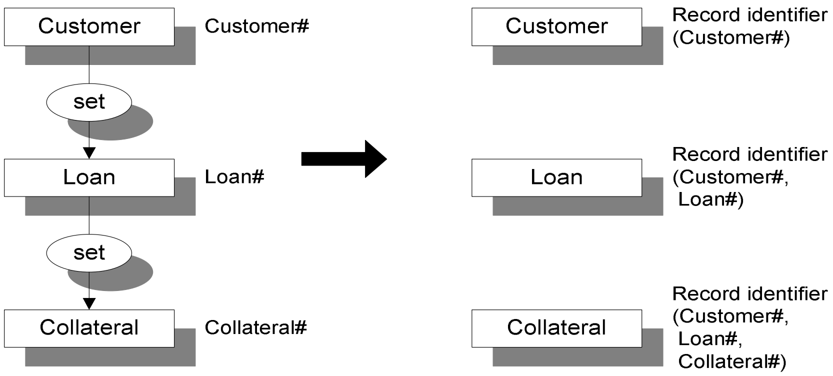

Customer
Customer#
set
Loan
Loan#
set
Collateral
Collateral#
Customer
Record identifier (Customer#)
Loan
Record identifier (Customer#, Loan#)
Collateral
Record identifier (Customer#, Loan#, Collateral#)

Figure 3-14 Map network schema with partially internally identifier to relational

- Internally Unidentified - The record key does not exist. Some other property (such as ordering) may be used to impart an implicit internal identifier. This is an extreme case of a partially internally identified group for which an augmented identifier consists solely of external identifiers. For example, in the same loan system, the Collateral record may not have a key. Its record identifiers must then be derived as in Figure 3-15. Here

Sequence# is added as an additional field for the identifier.

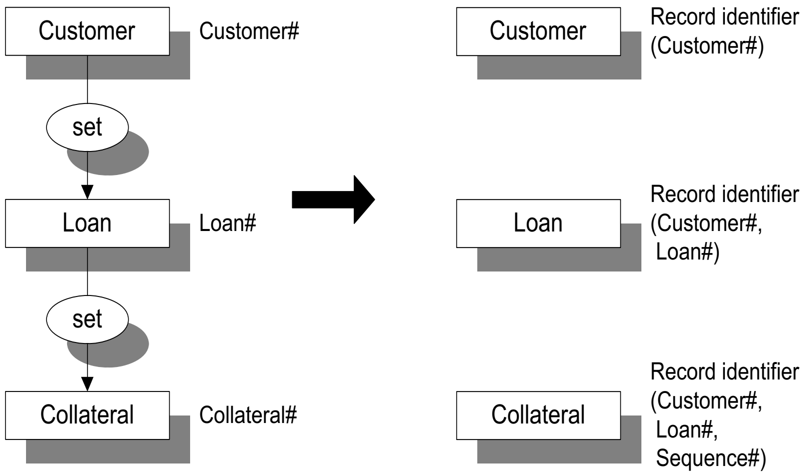

Customer
Customer#
set
Loan
Loan#
set
Collateral
Collateral#
Customer
Record identifier (Customer#)
Loan
Record identifier (Customer#, Loan#)
Collateral
Record identifier (Customer#, Loan#, Sequence#)

Figure 3-15 Map network schema with internally unidentified to relational

These identifiers are mapped into entity keys. Partial internally identified is taken as the default, and the user confirms this, or specifies the entity key for the other two cases.

Note that the record identifier for the partially internally identified is the concatenation of owner record identifier with the target record identifier. The record identifier for the internally unidentified record type is the concatenation of the owner record identifier with a unique sequence#.

The member record types with the SET membership clause fixed-automatic or mandatory-automatic must be connected to their owner record. For the SET membership clause of fixed-manual, mandatory-manual, optional-manual, the member may be disconnected from the owner record. If they are connected to owner records, their FDs and IDs can be derived. If they are disconnected with owner records, there is only an FD as illustrated in Figure 3-16.

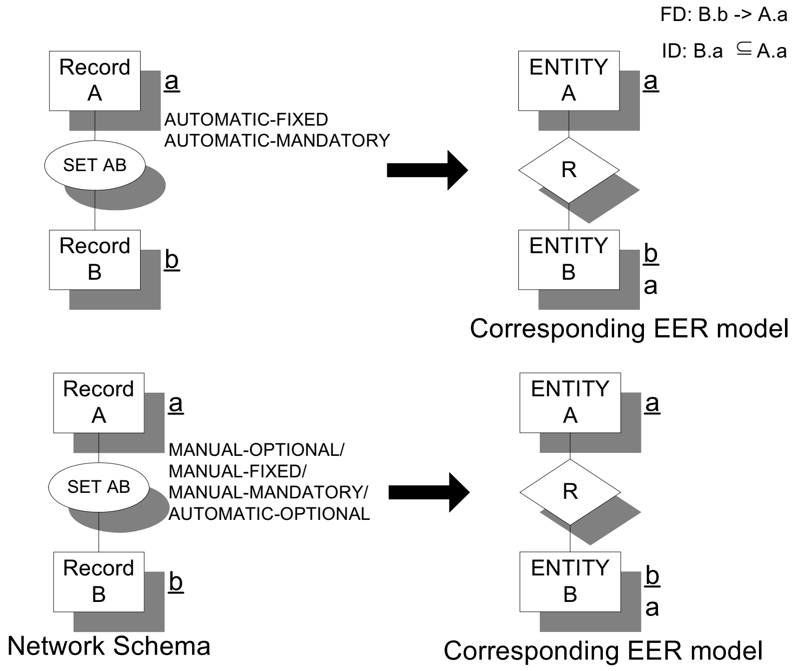


Figure 3-16 network schema dependency relationship translation

Substep 8 - Draw EER model.

Draw a derived EER model as a result of the previous steps. This is provided to enable the users to review the translated semantics of the original network schema. The above steps can be assisted by a knowledge-based system as described in chapter 1.

Step 2 - Forward engineering from conceptual EER model to relational schema.

This section describes the procedure to map EER model to relational schema:

Substep 1 - Map entities into relations.

Translate each entity into a relation containing the key and non-key attributes of the entity. If there is an n:1 relationship between an entity and another entity, add the key of the entity on the '1' side into the relation as shown in Figure 3-17. If there is a 1:1 relationship between an entity and another entity, then add the key of one of the entities into the relation for the other entity (i.e., the addition of a foreign key due to a 1:1 relationship can be made in either direction). For a unary relationship, the foreign key of

1:1 and a 1:n relationship can be mapped in the same or different relation(s). For a unary m:n relationship, a relationship relation must be mapped into the relational schema.

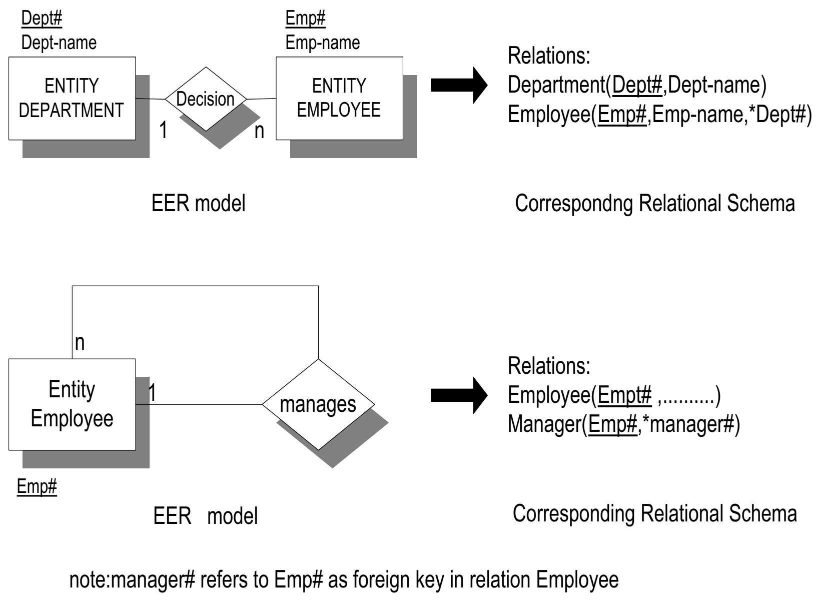
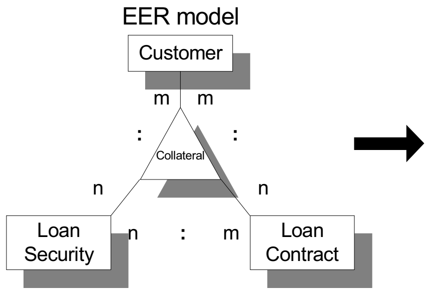

Dept#
Dept-name
ENTITY DEPARTMENT
Decision
1
n
Emp#
Emp-name
ENTITY EMPLOYEE
Relations:
Department(Dept#,Dept-name)
Employee(Emp#,Emp-name,*Dept#)
EER model
Correspondng Relational Schema
n
1
Entity Employee
manages
Emp#
Relations:
Employee(Empt# ,..........)
Manager(Emp#,*manager#)
EER model
Corresponding Relational Schema
note:manager# refers to Emp# as foreign key in relation Employee

Figure 3-17 Map binary and unary relationship in EER model to relationship schema

Substep 2 - Map an n-ary relationship into relationship relation.

An n-ary relationship has n+1 possible varieties of connectivity: all n sides with connected "1", n-1 sides with connected "1" and one side with connectivity "n", n-2 sides with connectivity "1" and two sides with "n" and so on, until all sides are "n". As an example, consider a Collateral system where customers provide a loan security for various loan contracts. Four of the possible ternary relationships are illustrated in cases 1 to 4.

Case 1: Many customers may participate in any one collateral for many loan contracts secured by many loan securities as shown in Figure 3-18.

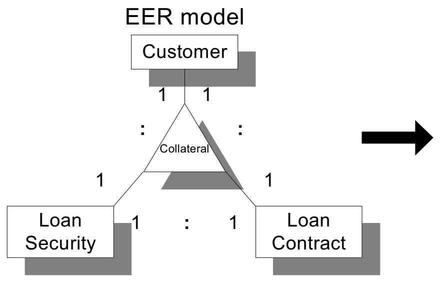


Mapped Relational Schema

Relation Customer (Customer#,....)
Relation Loan Security (Security#,.....)
Relation Loan Contract (Loan#,....)
Relation Collateral (*Customer#,
*Security#,
*Loan#,
Mortgage)

Figure 3-18 Map ternary relationship of all n:m relationship from EER model to relational schema

Case 2: A customer may participate in any one collateral for one contract secured by one loan security as shown in Figure 3-19.



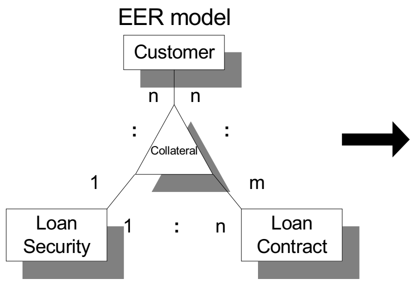
Mapped Relational Schema

Relation Customer (Customer#,....)
Relation Loan Security (Security#,.....)
Relation Loan Contract (Loan#,....)
Relation Collateral (*Customer#,
*Security#,
*Loan#,
Mortgage)

Any two of Customer#, Security#, Loan# can be candidate Key

Figure 3-19 Map ternary relationship of all 1:1 relationship from EER model to relational schema

Case 3: Many customers may participate in any one collateral for many loan contracts secured by one loan security as shown in Figure 3-20.

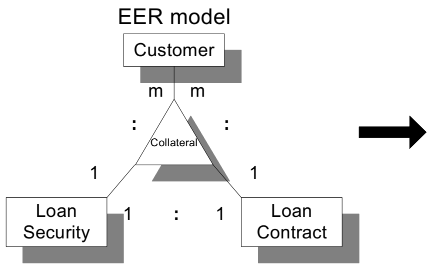


Mapped Relational Schema

Relation Customer (Customer#,....)
Relation Loan Security (Security#,.....)
Relation Loan Contract (Loan#,....)
Relation Collateral (*Customer#,
*Security#,
*Loan#,
Mortgage)

Figure 3-20 Map ternary relationship of 2 m:n relationship from EER model to relational schema

Case 4: Many customers may participate in any one collateral for one loan contract secured by one loan security as shown in Figure 3-21.



Mapped Relational Schema

Relation Customer (Customer#,....)
Relation Loan Security (Security#,.....)
Relation Loan Contract (Loan#,....)
Relation Collateral (*Customer#*,
*Loan#,
Security#,
Mortgage)

Fields in italic are candidate key

Figure 3-21 Map ternary relationship of two 1:1 relationships from EER model to relational schema

Substep 3 - Map aggregation, generalization, and categorization into relations.

An aggregation is derived when a relationship relation is further related to another entity. This is treated as an entity to be related to the third entity in a relationship. The mapping of such a relationship follows steps 1 and 2.

For disjoint generalization, superclass and subclass entities are mapped into relations on a one-to-one basis. The superclass entity key will be mapped as the primary key for all the mapped relations. The "predicate" attribute will be mapped as an attribute of the "generalized" relation. As an example, the disjoint generalization of Figure 3-10 can be mapped to the following relations:

Relations

Employee (Employee#, Employee-name, paid-scale)
Salaried-employee (*Employee#, month-salary, bonus)
Hourly-employee (*Employee#, hourly-salary, overtime-paid)

where paid-scale ("predicate" attribute) must be either "salaried" or "hourly".

For an overlap generalization, the superclass and subclass entities are mapped into relations on a one-to-one basis. The superclass entity key will be mapped as the primary key for all the mapped relations. The "subclass predicate" attributes (one for each subclass entity) will be mapped as attributes of the "generalized" relation. As an example, the overlap generalization of Figure 3-11 can be mapped to the following relations:

Relations

Person (Name, Address, Phone#, Age, Sex, Employee-flag, Alumnus-flag, Student-flag)
Employee (*Name, Start-date, Salary)
Alumnus (*Name, Graduation-date, degree)
Student (*Name, Supervisor, department)

where Employee-flag, Alumnus-flag and Student-flag are used to indicate the membership of a person who can be an employee and an alumnus and a student.

An example of mapping network schema to relational schema is illustrated as follows:

Case Study of Mapping a Network Schema to Relational

Figure 2-3 is a network schema for a university enrollment application in which departments offer courses in sections that are taught by instructors. Students enroll for sections of courses. Each course has one prerequisite. Each department has instructors who teach sections of courses. Students obtain grades for the sections they take. The following steps illustrate the different stages in the translation process.

Preprocess step 1 (implied relationship), preprocess step 2 (alternative paths), step 1 (derive unary relationship), and step 3 (derive n-ary relationship) are not applied since there are no implied relationships (i.e., no duplicate key fields), no multiple access paths (i.e., no alternative paths), no unary relationships (i.e., no member records consisting of pointers only and referring back to its owner record occurrences), and no n-ary relationships (i.e., more than two owners or member record types linked to each other through sets).

Step 2 - Derive binary relationships.

The user specifies a 1:1 relationship between Course and Prerequisite. The relationships between the entities are shown in Figure 3-22.

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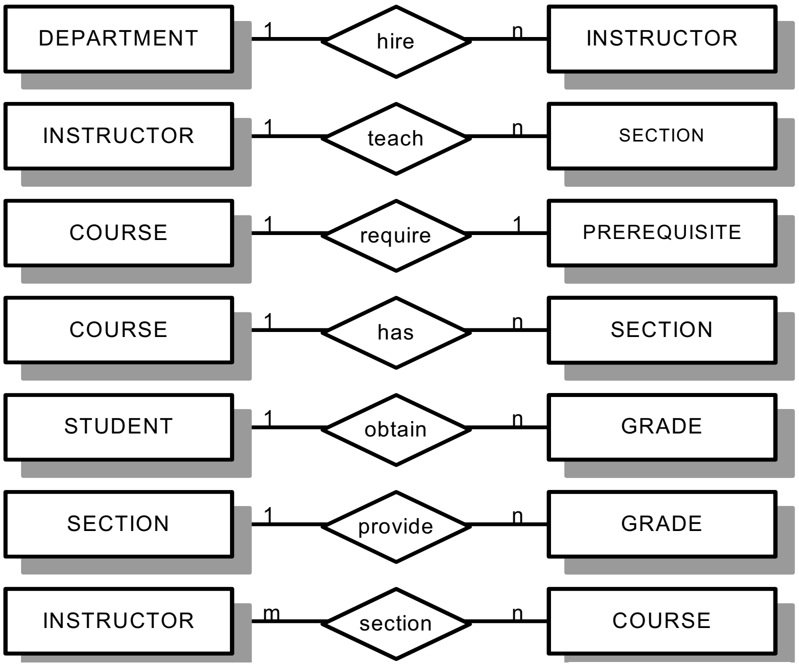


Figure 3-22 Derive binary relationships in university enrollment

Step 4 - Derive aggregation entities.

The m:n relationship derived in step 2 is in aggregation because its relationship relation Section also relates to the entity Student in another m:n relationship as shown in Figure 3-23.

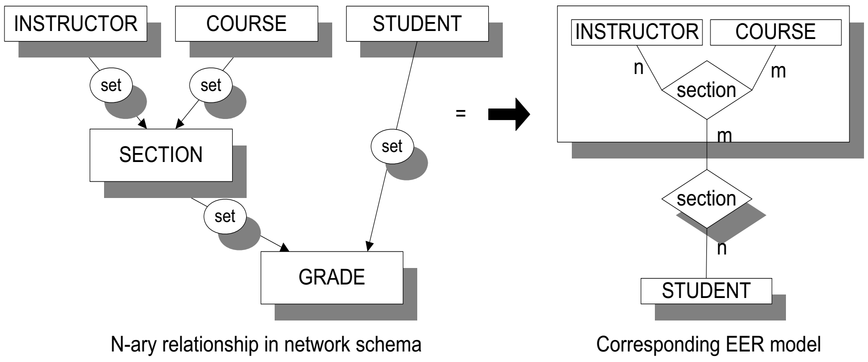


Figure 3-23 Map n-ary relationship into EER model in university enrollment

Step 5 - Derive entities keys.

Entities are partial internally identified by default. In this case, the identifier type of record Prerequisite has been changed from partially internally identified to fully internally identified through user interogation. Thus, we have its key changed as follows:

Entity	Entity key
Department	Department#
Student	Student#
Instructor	Department#, Instructor_name
Course	Course#
Prerequisite	Prerequisite#
Section	Department#, Instructor_name, Course#
Grade	Student#, Department#, Instructor_name, Course#

Step 6 - Draw EER model.

As a result of the previous steps, an EER model can be drawn, as shown in Figure 3-24.

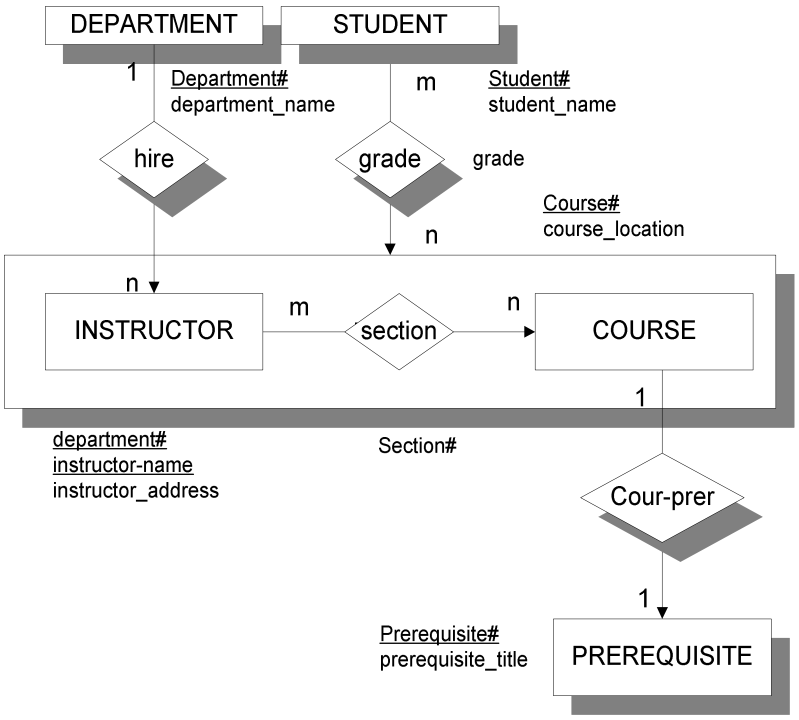


Figure 3-24 Mapped EER model for university enrollment

The following steps map the derived EER model into a relational schema:

Step 1 - Map entities into relations.
Each entity can be translated into a relation as shown below:

Relation Department (Department#, Department_name)
Relation Instructor (*Department#, Instructor_name, Instructor_address)
Relation Course (Course#, Course_location)
Relation Prerequisite (Prerequisite#, Prerequisite_title, *Course#)
Relation Student (Student#, Student_name)

Step 2 - Map m:n relationships into relationship relation.
In this example, the relation Section is derived as follows:

Relation Section (*Department#, *Course#, *Instructor_name, Section#)

Step 3 - Map aggregation into relation.
As relationship relation Section is related to entity Student in an m:n relationship, there is an aggregation relation as follows:

Relation Grade (*Department#, *Instructor_name, *Course#, *Student#,
Grade)

As a result of the previous steps, the derived relations can be merged as follows:

Relation Department (Department#, Department_name)
Relation Instructor (*Department#, Instructor_name, Instructor_address)
Relation Course (Course#, Course_location)
Relation Prerequisite (Prerequisite#, Prerequisite_title, *Course#)
Relation Student (Student#, Student_name)
Relation Section (*Department#, *Course#, *Instructor_name, Section#)
Relation Grade (*Department#, *Instructor_name, *Course#, *Student#,
Grade)

3.4 INDIRECT TRANSLATING A HIERARCHICAL MODEL TO A RELATIONAL MODEL

Since the hierarchical model can be taken as subset of the network model, the procedure for translating a hierarchical schema to relational is similar to the procedure of translating network schema to relational except for the following steps:

- Substep 2 is not applied because of lack of multiple (alternative) access paths between two segments in a hierarchical database.
- Substep 4, Derivation of entities of an m:n binary relationship, is not applied.

To implement an m:n relationship in a hierarchical schema, in general, two definition trees are needed, with each segment type represented as a parent segment in one tree, but as a child segment in another as shown below in Figure 3-25:

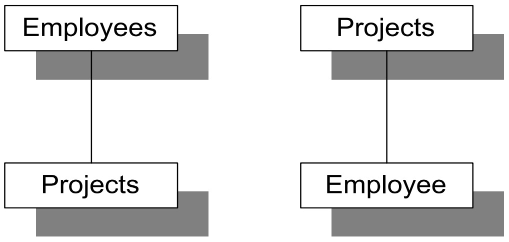


Figure 3-25 m:n relationship with redundant hierarchical segments

However, some hierarchical DBMSs provide mechanisms whereby it is possible to define logical views on one physical storage structure. The IMS database supports m:n relationships through pair logical segments as shown in Figure 3-26.

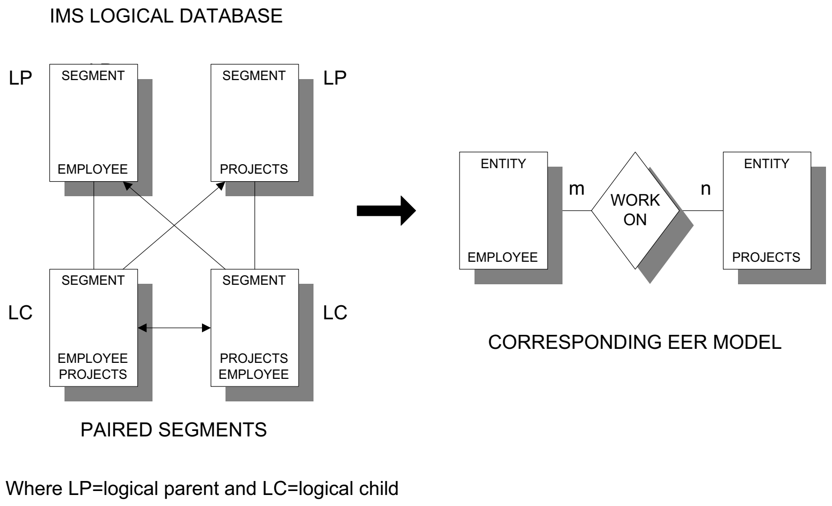


Figure 3-26 Map IMS logical database into EER model

Substeps 4, 5, and 6 are not applied because of lack of similar data structure in the hierarchical schema.

3.5 TRANSLATING A RELATIONAL MODEL TO AN EER MODEL

Although the relational data model has become the standard for data processing applications, its data modeling are extremely limited when compared with object-oriented data model. For object-oriented data model, however, at present there are no formal standards describing the exact format and syntax for representing an object-oriented database. Therefore, in the work described below, we define a methodology to reengineer existing relational model schemas into the UML model. The relational model is first reverse engineered into an EER model with users input to recover some lost semantics. The EER model is then mapped into an UML model. This latter transformation is prescribed by a set of transformation rules devised by the author. Such reengineering practices can not only provide us with significant insight to the "interoperability" between the object-oriented and the traditional semantic model techniques, but also can lead us to the development of a practical design methodology for object-oriented database.

Step 1 -Reverse engineering from relational model to conceptual EER model (Navathe & Awong, 1988).

The translation process can be described as follows:

Substep 1 - Define each relation, key, and field.

The relations are preprocessed by making any necessary candidate key substitutions as follows:

- Primary relation. These relations describe entities.
- Primary relation - Type 1 (PR_1). This is a relation whose primary key does not contain a key of another relation.
- Primary relation - Type 2 (PR_2). This is a relation whose primary key does contain a key of another relation.
- Secondary relation. This is a relation whose primary key is full or partially formed by concatenation of primary keys of other relations.
- Secondary relation - Type 1 (SR_1). If the key of the secondary relation is formed fully by concatenation of primary keys of primary relations, it is of Type 1 or SR_1.
- Secondary relation - Type 2 (SR_2). Secondary relations that are not of Type 1.
- Key attribute - Primary (KAP). This is an attribute in the primary key of a secondary relation that is also a key of some primary relation.
- Key attribute - General (KAG). These are all the other primary key attributes in a secondary relation that are not of the KAP type.
- Foreign key attribute (FKA). This is a non-primary key attribute of a primary relation that is a foreign key.
- Nonkey attribute (NKA). The rest of the non-primary-key attributes.

For example, the following relations are for an university enrollment system:

Relation Department (<u>Dept#</u>, Dept_name,)

Relation Instructor (*Dept#, Inst_name, Inst_addr)
Relation Course (Course#, Course_location)
Relation Prerequisite (Prer#, Prer_title, *Course#)
Relation Student (Student#, Student_name)
Relation Section (*Dept#, *Course#, *Inst_name, Section#)
Relation Grade (*Dept#, *Inst_name, *Course#, *Student#, *Section#, Grade)

The following relations and attributes classification table is derived:

Relation Name	Rel Type	Primary-Key	KAP	KAG	FKA	NKA
DEPT	PR_1	Dept#				Dept_name
INST	PR_2	Dept#	Dept#	Inst_name	Inst_name	Inst_addre
COUR	PR_1	Course#				Course_location
STUD	PR_1	Student#		Stud_name		
PREP	PR_1	Prer			Course#	Prer_title
SECT	SR_2	Course#	Course#	Inst_name	Inst_name	
		Dept#	Dept#			
		Section#		Section#		
GRADE	SR_1	Inst_name	Inst_name			Grade
		Course#	Course#			
		Student#	Student#			
		Dept#	Dept#			
		Section#	Section#			

Substep 2 - Map each PR_1 into an entity.

For each Type 1 primary relation (PR_1), define a corresponding entity type and identify it by the primary key. Its nonkey attributes map to the attributes of the entity type with the corresponding domains. For example, the PR_1 relational types in the classification table can be mapped to the following entities in Figure 3-27.

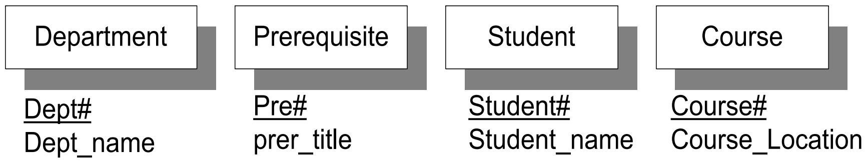


Figure 3-27 Map primary relations to entities

Substep 3 - Map each PR_2 into a weak entity.

For each Type 2 primary relation (PR_2), define a weak entity with its primary key being the key of the PR_2 relation. The entity on which it is ID-dependent will be that entity identified by the primary key on which the PR_2 primary key is dependent. Define a relationship between the owner and the weak entities. All NKA type attributes of the PR_2 relation will be attributes of the weak entity defined. For example, the PR_2 relational type in the classification table can be mapped to the following entities and their relationships in Figure 3-28.

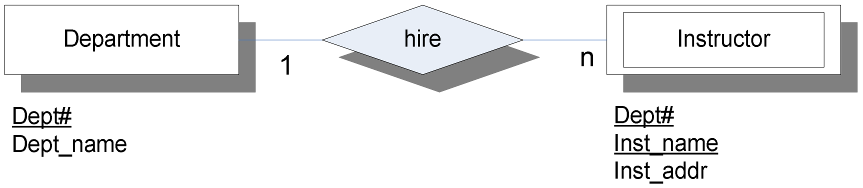


Figure 3-28 Map PR_2 into EER model

Substep 4 - Map SR_1 into a binary/n-ary relationship.

For each SR_1 secondary relation, identify the relationship by the primary key of the SR_1 relation. Define the NKA type attributes as the attributes of the relationship type. If the key of the SR_1 relationship is part of the primary key of another secondary relation, then it is mapped as an n-ary relationship in the EER model. For example, the SR_1 relational type in the classification table can be mapped to following entities and their relationships in Figure 3-29.

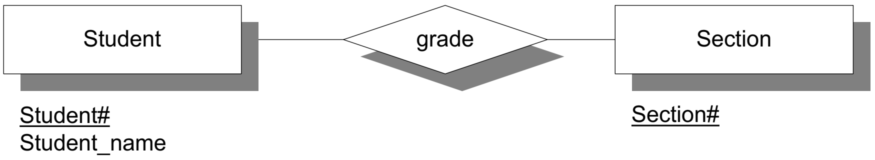


Figure 3-29 Map SR_1 into EER model

Substep 5 - Map SR_2 into a binary/n-ary relationship.

For each SR_2 relation, define an entity type for each of the KAG type attributes, with the KAG attribute as its entity key. Define a binary relationship type between all the entity types defined by the KAP and KAG attributes in the key of this SR_2 relation. The NKA attributes form the attributes of this binary relationship type. If the key of the SR_2 relationship is part of the primary key of another secondary relation, then it is mapped as an n-ary relationship in the EER model. For example, the SR_2 relational type in the classification table can be mapped to the following entities and their relationships in Figure 3-30.

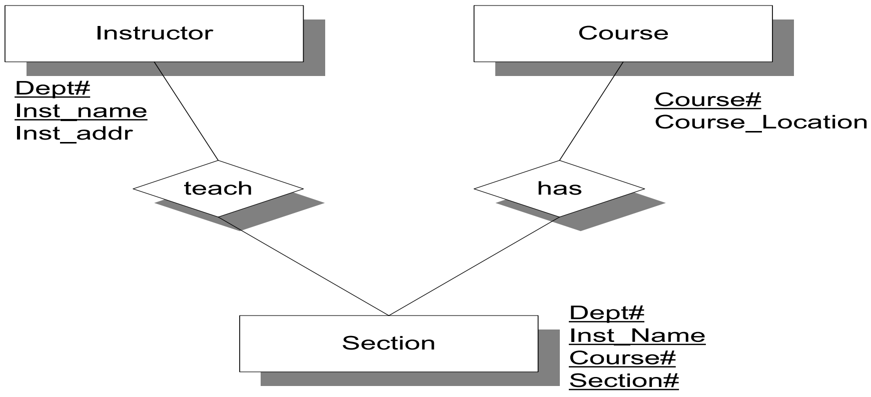


Figure 3-30 Map SR_2 into EER model

Substep 6 - Map each FKA into a relationship.

For each FDA type attribute of a primary relation, R_1, define a relationship type between the entity defined from R_1 and the entity that has the FKA as its primary key.

The following entities and relationships can be derived from the classification table in Figure 3-31.

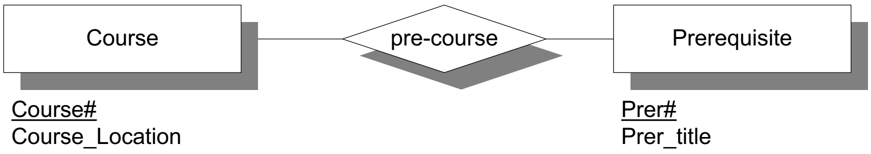


Figure 3-31 Map FKA into EER model

SubStep 7 - Map each inclusion dependency into semantics (binary/n-ary relationship).

If IDs have been derived between two entities, entity A with a as entity key and b' as foreign key, and entity B with b as entity key and a' as foreign key, then their semantics can be derived as follows:

Case 1. If given ID; $a' \subseteq a$, then entity A is in a 1:n relationship with entity B.

Case 2. If given IDs: $a' \subseteq a$, and $b' \subseteq b$ (optional), then entity A is in a 1:1 relationship with entity B.

Case 3. If given IDs: $a' \subseteq a$, and $b' \subseteq b$, and a'b' is a composite key, then entity A is in an m:n relationship with entity B.

For example, Table 1 shows the derived semantics from the inclusion dependencies of the enrollment system:

Table 1 Derive semantics from inclusion dependencies

Given derived inclusion dependency	Derived Semantics
Instructor.Dept# $\subseteq$ Department.Dept#	n:1 relationship between entities Instructor and Department
Section.Dept# $\subseteq$ Department.Dept# Section.Inst_name $\subseteq$ Instructor.Inst_name Section.Course# $\subseteq$ Course.Course#	1:n relationship between entities Instructor and Section and between Course and Section.
Grade.Dept# $\subseteq$ Section.Dept# Grade.Inst_name $\subseteq$ Section.Inst_name Grade.Course# $\subseteq$ Section.Course# Grade.Student# $\subseteq$ Student.Student#	m:n relationship between relationship Section and entity Student.
Prerequisite.Course# $\subseteq$ Course.Course#	1:1 relationship between Course and Prerequisite

Substep 8. Draw EER model.

Put together an EER model as a result of the above steps as shown in Figure 3-32.

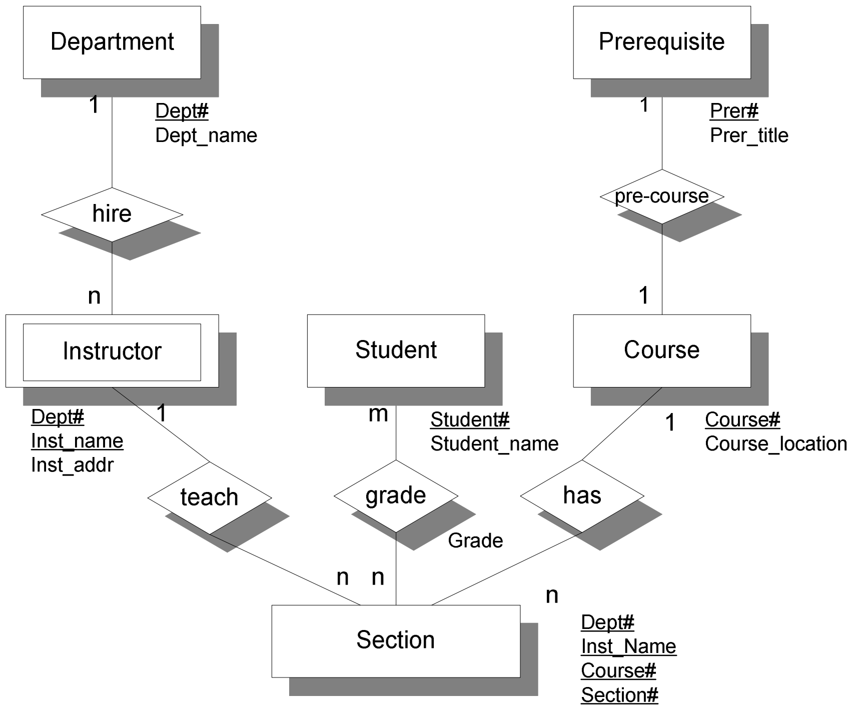


Figure 3-32 Derived EER model in reverse engineering

3.6 TRANSLATING AN EER MODEL TO A UML

The following procedure transforms an EER model to a UML model (Fong, 1994):

Step 1 - Map entity to class.

An EER model works with entity types and their corresponding attributes. Attributes of a particular entity may be considered as instance variables of the class instance. For example, an entity type Student can be mapped into a class Student of UML as shown in Figure 3-33.

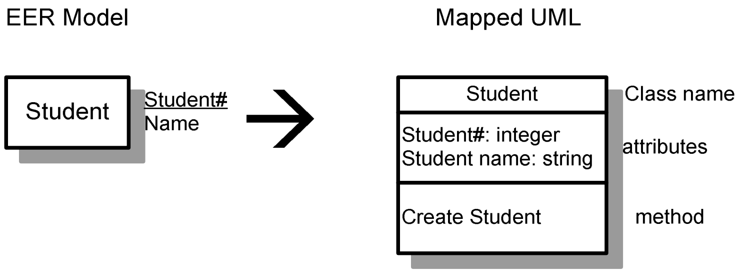


Figure 3-33 Map an entity to a class

Step 2 - Map relationship to association.

In an EER model, relationships are represented as named associations among entities. In an object-oriented schema, they are links and associations between superclass(es) and subclass(es). A link is a physical conceptual connection between object instances. Association describes a group of link with common structure and semantics and can be represented as an attribute that explicitly references another object. The relationship in the EER model can be mapped into an association in object-oriented schema on a 1:1 basis with its corresponding multiplicity of links and pointers. When constrained by cardinality, appropriate symbols must be specified by a line (link) with or without a solid dot sign. For example, the 1:n relationship in Figure 3-34 can be mapped into the UML where "Cour-prer" is an association between the classes and Prerequisite.

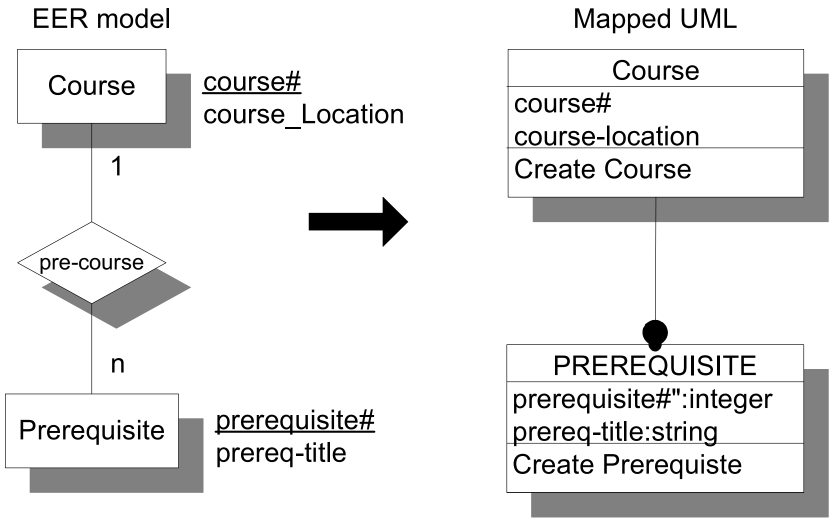


Figure 3-34 Map a relationship to an association in UML

Step 3 - Map generalization to method.

For generalization, the variances among entities are suppressed and their commonalities are identified by generalizing them into one single class. The original entities with each of its unique differences are special subclass(es). The mutually exclusive subclass(es) are called disjoint generalization. The mutually inclusive subclasses are called overlap generalization. For example, disjoint generalization in Figure 3-35 can be mapped into the UML where subclass(es) Contract-Staff and Permanent-Staff inherit the properties and operations of superclass Staff. The mapping of overlap generalization into the object-oriented schema is similar to the mapping of disjoint generalization into the object-oriented schema except that the check statement is omitted and a solid triangle is used to indicate overlapped subclass(es).

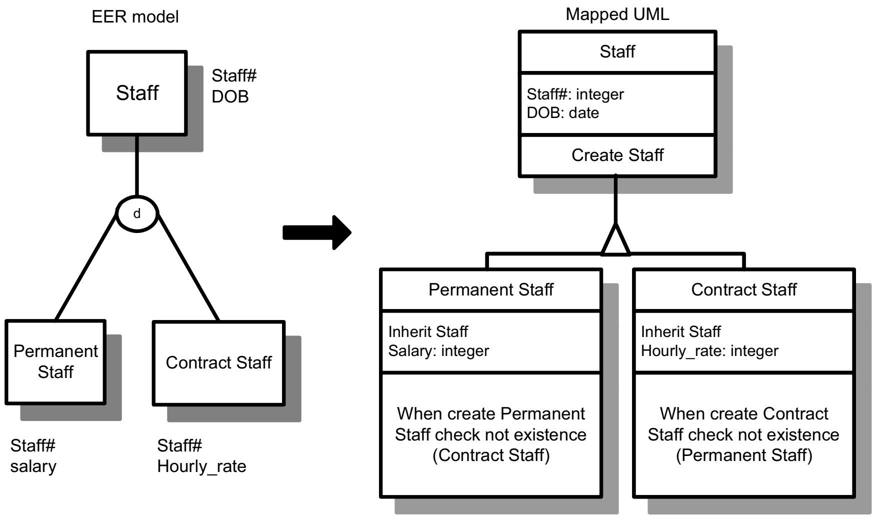


Figure 3-35 Map disjoint generalization to method

Step 4 - Map categorization to “Multiple” inheritance.

A categorization is derived by mapping isa relationships and their record types to a superclass/subclass such that a set of superclass(es) can be united to form a superclass. All these superclass(es) may have different key attributes as they are originally independent classes. For example, the categorization in Figure 3-36 can be mapped into the following UML model where the subclass Research-Assistant comes from one of the two superclass(es): Faculty or Graduate Student.

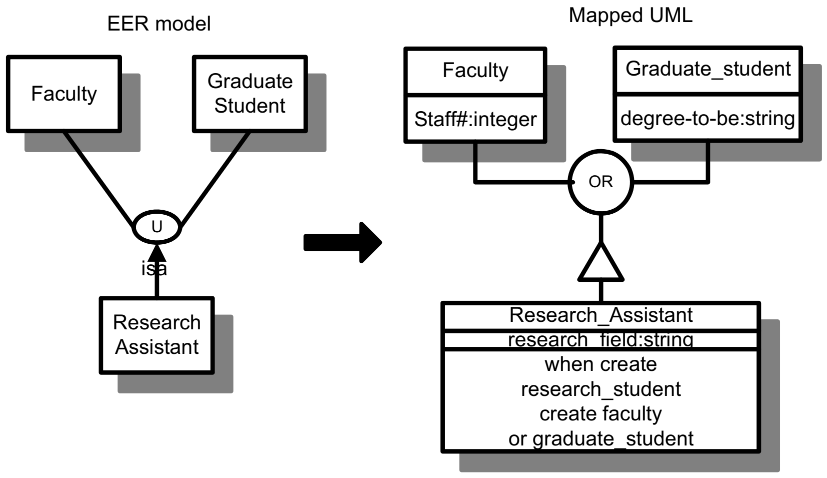


Figure 3-36 Map categorization to method

Step 5 - Map isa relationship to inheritance.

The concept of inheritance associated with a generalization (isa) relationship in object-oriented schema permits classes to be organized in which specialized class(es) inherit the properties and operations of a more generalized class. Class carries common properties while deriving a specialized subclass. For example, the isa relationship in Figure 3-37 can be mapped into the following UML model where subclass Graduate_Student inherits the properties of its superclass Student.

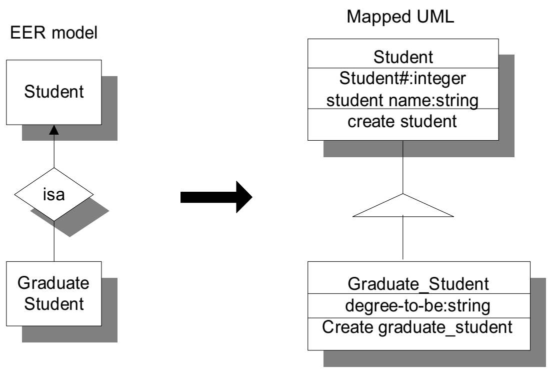


Figure 3-37 Map isa relationship to inheritance

Step 6 - Map weak entity to component class.

The existence of a weak entity in the EER model depends on its owner entity. For example, the weak entity Instructor in Figure

3-38 can be mapped into UML where class Department is a composite object class that owns a component class Instructor. The own statement implies an existence dependency of component class Instructor such that if an instance of class Department is deleted, its corresponding component class Instructor instances are also deleted.

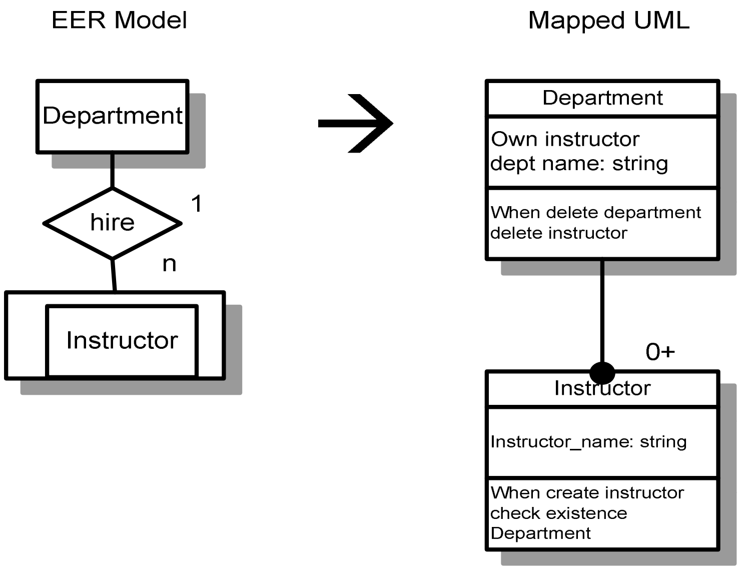


Figure 3-38 Map weak entity to method

Step 7 - Map aggregation to composite class.

The entities and their relationship in the EER model can be aggregated to form an entity. In an object-oriented model, this permits the combination of classes that are related into a higher level composite class. For example, the aggregation in Figure 3-39 can be mapped to the object-oriented schema where the composite class Section is an aggregation of two component classes: class Instructor and class Course.

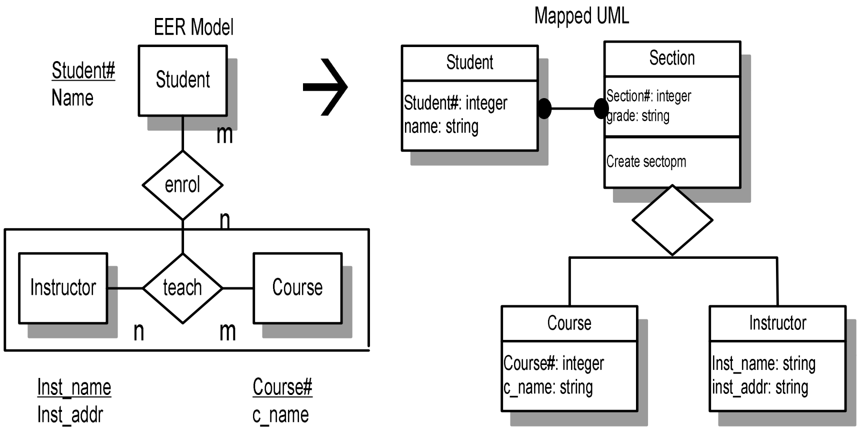


Figure 3-39 Map generalization to method

3.7 TRANSLATING A RELATIONAL SCHEMA TO A DOCUMENT TYPE DEFINITION

With XML adopted as the technology trend on the Internet, and with the investment in the current relational database systems, companies must convert their relational data into XML documents for data transmission on the Internet. In the process, to preserve the users' relational data requirements of data constraints into the converted XML documents, the user must define a required XML view as a root element for each XML document. The construction of an XML document is based on the root element and its relevant elements. The root element can be selected from a relational entity table in the existing relational database, which depends on the requirements to present the business behind. The relevant elements are mapped from the related entities, based on the navigability of the chosen entity. The derived root and relevant elements can form a Data Type Definition Graph (DTD-graph) as an XML conceptual schema diagram, which can be mapped into a Data Type Definition (DTD) of an XML schema. The result is a translated XML schema with semantic constraints transferred from an extended entity relationship (EER) model.

Interoperation of a relational database and an XML database involves schema translation between relational and XML databases. The translated XML schema helps sharing business data with other systems, interoperability with incompatible systems, exposing legacy data to applications that use XML, ecommerce, object persistence using XML, and content syndication. The process involves a classification table recovering the data semantics from the relational database into EER model, and then mapping them into a DTD.

The standardized method for creating DTD is through the use of markup declarations. What is needed is a method of augmenting the existing set of DTD properties with additional properties to achieve true information understanding. There are ways to accomplish this goal by using XML. The XML schema provides a means of using XML instances to define augmented DTDs. The transformation adopts a reverse engineering approach. It reconstructs the semantic model in an EER model from the logical relational schema by capturing user's knowledge. It then reengineers the EER model into a DTD-graph (Funderburk, 2002).

To make relational schema compatible with the XML schema, based on each constraint in the relational schema, we map the relational schema with its semantic constraints into a DTD and a DTD-graph. A DTD-graph is an XML logical schema in the form of a hierarchical containment. To draw a DTD-graph, we select an element as root and then put its relevant information into a document. The selection is usually driven by the business nature. In other words, it depends on the requirements to present the business behind. Relevance concerns which entities are related to the selected entity to be processed. The relevant classes include the selected and related entities that are navigable. Navigability specifies whether traversal from an entity to its related entity is possible. Relationship can be directional with navigability. Unidirectional means only one relationship end is navigable. Bi-directional means both relationship ends are navigable.

An XML document is in the form of a spool of text in particular sequence and the sequence will affect the output statement and finally the whole database schema. An XML schema consists of a root element and then each element is laid down one by one as branches and leaves in the schema. There is a top-down relationship of the element in an XML schema. Even the element's attributes are also ordered in the schema.

On the other hand, a DTD-graph node diagram uses a graphical interface. Each node in a DTD-graph does not carry any ordering information. There is no explicit root-branch relationship between nodes in the DTD-graph nodes diagram.

In order to solve the problem due to this structural difference, an arbitrary XML view, a database object, has to be created in order to start the branching from root. Branching from this root element are the basic classes and various constraints, included in the DTD-graph specification. To prepare for the transformation, the non-ordered DTD-graph node diagram must be replaced with a listing of all related components in the entity diagram. This process is “decomposition.” With the component list, a process sequence is drawn to transform each kind of DTD-graph component into its XML correspondence of DTD. The structural difference problem could be solved.

Figure 3-40 shows the general architecture of re-engineering relational schema into XML schema DTD.

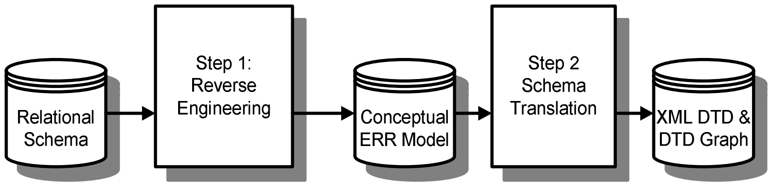


Figure 3-40 Architecture of translating schema from relational into XML

By following the procedure in Figure 3-40, we translate a relational schema into an XML schema based on a selected XML view, and then load relational data into an XML schema. It consists of three steps:

1. Reverse engineering relational schema into an EER model.
2. Schema translation from an EER model into a DTD-graph and DTD.
3. Data conversion from relational database to XML documents.

Step 1 - Reverse engineering a relational schema into an EER model

By use of classification tables to define the relationship between keys and attributes in all relations, we can recover their data semantics in the form of an EER model. Refer to section 3.5 for details.

Step 2 - Schema translation from EER model into a DTD-graph and DTD.

We can map the data semantics in the EER model into a DTD-graph according to their data dependencies constraints. These constraints can then be transformed into a DTD as an XML schema as shown in the following:

Rule 1: Define an XML view root element in DTD

To select an XML view of the source relational schema as a root element, its relevant information must be transformed into an XML logical schema including the selected entity and all its relevant entities that are navigable.

Navigability specifies the feasibility of the traversal from an entity to its related entities. The relationship can be directional with navigability. The process is similar to the process when we walk the tree structure of a DTD-graph. We navigate each relationship, then each relationship from the children table of the previous relationships and so on.

In Figure 3-41, entity E is the selected entity for an XML view, The navigable entities in the EER model are mapped as sub-elements under root elements in a hierarchy structure. Each attribute of the relevant entity is mapped into the attribute of the corresponding element. In the example, this selected XML view and its relevant relations can be mapped as elements of an XML schema. The relevance of the relaitons depends on the connectivity and the constraints of the hierarchical tree of the elements The one-to-many cardinality can be mapped into one parent and many child elements, and the many-to-one cardianlity can be mapped into a one parent and one child elements of a translated XML schema.

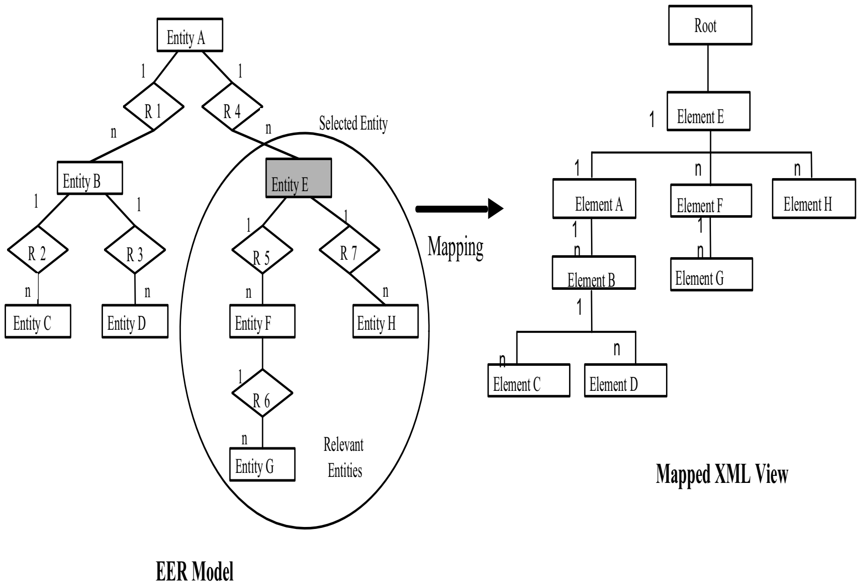
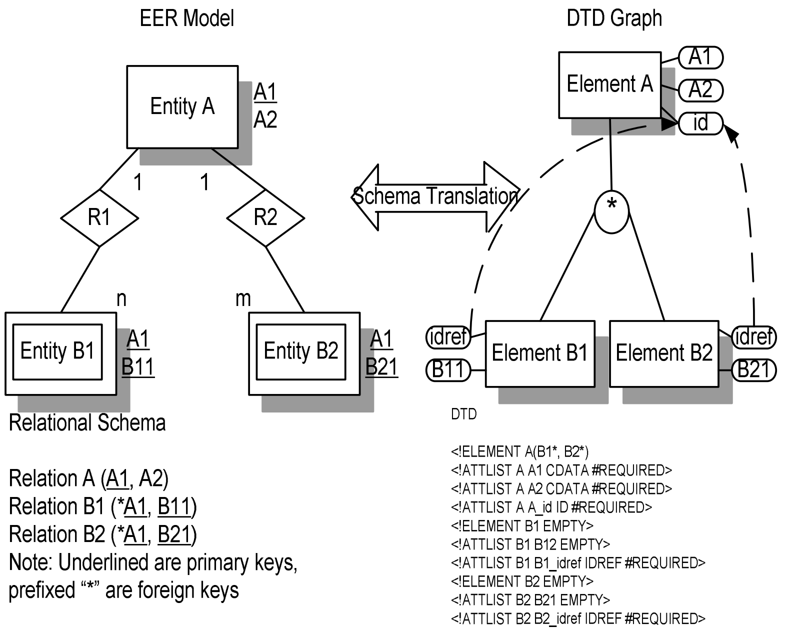


Figure 3-41 Selected XML view and its mapped XML tree

Rule 2: Mapping weak entity from RDB to DTD

A weak entity depends on its strong entity such that the primary key of the weak entity is also a foreign key addressing to the primary key of its strong entity, and cannot be a null value. In DTD, we transform the strong entity into an element with ID and the weak entity into another element that refers to the ID element using IDREF as shown in Figure 3-42.



Relational Schema

Relation A (A1, A2)
Relation B1 (*A1, B11)
Relation B2 (*A1, B21)
Note: Underlined are primary keys, prefixed "*" are foreign keys

DTD

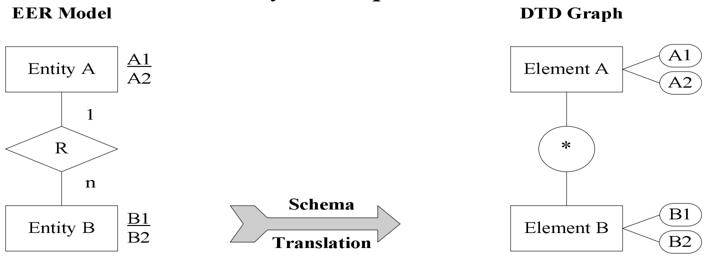
```
<!ELEMENT A(B1*, B2*)
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ATTLIST A A_id ID #REQUIRED>
<!ELEMENT B1 EMPTY>
<!ATTLIST B1 B12 EMPTY>
<!ATTLIST B1 B1_idref IDREF #REQUIRED>
<!ELEMENT B2 EMPTY>
<!ATTLIST B2 B21 EMPTY>
<!ATTLIST B2 B2_idref IDREF #REQUIRED>
```

Figure 3-42 Schema translation of weak entity

Rule 3: Mapping participation from RDB to DTD

A child table is in total participation with a parent table provided that all data occurrences of the child table must participate in a relationship with the parent table. A foreign key of a child table in total participation must address to the primary key of its parent table and cannot be a null value. A child table is in partial participation with a parent table provided that the data occurrences of the child table are not totally participated in a relationship with the parent table. A foreign key of a child table in partial participation must address to the primary key of its parent table and can be a null value. In DTD, we translate the total and partial participations into an optional occurrence as shown in Figures 3-43 and 3-44.

Case 1: Total / Mandatory Participation



Relational Schema

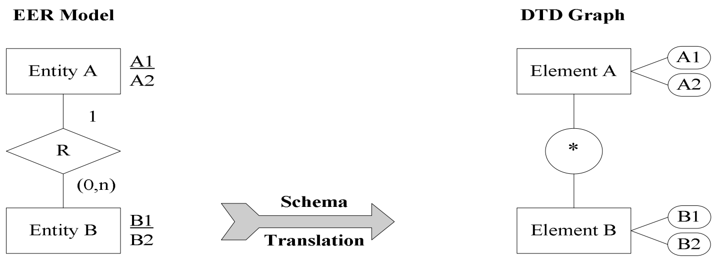
Relation A(A1, A2)
Relation B(B1, B2, *A1)

DTD

```
<!ELEMENT  A(B)*>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
```

Figure 3-43 Schema translation of total participation

Case 2: Partial / Optional Participation



Relational Schema

Relation A(A1, A2)
Relation B(B1, B2, *A1)

Note: foreign key nullable

DTD

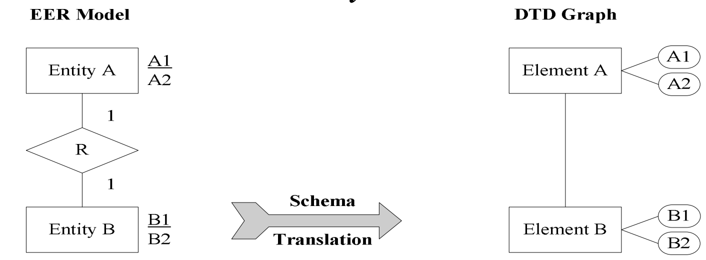
```
<!ELEMENT  A(B)*>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
```

Figure 3-44 Schema translation of partial participation

Rule 4: Mapping cardinality from RDB to DTD

One-to-one cardinality indicates that a foreign key of a child table addresses to a primary key of a parent table in a one to one occurrence. One-to-many cardinality indicates that a primary key of a parent table is addressed by many foreign keys of a child table in a one-to-many occurrence. Many-to-many cardinality indicates that a primary key of a parent table is addressed by many foreign keys of a child table and vice versa. This pair of tables are thus in a many-to-many cardinality. In DTD, we translate one-to-one cardinality into parent and child element (Figure 3-45) and one-to-many cardinality into a parent and child element with multiple occurrences (Figure 3-46). In many-to-many cardinality, it is mapped into DTD of a hierarchy structure with ID and IDREF as shown in Figure 3-47.

Case 1: One-to-One Cardinality



Relational Schema

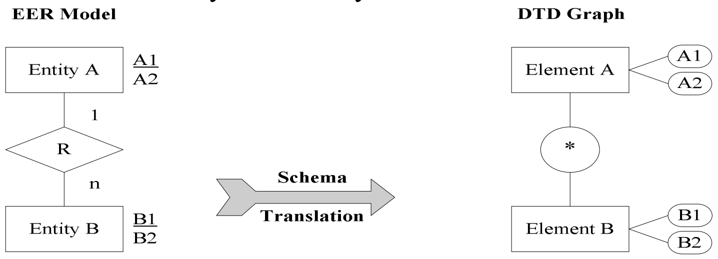
Relation A(<u>A1</u>, A2)
Relation B(<u>B1</u>, B2, *A1)

DTD

```
<!ELEMENT  A(B)>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
```

Figure 3-45 Schema translation of One-to-One cardinality

Case 2: One-to-many Cardinality



Relational Schema

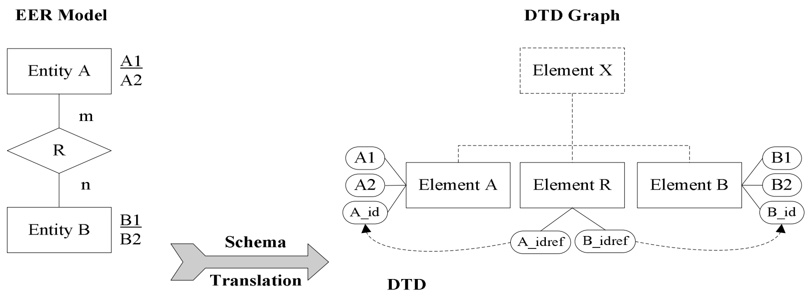
Relation A(<u>A1</u>, A2)
Relation B(<u>B1</u>, B2, *A1)

DTD

```
<!ELEMENT  A(B)*>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
```

Figure 3-46 Schema translation of One-to-Many cardinality

Case 3: Many-to-Many Cardinality



DTD

```
<!ELEMENT A EMPTY>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ATTLIST A A_id ID #REQUIRED>
<!ELEMENT R EMPTY>
<!ATTLIST R A_idref IDREF #REQUIRED>
<!ATTLIST R B_idref IDREF #REQUIRED>
<!ELEMENT B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
<!ATTLIST B B_id ID #REQUIRED>
```

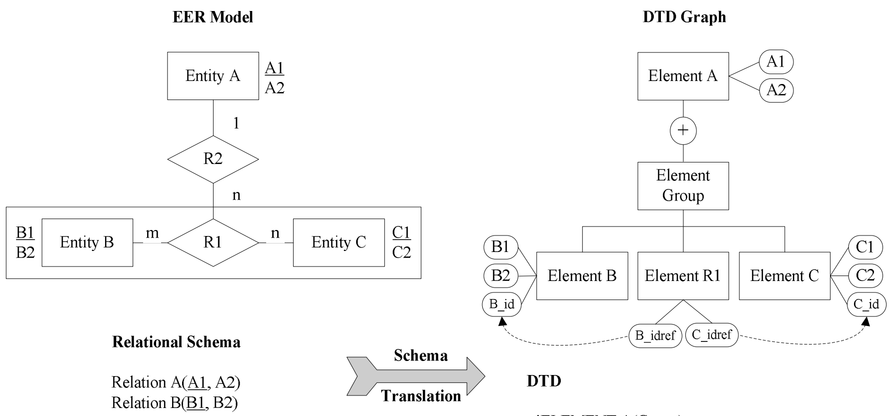
Relational Schema

Relation A(A1, A2)
Relation B(B1, B2)
Relation R(*A1, *B1)

Figure 3-47 Schema translation of many-to-many cardinality

Rule 5: Mapping aggregation from RDB to DTD

An aggregation specifies a whole-part relationship between an aggregate such that a class represents the whole and a constituent represents part. DTD can construct part-of relationship in the element content. For example, in Figure 3-48, entity B, entity C and relationship R1 form an aggregate entity that is related to another entity A. They can be mapped into DTD as follows:



Relational Schema

Relation A(A1, A2)
Relation B(B1, B2)
Relation C(C1, C2)
Relation R1(*B1, *C1, *A1)

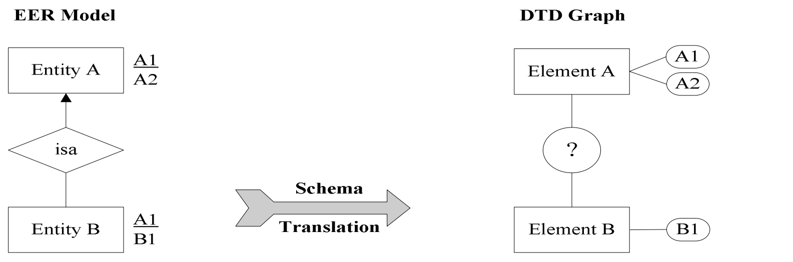
DTD

```
<!ELEMENT A(Group)+>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT Group(B, R1, C)>
<!ELEMENT B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
<!ATTLIST B B_id ID #REQUIRED>
<!ELEMENT R1 EMPTY>
<!ATTLIST R1 B_idref IDREF #REQUIRED>
<!ATTLIST R1 C_idref IDREF #REQUIRED>
<!ELEMENT C EMPTY>
<!ATTLIST C C1 CDATA #REQUIRED>
<!ATTLIST C C2 CDATA #REQUIRED>
<!ATTLIST C C_id ID #REQUIRED>
```

Figure 3-48 Schema translation of aggregation

Rule 6: Mapping ISA relationship from RDB to DTD

The isa defines as relationship between a subclass entity to a superclass entity. In DTD, we transform each subclass entity as a child element that refers to its parent element such that each parent element can have zero to one child elements as:



Relational Schema

Relation A(A1, A2)
Relation B(*A1, B1)

DTD

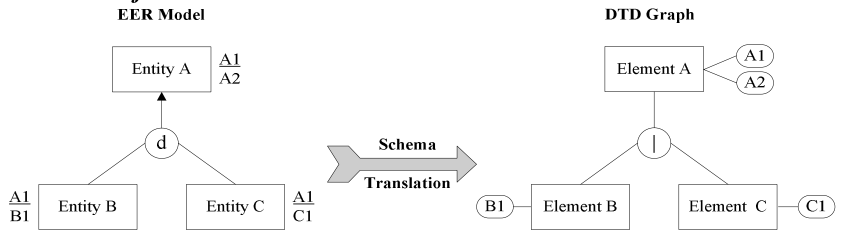
```
<!ELEMENT  A(B)?>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
```

Figure 3-49 Schema translation of ISA relationship

Rule 7: Mapping generalization from RDB to DTD

The generalization defines a relationship between entities to build a taxonomy of classes: One entity is a more general description of a set of other entities. In DTD, we transform the general superclass entity into an element, the element type originating from the superclass. For example, in Figure 3-50 and Figure 3-51, we present the generalization of entity B and entity C into entity A in DTD.

Case 1: Disjoint Generalization



Relational Schema

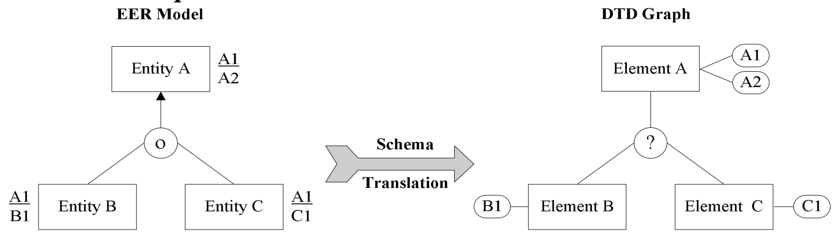
Relation A(A1, A2)
Relation B(*A1, B1)
Relation C(*A1, C1)

DTD

```
<!ELEMENT  A(B | C)>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ELEMENT  C EMPTY>
<!ATTLIST C C1 CDATA #REQUIRED>
```

Figure 3-50 Schema translation of disjoint generalization

Case 2: Overlap Generalization



Relational Schema

Relation A(A1, A2)
Relation B(*A1, B1)
Relation C(*A1, C1)

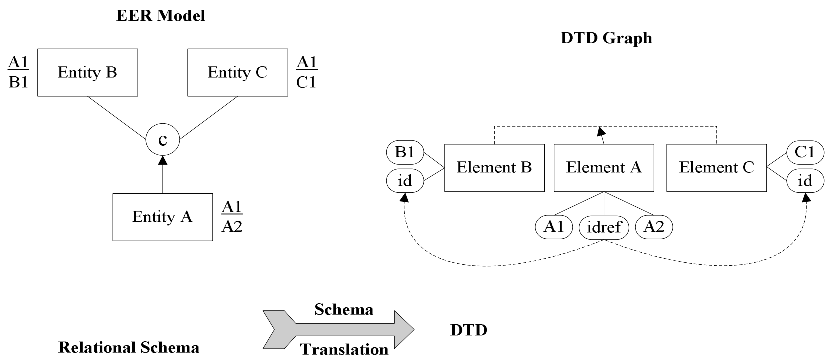
DTD

```
<!ELEMENT  A(B?, C?)>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT  B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ELEMENT  C EMPTY>
<!ATTLIST C C1 CDATA #REQUIRED>
```

Figure 3-51 Schema translation of overlap generalization

Rule 8: Mapping categorization from RDB to XML

A subclass table is a subset of a categorization of its superclass tables. In other words, a subclass table is a subset of a union superclass tables such that the data occurrence of a subclass table must appear in one and only one superclass table. In DTD, we transform the super classes into elements, and their common subclass into an element on the same level. Each element receives an additional "artificial" ID attribute declared as #REQUIRED referred by their common element's IDREF in DTD as shown in Figure 3-52.



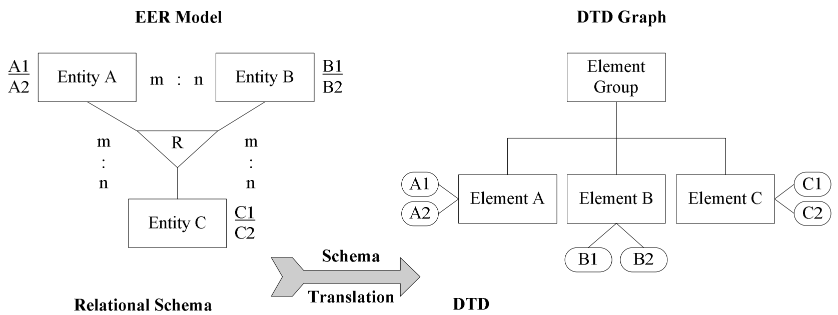
Relation B(A1, B1)
Relation C(A1, C1)
Relation A(*A1, A2)

```
<!ELEMENT B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B id ID #REQUIRED>
<!ELEMENT A EMPTY>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ATTLIST A idref IDREF #REQUIRED>
<!ELEMENT C EMPTY>
<!ATTLIST C C1 CDATA #REQUIRED>
<!ATTLIST C id ID #REQUIRED>
```

Figure 3-52 Schema translation of categorization

Rule 9: Mapping N-ary Relationship from RDB to XML

Multiple tables relate to each other in an n-ary relationship. An n-ary relationship is a relationship relation for multiple tables such that components of the former's compound primary key addressing to the primary keys of the latter, which are related to each other. In DTD, we transform n-ary relationship into group of element as shown in Figure 3-53.



Relational Schema

Relation A(A1, A2)
Relation B(B1, B2)
Relation C(C1, C2)
Relation R(*A1, *B1, *C1)

DTD

```
<!ELEMENT Group(A, B, C)>
<!ELEMENT A EMPTY>
<!ATTLIST A A1 CDATA #REQUIRED>
<!ATTLIST A A2 CDATA #REQUIRED>
<!ELEMENT B EMPTY>
<!ATTLIST B B1 CDATA #REQUIRED>
<!ATTLIST B B2 CDATA #REQUIRED>
<!ELEMENT C EMPTY>
<!ATTLIST C C1 CDATA #REQUIRED>
<!ATTLIST C C2 CDATA #REQUIRED>
```

Figure 3-53 N-ary relationship: schema translation

3.8 CASE STUDY OF TRANSLATING A RELATIONAL SCHEMA TO A DOCUMENT TYPE DEFINITION

Consider a case study of a hospital database system. In this system, a patient can have many record folders. Each record folder can contain many different medical records of the patient. The AE, a ward, and an outpatient record can be generalized as a medical record. A country has many patients. A borrower of the record folder of the patient can be a department, a doctor or other hospital for their references or checking. Once a record folder is borrowed, a loan history is created to record the details about it. The relational schemas for this case study are shown below. *Notice that underlined and italic means primary key and * means foreign key.*

Relation Country	(Country_No, Country_Name)
Relation Patient	(HKID, Patient_Name, *Country_No)
Relation Record_Folder	(Folder_No, Location, *HKID)
Relation AE_Record	(*Medical_Rec_No, AE_No)
Relation Medical_Record	(Medical_Rec_No, Create_Date, Sub_Type *Folder_No)
Relation Borrower	(*Borrower_N, Borrower_Name)
Relation Borrow	(*Borrower_No,,*Folder_No)

Relation Loan_History	(*Borrower_No, *Folder_No, Loan_Date)
Relation Department	(Borrower_No ,Department_Name)
Relation Doctor	(Borrower_No, Doctor_Name)
Relation Other_Hospital	(Borrow_No, Hospital_Name)

By following the procedures that were mentioned before, we now translate this relational schema into DTD as shown below.

Step 1 - Reverse engineering relational schema into an EER model
By using the classification table, we can recover the EER model from the given relational schemas as shown in Figure 3-54.

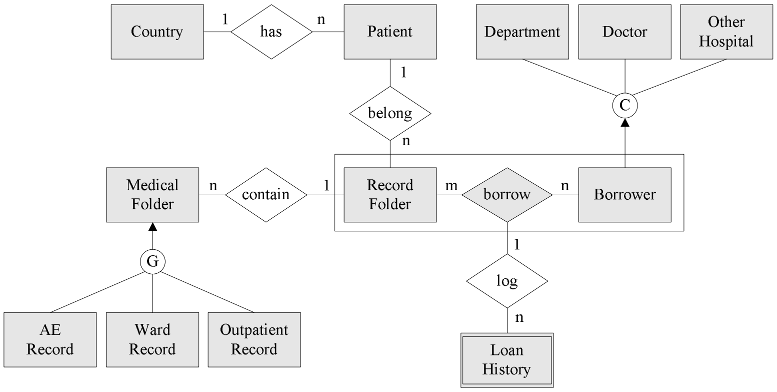


Figure 3-54 EER model for a hospital database system

Step 2.1 - Defining an XML View
In this case study, suppose we concern the patient medical records, so the entity Patient is selected. Then we define a meaningful name for the root element, called Patient_Records. All patients are under the root element as shown below.

XML Schemas (DTD):
<!ELEMENT Patient_Records (Patient)+>

We start from the entity Patient in the EER model and then find the relevant entities for it. The relevant entities include the related entities that are navigable from the parent entity. Entities Record Folder, Medical Record, and Borrow are considered relevant entities because they are navigable from the entity Patient. Since the relationship between the entity Patient and the entity Country is many-to-one, then the entity County is considered not navigable from the entity Patient according to our methodology. As a result, a DTD-graph that starts from the entity Patient is formed and shown in Figure 2-9 in Chapter 2.

Entity Patient is a direct child of the root element, Patient_Records. Since the entities Record Folder and Medical Record are navigable from the Patient entity, then we map all those entities into the elements of the XML DTD. We then define the attributes of those elements by using the definition of the relational schema as shown below:

Listing 1 Translated XML schema in DTD for relations Patient, Record_Folder, and Medical_Record

```
<!ELEMENT Patient_Records (Patient) +>
<!ELEMENT Patient (Record_Folder)>
<!ELEMENT Record_Folder (Medical_Record)>
<!ELEMENT Medical_Record EMPTY>
<!ATTLIST Patient HKID CDATA #REQUIRED>
<!ATTLIST Patient Patient_Name CDATA #REQUIRED>
<!ATTLIST Patient Country_Code CDATA #REQUIRED>
<!ATTLIST Record_Folder Folder_No CDATA #REQUIRED>
<!ATTLIST Record_Folder Location CDATA #REQUIRED>
<!ATTLIST Record_Folder HKID CDATA #REQUIRED>
<!ATTLIST Medical_Record Medical_Rec_No CDATA #REQUIRED>
<!ATTLIST Medical_Record Create_Date CDATA #REQUIRED>
<!ATTLIST Medical_Record Sub_Type CDATA #REQUIRED>
<!ATTLIST Medical_Record Folder_No CDATA #REQUIRED>
```

Step 2.2 - Mapping weak entity into content model.
It is not applicable in this step.

Step 2.3 - Mapping participation into content model.
The relationship between the entities Patient and the Record Folder is total participation. The relationship between the entities Record Folder and the Medical Record is also in total participation. Therefore, the content model of the XML schema is translated as shown below. *Notice that all foreign keys in relational schema will not be mapped into XML DTD because they will be represented in containment or ID and IDREF.*

Listing 2 Translated XML Schema for relations Patient, Record_Folder and Medical_Record:

--

```
<!ELEMENT Patient (Record_Folder*)>
<!ELEMENT Record_Folder (Medical_Record*)>
<!ELEMENT Medical_Record EMPTY>
<!ATTLIST Patient HKID CDATA #REQUIRED>
<!ATTLIST Patient Patient_Name CDATA #REQUIRED>
```

```
<!ATTLIST Patient Country_Code CDATA #REQUIRED>
<!ATTLIST Record_Folder Folder_No CDATA #REQUIRED>
<!ATTLIST Record_Folder Location CDATA #REQUIRED>
<!ATTLIST Medical_Record Medical_Rec_No CDATA #REQUIRED>
<!ATTLIST Medical_Record Create_Date CDATA #REQUIRED>
<!ATTLIST Medical_Record Sub_Type CDATA #REQUIRED>
```

Step 2.4 - Mapping cardinality into content model.
The relationship between entities Borrower and entity Record_Folder is in many-to-many cardinality. It is because a borrower can borrow many record folders and a record folder can be borrowed by many borrowers. In this many-to-many cardinality, we will not include the relationship between entities borrow and borrower since they are in a many-to-one relationship. The translated DTD together with the many-to-many relationship is shown below:

Listing 3 Translated XML schema for relations Record_Folder and Borrow

```
<!ELEMENT Record_Folder (Borrow*, Medical_Record*)>
<!ELEMENT Medical_Record EMPTY>
<!ELEMENT Borrow EMPTY>
<!ATTLIST Borrow Borrower_No CDATA #REQUIRED>
```

Since the entity Loan_History is also navigable from the Borrow entity and they are in a one-to-many relationship, so the modified XML schema will be:

Listing 4 Translated XML Schema for relation Loan_History

```
<!ELEMENT Borrow (Loan_History*)>
<!ELEMENT Loan_History EMPTY>
<!ATTLIST Loan_History Folder_No CDATA #REQUIRED>
<!ATTLIST Loan_History Loan_Date CDATA #REQUIRED>
```

Step 2.5 - Mapping aggregation into content model.
It is not applicable in this case study.

Step 2.6 - Mapping ISA into content model.
It is not applicable in this case study.

Step 2.7 - Mapping generalization into content model.
Since the medical record can be an AE, a ward or an outpatient record, so it is a disjoint generalization. Then the translated DTD for the entity

Listing 5 Translated XML schema for relations Medical_Record, AE_Record, Ward_Record, and Outpatient_Record

```
<!ELEMENT Medical_Record (AE | Ward | Outpatient)>
<!ATTLIST Medical_Record Medical_Rec_No CDATA #REQUIRED>
<!ATTLIST Medical_Record Create_Date CDATA #REQUIRED>
<!ATTLIST Medical_Record Sub_Type CDATA #REQUIRED>
<!ELEMENT AE EMPTY>
<!ATTLIST AE AE_No CDATA #REQUIRED>
<!ELEMENT Ward EMPTY>
<!ATTLIST Ward Ward_No CDATA #REQUIRED>
<!ATTLIST Ward Admission_Date CDATA #REQUIRED>
<!ATTLIST Ward Discharge_Date CDATA #REQUIRED>
<!ELEMENT Outpatient EMPTY>
<!ATTLIST Outpatient Outpatient_No CDATA #REQUIRED>
<!ATTLIST Outpatient Specialty CDATA #REQUIRED>
```

Step 2.8 - Mapping categorization into content model.
Although there is a categorization in this case study, it is not navigable from the entity Patient. Thus it is not applicable.

Step 2.9 - Mapping N-ary relationship into content model.
It is not applicable in this case study.

As a result, the final XML DTD is shown in Listing 6.

Listing 6 Patient Records DTD

```
<!ELEMENT Patient_Records (Patient+)>
<!ELEMENT Patient (Record_Folder*)>
<!ATTLIST Patient
        HKID                    CDATA           #REQUIRED
        Patient_Name            CDATA           #REQUIRED>
        Country_No              CDATA           #REQUIRED
<!ELEMENT Record_Folder (Borrow*, Medical_Record*)>
<!ATTLIST Record_Folder
        Folder_No               CDATA           #REQUIRED
        Location                CDATA           #REQUIRED
<!ELEMENT Borrow (Loan_History*)>
<!ATTLIST Borrow
        Borrower_No             CDATA           #REQUIRED>
<!ELEMENT Loan_History EMPTY>
<!ATTLIST Loan_History
        Loan_Date               CDATA           #REQUIRED>
```

```
<!ELEMENT    Medical_Record    (AE_Record    |    Outpatient_Record    |
Ward_Record)>
<!ATTLIST Medical_Record
        Medical_Rec_No            CDATA          #REQUIRED
        Create_Date               CDATA          #REQUIRED
        Sub_Type                  CDATA          #REQUIRED>
<!ELEMENT AE_Record EMPTY>
<!ATTLIST AE_Record
        AE_No                     CDATA          #REQUIRED>
<!ELEMENT Outpatient_Record EMPTY>
<!ATTLIST Outpatient_Record
        Outpatient_No             CDATA          #REQUIRED
        Specialty                 CDATA          #REQUIRED>
<!ELEMENT Ward_Record EMPTY>
<!ATTLIST Ward_Record
Ward_No                           CDATA          #REQUIRED>
        Admission_Date            CDATA          #REQUIRED
         Discharge_Date           CDATA          #REQUIRED
```

3.9 TRANSLATING A RELATIONAL SCHEMA TO AN XML SCHEMA DEFINITION

We can also translate a relational schema into an XML Schema Definition (XSD). Like DTD, an XSD is also an XML logical schema, and it has more features than DTD. The translation process is also very similar to Section 3.7. As shown in Section 3.7, the three processes of mapping relational schema into an XSD are through an EER model and XSD Graph as follows (Fong and Cheung, 2005).

Step 1 - Reverse engineering a relational schema into an EER model.
Same as in the step 1 of section 3.7.

Step 2 - Reengineering an EER model to an XSD Graph:
The transformation between an EER model and an XSD Graph is a semantic-based methodology. The transformation consists of the following nine rules outlining the basic framework between the EER model and the XSD Graph. The steps are defined for capturing relationships and constraints among entities. Besides mapping an EER model to an XSD Graph, we preserve the data semantics of the source relational schema in a target XSD in a hierarchical tree model.

Rule 1: Define an XML view in XSD

Similar to rule 1 in Section 3.7, we can abstract an XML view of EER model upon user supervision into an XML tree as shown in Figure 3-55.

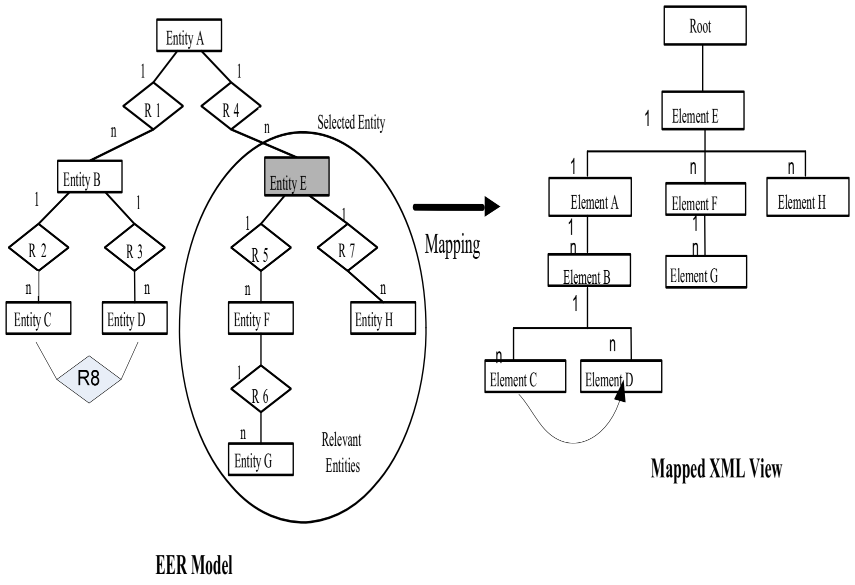
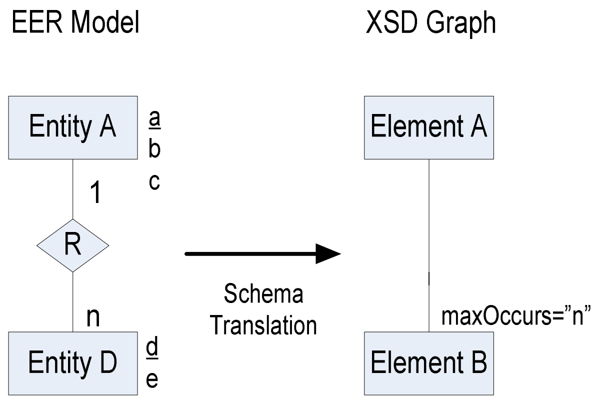


Figure 3-55 Map selected entities in EER model into an XML tree

Rule 2 Mapping foreign key from RDB to XSD

The “Entities” and “Attributes” of the EER model are represented as Elements and Attributes of an XML model. We use the sub-element for applying the cardinality primitive in the XML model. If we find the multi-valued attributes, we place them as sub-elements with “maxOccurs = unbounded” in the XSD. In an XML model, a unique attribute can be represented as a “key”. Thus, the primary key of an EER model is presented by a <key> tag in the XML model. A foreign key d is eliminated in the translated XSD because the foreign key between a parent relation and child relations in the relational schema is mapped into the hierarchical structure between a parent element and its child elements in an XSD. See Figure 3-56.



Relational Schema

PR1: Relation A (a, b, c, *d)
PR2: Relation D (d, e)

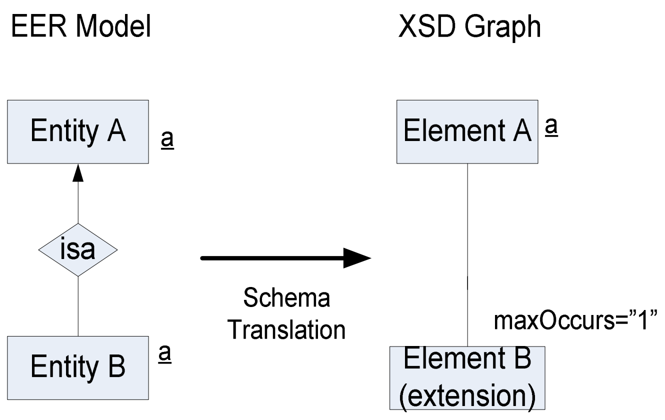
XSD

```
<xs:element name = "A">
        <xs:attribute name = "a", type="xs:string"/>
        <xs:attribute name = "b", type="xs:string"/>
        <xs:attribute name = "c", type="xs:string"/>
        <xs:element name = "D">
                <xs:attribute name = "d", type="xs:string"/>
                <xs:attribute name = "e", type="xs:string"/>
        <xs:element>
<xs:element>
```

Figure 3-56 Map a foreign key into parent child elements in XSD

Rule 3 Mapping Isa Relationship from RDB to XSD

The relationship between the sub-type and super-type is an "isa" relationship. When we map an EER model to an XSD Graph, we can use the "extension" tag for the "isa" relationship. The "complexType" feature can be applied for this primitive in the XML model. The child "complexType" inherits properties of the parent "complexType" by applying the "extension" tag on the child definition. Its attributes can be added on to complete the "complexType" definition. See Figure 3-57.



Relational Schema

PR1: Relation A (a, ….)
PR2: Relation B (*a, b,...)

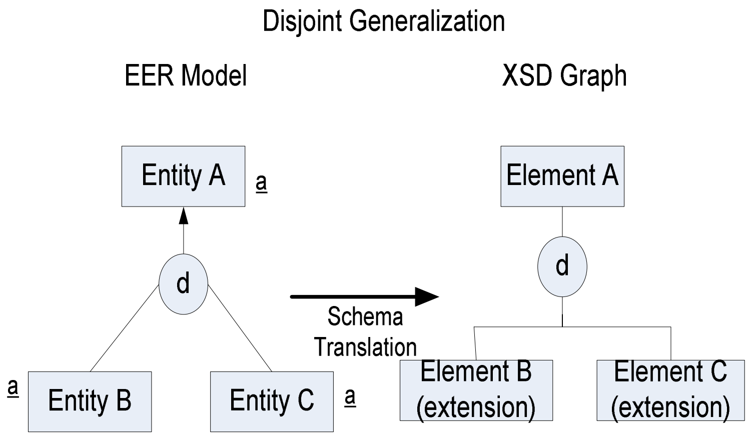
XSD

```
<xs:element name = “b” type=”b_type”/>
<xs:complexType name=”b_type”>
        <xs:extension base=”a”/>
</xs:complexType>
<xs:complexType name=”a”>
        <xs:element name=”name” type=”xs:string”/>
</xs:complexType>
```

Figure 3-57 Map isa relationship into element extension in XSD

Rule 4. Mapping of Generalization from RDB to XSD

Generalization is a concept that some entities are subtypes of other entities. The disjoint generalization is mapped into a complex element such that its component elements are mutually exclusive by a "choice" keyword. The overlap generalization is mapped into a complex element such that its component elements are mutually inclusive. See Figure 3-58.

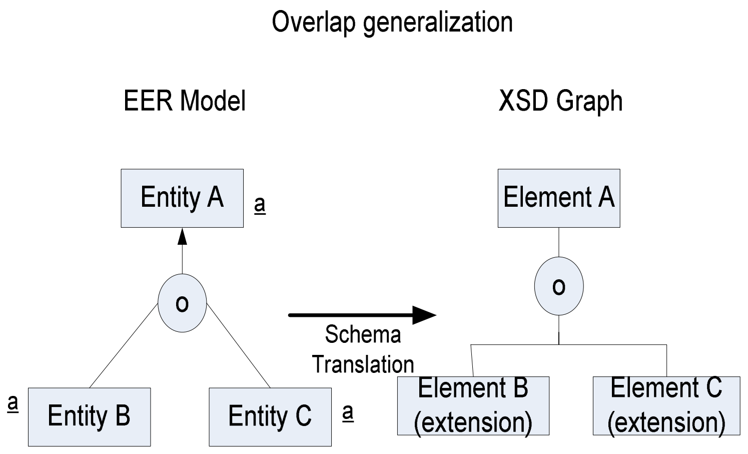


Relational Schema

PR1: Relation A (a, ….)
PR2: Relation B (*a, b,...)
PR2: Relation C (*a, c,...)

XSD

```
<xs:element name = “A”>
<xs:choice>
      <xs:element ref=”b”/>
      <xs:element ref=”c”/>
</xs:choice>
<xs:element name=”a_name” type=”xs:string”/>
<xs:element>
</xs:element name=”b” type=”b_type”/>
<xs:complexType name=”b_type”>
            <xs:extension base=”a”/>
</xs:complexType>
</xs:element name=”c” type=”c_type”/>
<xs:complexType name=”c_type”>
            <xs:extension base=”a”/>
</xs:complexType>
<xs:complexType name=”a”>
             <xs:element name=”a_name” type=”xs:string”/>
</xs:complexType>
```



Relational Schema

PR1: Relation A (<u>a</u>, ….)
PR2: Relation B (*<u>a</u>, b,...)
PR2: Relation C (*<u>a</u>, c,...)

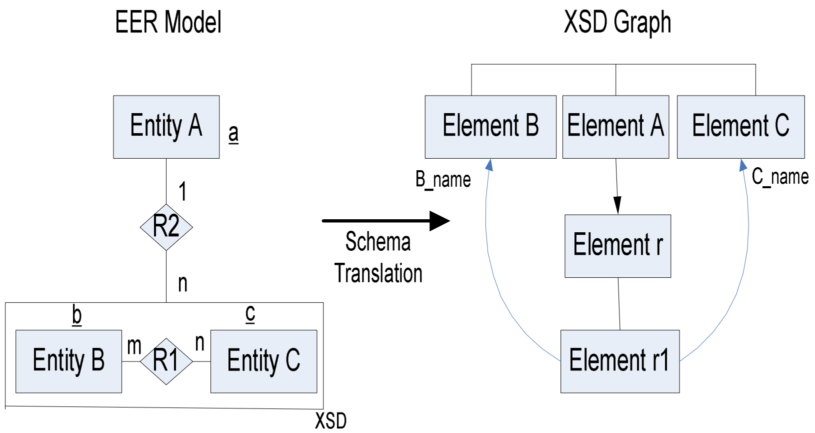
XSD

```
<xs:element name = “A”>
        <xs:element ref=”b”/>
        <xs:element ref=”c”/>
        <xs:element name=”a_name” type=”string”/>
<xs:element>
</xs:element name=”b” type=”b_type”/>
<xs:complexType name=”b_type”>
            <xs:extension base=”a”/>
</xs:complexType>
</xs:element name=”c” type=”c_type”/>
<xs:complexType name=”c_type”>
            <xs:extension base=”a”/>
</xs:complexType>
<xs:complexType name=”a”>
             <xs:element name=”a_name” type=”xs:string”/>
</xs:complexType>
```

Figure 3-58 Map generalization into multiple references of a complex element in XSD

Rule 5. Mapping of aggregation from RDB to XSD

An aggregation is an abstraction through which relationships are treated as higher-level entities. In an XML schema, the transformation of the aggregation is to group child elements under a parent element. In the whole-class element definition, the part-class element is included in the attribute list of the whole-class by using the “ref” keyword for the type parameter. See Figure 3-59.



XSD

```
<xs:element name = "b">
      <xs:attribute name="b_name" type="xs:string"/>
</xs:element>
<xs:element name = "c">
      <xs:attribute name="c_name" type="xs:string"/>
</xs:element>
<xs:element name = "r">
          <xs:element name="r1" minOccurs="1" maxOccurs="unbounded">
                 <xs:element ref="b"/>
                 <xs:element ref="c"/>
          </xs:element>
</xs:element>
<xs:element name="a">
     <xs:element ref="r" minOccurs="1" maxOccurs="unbounded">
</xs:element>
```

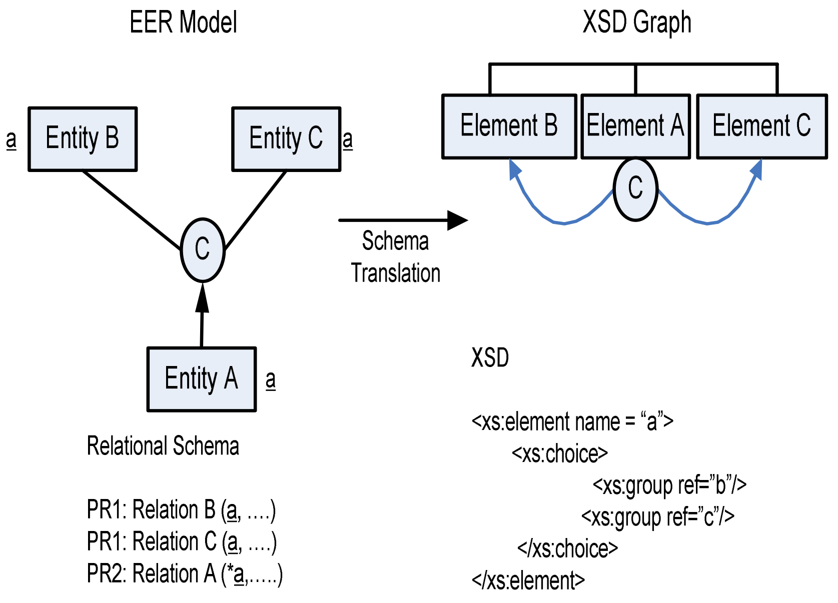
Relational Schema

PR1: Relation A (a, ...)
PR1: Relation B (b, ...)
PR1: Relation C (c, ...)
SR1: Relation R1(*b, *c, .*a)

Figure 3-59 Map aggregation into a complex element sequence in XSD

Rule 6. Mapping of categorization from RDB to XSD

A categorization is a relationship in connection with multiple superclass elements and one subclass element. The key in the subclass element instance must refer to one of the superclass elements. By using the "choice" keyword for making a constraint, this primitive can be functioned in an XSD. Either element B or element C must appear as a superclass in the subclass element A. We use the "group" feature for defining the properties on the element side. See Figure 3-60.



PR1: Relation B (a, ...)
PR1: Relation C (a, ...)
PR2: Relation A (*a,.....)

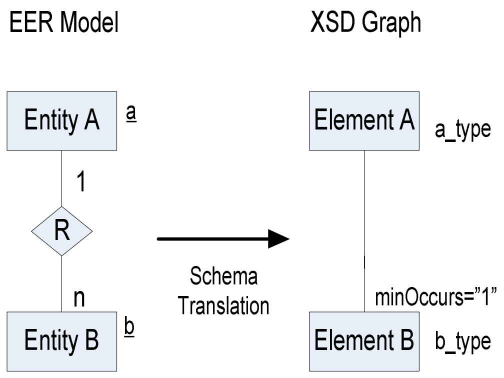
```
<xs:element name = "a">
      <xs:choice>
                  <xs:group ref="b"/>
                <xs:group ref="c"/>
       </xs:choice>
</xs:element>
```

Figure 3-60 Map categorization into a complex element choice in XSD

Rule 7. Mapping of participation from RDB to XSD

The partial and total participations can be used for distinguishing two types of relationships between parent and child entities. A total participation means a mandatory relationship between parent and child elements. In an XSD, there is a more flexible way to maintain the referential integrity by using an attribute group, element group, or global element with "minOccurs" and "maxOccurs". See Figure 3-61.

Total Participation



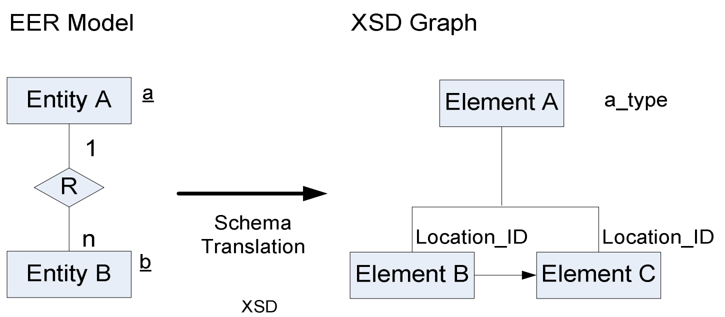
Relational Schema

PR1: Relation A (a,….)
PR1: Relation B (b, ...*a)
Where *a is without null value

XSD

```
<xs:element name = “a”>
        <xs:attribute name = “b”, minOccurs=”1" maxOccurs=”unbounded”>
        <xs:attribute name = “a_type”, type=”xs:string”/>
        <xs:element>
                <xs:attribute name = “a_type”, type=”xs:string”/>
</xs:element>
```

Partial Participation



XSD

Relational Schema

PR1: Relation A (a,….)
PR1: Relation B (b, ...*a)
Where *a is with null value

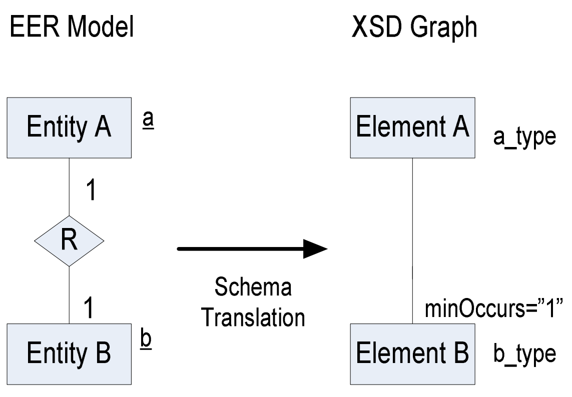
```
<xs:element name = “root”>
         <xs:element name = “b”>
             <xs:attribute name = “locationID”/>
         </xs:element>
         <xs:element name = “a”>
             <xs:attribute name = “locationID”/>
         </xs:element>
         <xs:keyref name=”atobRef” refer=”atobKey”>
                  <xs:selector xpath=”b”/>
                  <xs:field xpath=”@locationID”/>
                  </xs:keyref>
                  <xs:keref name=”atobKey”>
                  <xs:selector xpath=”a”/>
                  <xs:field xpath=”@locationID”/>
                  </xs:key>
</xs:element>
```

Figure 3-61 Map participation into a parent child relationship in XSD

Rule 8. Mapping of cardinality from RDB to XSD

We capture 1:1, 1:n, and m:n cardinalities in this step. A cardinality in the XSD Graph is represented as a sub-element or a global element. The name of the associating element is the association name in a m:n relationship. The associating element could be treated as a pointer referring to the associated elements and is assisted by the keyword of "minOccurs" defined on the element declaration. If an element is referred to by two or many elements, it is treated as a global element in the 1:1 and 1:n cardinalities. See Figure 3-62.

One-to-one cardinality



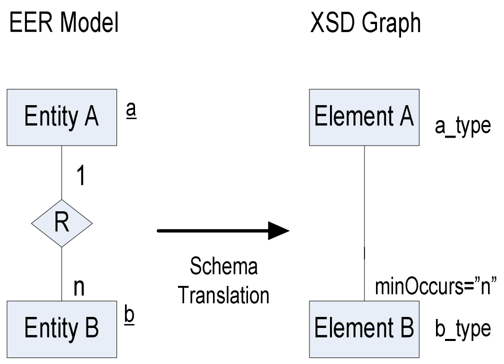
Relational Schema

PR1: Relation A (a,….)
PR1: Relation B (b, ...*a)

XSD

```
<xs:element name = "a">
        <xs:attribute name = "b", minOccurs="1" maxOccurs="1">
        <xs:attribute name = "a_type", type="xs:string"/>
        <xs:element>
                <xs:attribute name = "a_type", type="xs:string"/>
</xs:element>
```

One-to-many cardinality



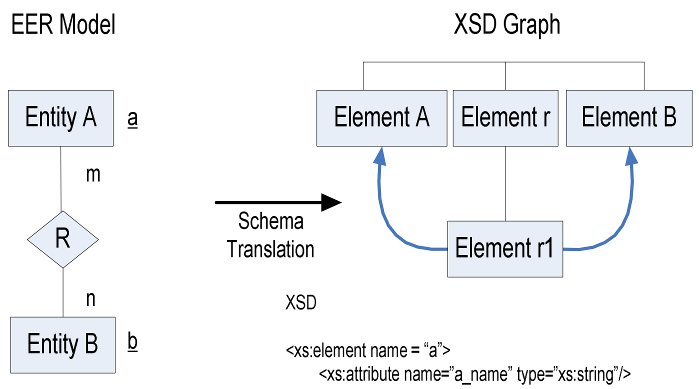
Relational Schema

PR1: Relation A (a,....)
PR1: Relation B (b, ...*a)

XSD

```
<xs:element name = "a">
        <xs:attribute name = "b", minOccurs="1" maxOccurs="unbounded">
          <xs:attribute name = "a_type", type="xs:string"/>
        </xs:element>
<xs:element>
```

Many-to-many cardinality



Relational Schema

PR1: Relation A (a, ...)
PR1: Relation B (b, ...)
SR1: Relation C (*a, *b,.....)

XSD

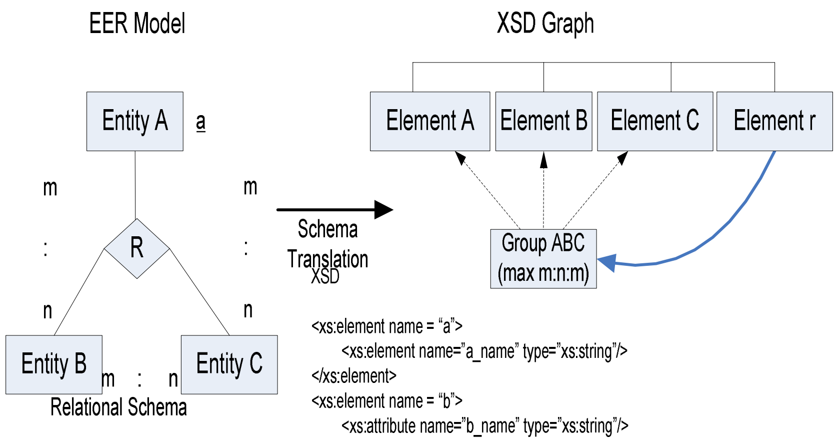
```
<xs:element name = "a">
    <xs:attribute name="a_name" type="xs:string"/>
</xs:element>
<xs:element name = "b">
    <xs:attribute name="b_name" type="xs:string"/>
</xs:element>
<xs:element="r">
     </xs:element name="r1" minOccurs="1" maxOccurs="unbounded">
               <xs:element ref="a">
               <xs:element ref="b">
        </xs:element>
</xs:element>
```

Figure 3-62 Map cardinality into the parent child elements in XSD

Rule 9. Mapping of n-ary relationship from RDB to XSD

We apply the concept of a ternary relationship from an EER model into an XSD Graph. The relationship relation is placed at the centre of three related relations in an EER diagram. In the XSD Graph, the three related relations are mapped into three associated elements. The relationship relation is mapped into a "group element" function. The occurrences of the associated elements depend on the cardinality between the related relations and the relationship relation. Therefore, mapping relations into the XSD Graph is performed according to the "minOccurs" and "maxOccurs" keywords with occurrences specification.

Ternary in Many-to-many cardinality



Relational Schema

PR1: Relation A (a, ...)
PR1: Relation B (b, ...)
PR1: Relation C (c,.....)
SR1: Relation R (*a, *b, *c)

```
<xs:element name = "a">
     <xs:element name="a_name" type="xs:string"/>
</xs:element>
<xs:element name = "b">
     <xs:attribute name="b_name" type="xs:string"/>
</xs:element>
<xs:element name = "c">
     <xs:attribute name="c_name" type="xs:string"/>
</xs:element>
<xs:element name="r">
      <xs:group ref="groupABC"/>
 <xs:element>
<xs:group name="groupABC">
          <xs:element name="group_a" maxOccurs="unbounded">
                    <xs:element ref="a"/>
                    <xs:element name="group_b" maxOccurs="unbounded">
                       <xs:element ref="b"/>
                        <xs:element name="group_c" maxOccurs="unbounded">
                           <xs:element ref="c"/>
          </xs:element>
</xs:element>
</xs:element>
```

Figure 3-63 Map n-ary relationship into a group element in XSD

3.10 SUMMARY

Schema translation is the first step of database reengineering. Direct mapping a logical schema from one model to another may not be able to capture all the original schema semantics. With user help in an knowledge engineering approach, we could recover the lost semantics by mapping logical network schema or hierarchical schema to the EER model. Such process is called reverse engineering. We can then map the EER model to another logical schema such as relational schema in forward engineering. Similarly, we can map relational schema into an object-oriented or XML schema. The knowledge engineering approach is to abstract primitive semantics such as parent-child relationships in the data structure of the hierarchical or network database from the DDL, and confirm the advanced semantics such as generalization, categorization and aggregation from the users.

Similarly, we can map relational schema to the EER model in reverse engineering with users assistance to recover the lost semantics. The process is to make use of the various keys in the existing relation, for example, primary keys, foreign keys, composite keys, and the components of the composite keys. These keys, along with the inclusion dependencies, the constraints of the relations, can be used to reconstruct primitive semantics of the schema. For the advanced semantics, users inputs are also needed. Once the EER model is reconstructed, we can then map the EER model to the UML model, a conceptual model for an object-oriented database, in forward engineering. From the UML model, we can map to an object-oriented database schema.. Similarly, we can map an EER model into a DTD Graph or XSD Graph.

The translation from an XML view of relational schema into an XML schema can be accomplished by recovering data semantics from relational schema into its conceptual schema in extended entity relationship model. Once these constraints are defined, we can select relations that can represent the XML view from the relational schema. The other relevant relations can also be extracted according to the one-to-many and superclass-to-subclass navigability of the XML tree. Together these relations are then mapped into the XML conceptual schema in DTD Graph, and then to DTD. The DTD Graph and DTD are XML schemas but in diagram form for DTD Graph as XML conceptual schema and in text form for DTD as XML logical schema.

Similarly, we can also map relational schema into an XSD and XSD Graph. The XSD and XSD Graph not only have the same functions as the DTD and DTD Graph, but also are richer in features and are more adaptable in the industry.

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Funderburk, J. E., Kierman, G., Shanmugasundaram, J., Shekita, E., and Wei, C. (2002) XTABLES: Bridging Relational technology and XML, IBM Systems Journal, Volume 41, No 4, page(s): 616-641.

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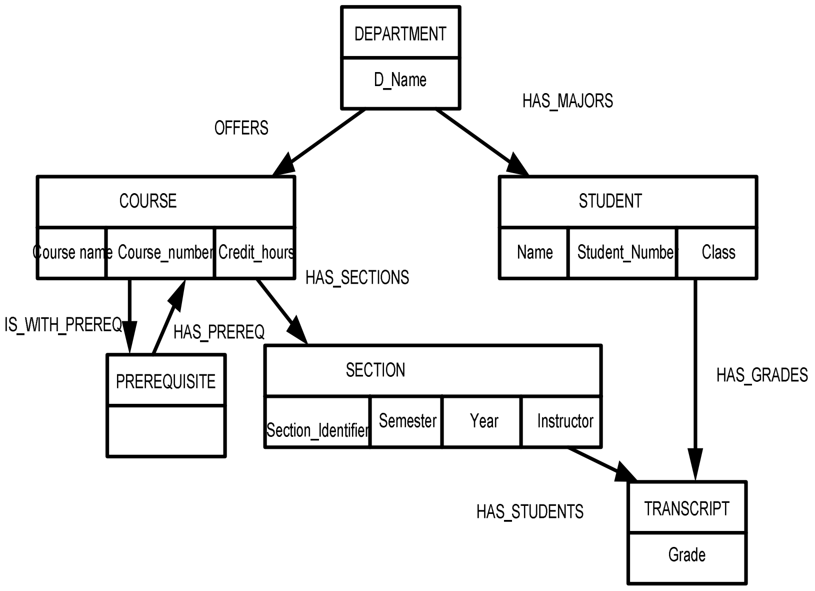
Zaniolo, C. (1979) Design of Relational Views Over Network Schemas, Proceedings of ACM SIGMOD 79 Conference, pp179-190.

QUESTIONS

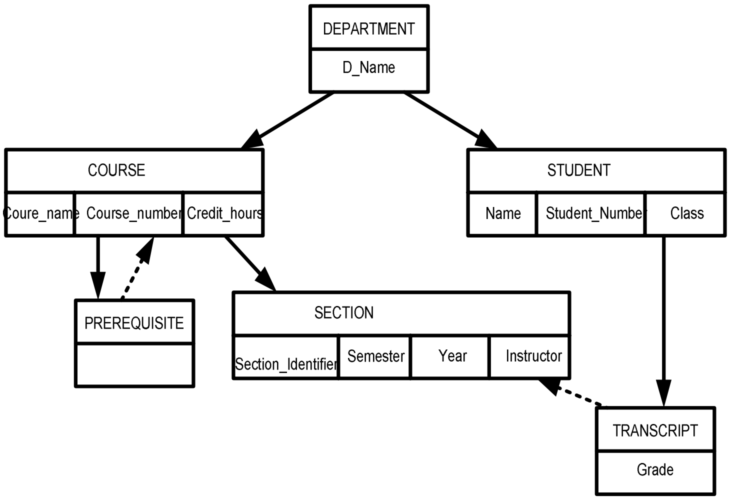
Question 3-1

Translate the following network database schema to network database DDL.



Question 3-2

Translate the following hierarchical database schema to network database DDL and also into a relational schema.



Question 3-3

How can one compare the abstract level of the EER model and UML, and the features of a relational database and object-oriented database?

Question 3-4

(a) Show the steps needed in designing an entity-relationship model. What are the steps of mapping an extended entity relationship model into a relational model.

(b) Consider a case study with the following business requirements and relational database:

- A company has two regions, A and B.
- Each region forms its own departments.
- Each department approves many trips in a year.
- Each staff makes many trips in a year.
- In each trip, a staff needs to hire cars for transportation.
- Each hired car can carry many staff for each trip.
- A staff can be either a manager or an engineer.

The data requirements are:

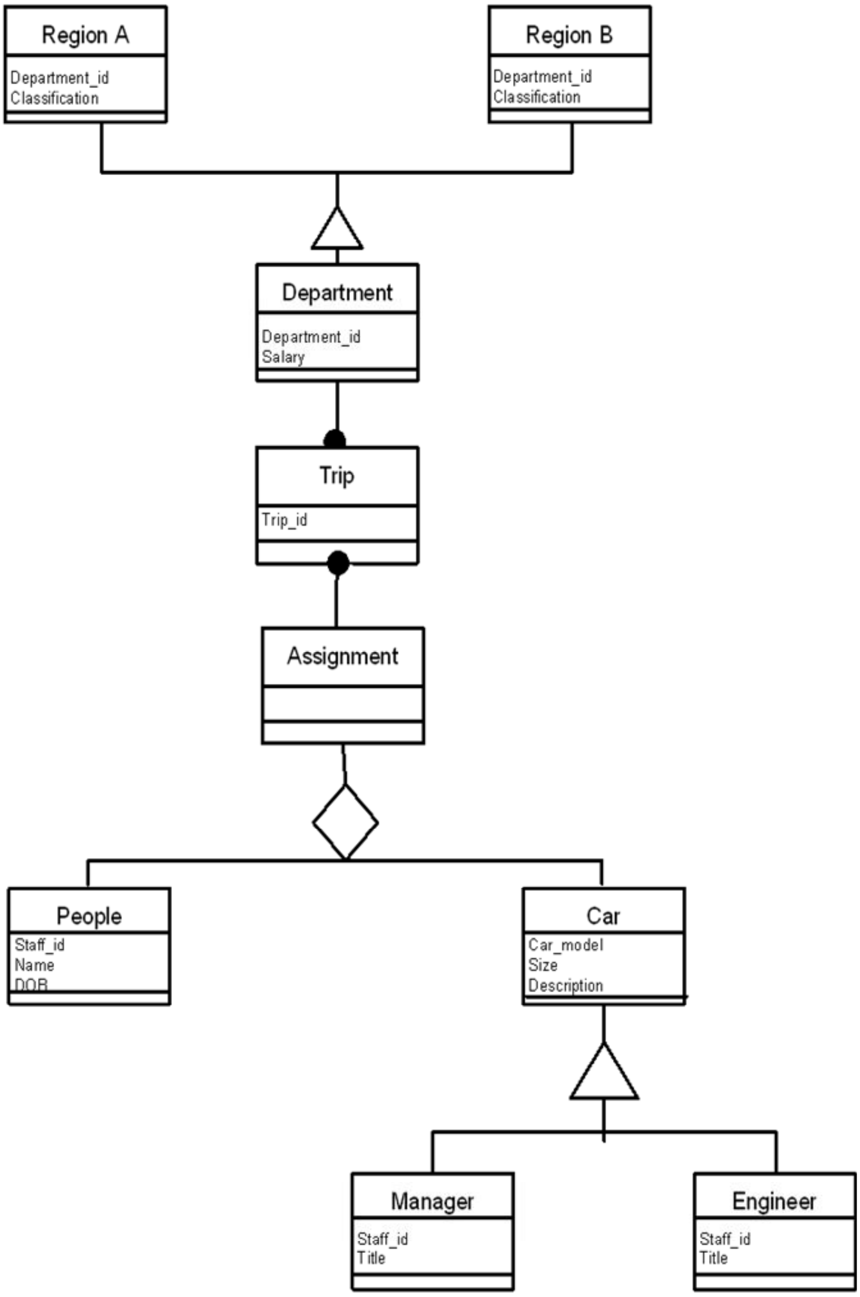
Data field	Description
Department_id	The identity number of department
Salary	The salary of department staff
Classification	The classification of regional office
Trip_id	The identity of each business trip by department staff
Car_model	The model of the car rented by staff during the business trip
Staff_id	The identity number of department staff
Name	The name of the staff who rent the car during business trip
DOB	Date of birth of department staff
Size	The size of the car rented by department staff for business trip
Description	Description of the car rented by department staff on business trip
Title	The job title of department staff on business trip

Based on the user and data requirement, design an extended entity relationship model to meet these requirements.

Question 3-5

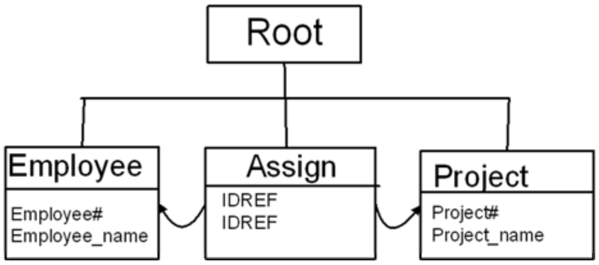
(a) What are the steps of mapping Unified Modeling Language into an object-oriented schema?

(b) Map the following Unified Modeling Language into an object-oriented schema:



Question 3-6
What is data type definition graph? How can one compare a data type definition graph with Extended Entity Relationship model?

Question 3-7
Show the steps of translating the following data type definition graph into data type definition?



Question 3-8
Translate the following relational schema into an XML schema definition such that the selected XML view is called "Factory" and the relevant relations under the root are relation Category and the other navigable relations.
Relational Schemas:
RELATION category (<u>item_code</u>, name, descript)
RELATION feature (<u>name</u>, descript, multivalue, *cate_id,)
RELATION featurevalue (<u>value_id</u>, value, *name)
RELATION catalogitem (<u>item_no</u>, cata_name, descript)
RELATION part (<u>item_no</u>, parttype)
RELATION supplier (*<u>item_no</u>, name, address)
RELATION catalog (<u>item_code</u>, name, descript, startdate, enddate)
RELATION productbundle (*Item_no, name, descript)
RELATION product (*<u>Item_code</u>, descript, url, *item_no)
RELATION service (*<u>Item_code</u>, descript, unitoftime)
RELATION unitoftime (<u>time_code</u>, name, hour, day, week, month, year)
RELATION resource (<u>item</u>, loc, name, *Item_code)
RELATION cat (*<u>item_code,</u> *<u>name</u>)

Where underlined words are primary key and words with"*" prefixes are foreign keys.

CHAPTER 4

DATA CONVERSION

The objective of data conversion is to convert between database systems without any loss of information. The data conversion process must transform the data from one data structure to another whilst preserving its semantics. Data conversion uses the data structure of the schema that results from schema translation.

As the relational model, object-oriented, and XML models become more popular, there is a need to convert production nonrelational databases to relational databases, and from relational databases to object-oriented databases and XML databases, i.e., XML documents stored in a native XML database or XML enabled database, to improve productivity and flexibility. The changeover includes schema translation, data conversion, and program translation. The schema translation consists of static data structure transformation from nonrelational to relational schema or from relational database schema to an object-oriented or an XML schema. This chapter describes a data conversion methodology to unload production nonrelational or a relational database to sequential files, and then upload them into a relational, object-oriented, or XML database. There are basically four techniques in data conversion: customized program, interpretive transformer, translator generator, and logical level translation. These are described in the following sections.

4.1 CUSTOMIZED PROGRAM APPROACH

A common approach to data conversion is to develop customized programs to transfer data from one environment to another (Fry et al., 1978). However, the customized program approach is very expensive because it requires a different program to be written for each M source file and N target, which sums up as m × n programs for all of them. Furthermore, these programs are used only once. As a result, totally depending on customized program for data conversion is unmanageable, too costly, and time consuming.

4.2 *INTERPRETIVE TRANSFORMER APPROACH*

An interpretive transformer accepts a source definition, a target definition and a mapping definition, and then maps the stored data from the source to the target database (Lochovsky & Tsichritzis,1982) as shown in Figure 4-1.

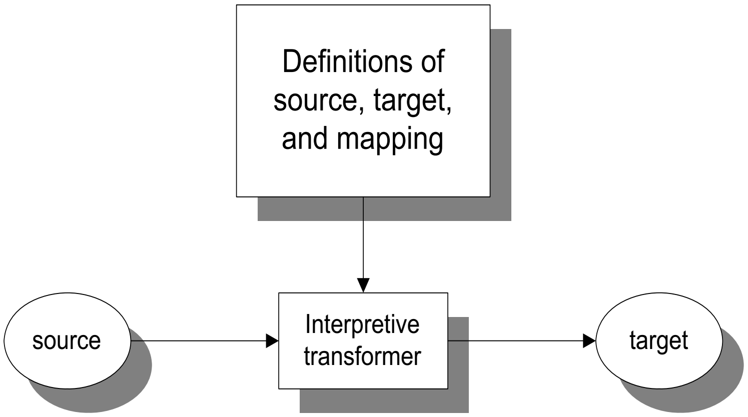


Figure 4-1 Interpretive transformer

Suppose that the database of a source nonrelational schema S_s is mapped to a target relational schema S_t. There are three distinct processes in this approach. One process accesses the source data (reading). Another process performs logical transformations on the data to place it into an internal form. A third process creates the target data (writing).

For example, Fry et al (1978) describe a method that uses two specialized languages, the Stored Data Definition Language (SDDL) and the Translation Definition Language (TDL), to define the structure of the two databases and the source to target translation parameters. Using these definitions, a series of programs (refer to Figure 4-2) are used to perform the data conversion process.

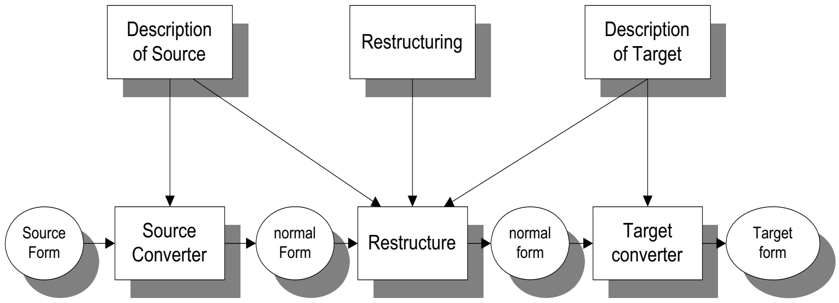


Figure 4-2 The general model for data translator

In order to separate the restructuring process from the source and target conversion function of the Translator, Normal Form of Data is introduced. A data structure expressed in the Normal Form will be viewed as a set of N-tuples of the form.

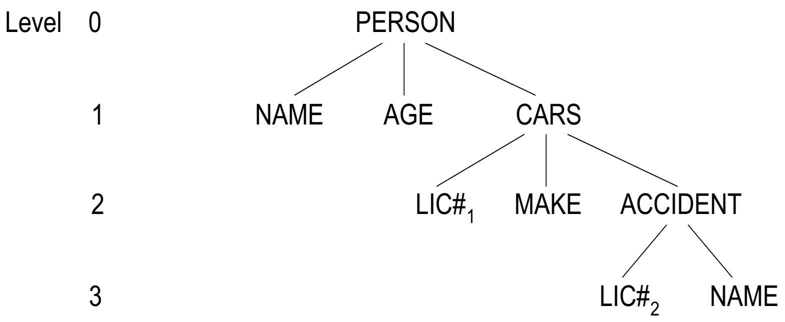
Ref-Name <Item, Item……>

The Normal Form presented here has two types of N-tuples: a data structure instance N-tuple and a relationship N-tuple.

The data structure instance N-tuple consists of the following: Data Structure Instance Name (Ref-Name), Identifier (unique), and Data Item(s).

The relationship N-tuple consists of: Relationship Name (Ref-Name) and Identifiers of all data instances involved in the relationship.

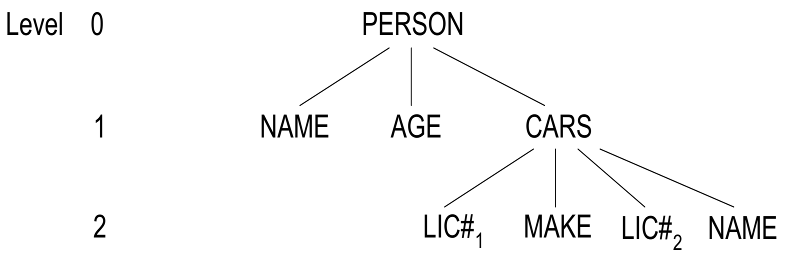
For instance, the following Cobol structure:



Can be expressed in using these SDDL statements:

Data Structure	PERSON <NAME, AGE>
Instance	CARS <LIC#$_1$, MAKE>
N-tuples	ACCIDENTS <LIC#$_2$, NAME>
Relationship	PERSON-CAR <NAME, LIC#$_1$>
N-tuples	CAR-ACCIDENT <LIC#$_1$, LIC#$_2$>

To translate the above three levels to the following two levels data structure:



The TDL statements are

```
FORM NAME FROM NAME
FORM LIC#1 FROM LIC#1
:
FORM PERSON IF PERSON
FORM CARS IF CAR AND ACCIDENT
```

There are many possible kinds of translation rules. The IF statement indicates the conditions that one might want to check while restructuring; for example, duplication and invalid values.

The data conversion problem can basically be resolved by available software tools. However, these tools are DBMS dependent and are supplied by the vendors only. A more generalized tool for data conversion is needed.

4.3 TRANSLATOR GENERATOR APPROACH

The translator reads the source definition, the target definition, and the mapping definition, and then generates a specialized program that will reformat and map the stored data from source to target as illustrated in Figure 4-3.

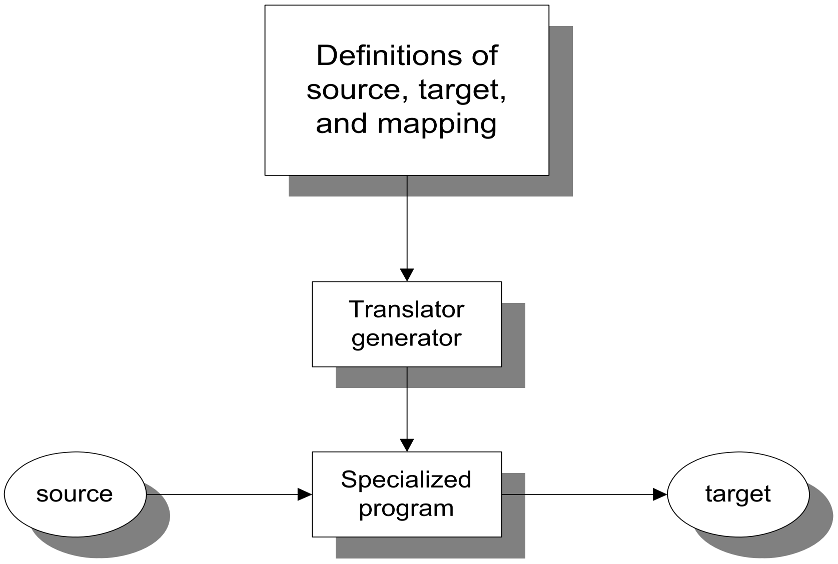


Figure 4-3 Translator generator

As in the case of the interpretive translator approach, two languages are used. One describes the source and target database file and the other describes the mapping between source and target database files. There are two phases to the translation process; the compile time phase and the run time phase. In the compile time phase, the specialized translator program is generated; in the run time phase, this program is executed.

For example, Shu et al. (1975) implemented EXPRESS, which can access a wide variety of data and restructure it for new uses by program generation techniques. The function of the EXPRESS system is to translate and execute the specification languages DEFINE and CONVERT. The DEFINE description is compiled into a customized PL/1 program for accessing source data. The restructuring specified in CONVERT is compiled into a set of customized PL/1 procedures to derive multiple target files from multiple input files. The general architecture of the DEFINE compile-time phase and the general architecture of the CONVERT compile-time system is shown in Figure 4-4.

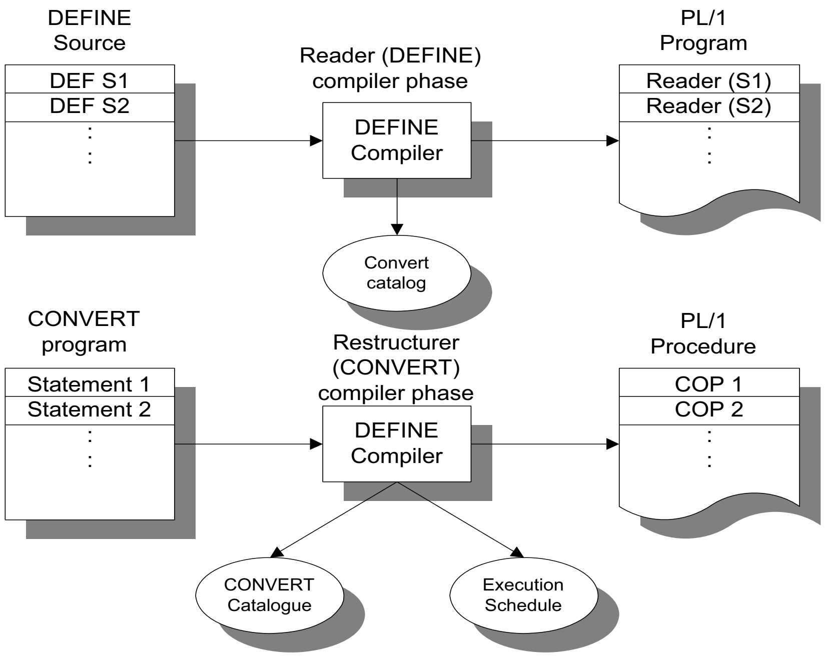


Figure 4-4 DEFINE and CONVERT compile phase

As an example, consider the following hierarchical database:

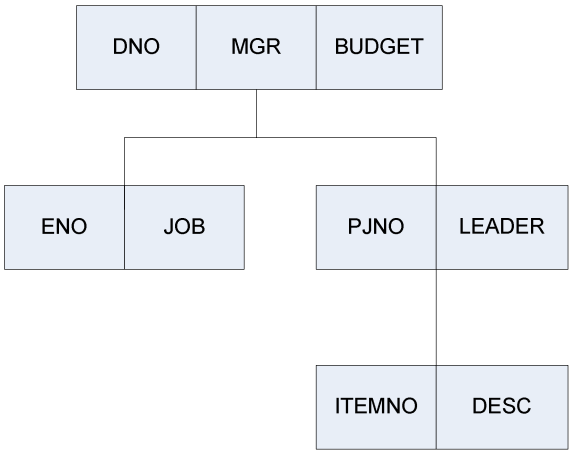


Figure 4-5 A sample hierarchical schema

Its DEFINE statements can be described in the following where for each DEFINE statement, code is generated to allocate a new subtree in the internal buffer.

```
GROUP DEPT:
    OCCURS FROM 1 TIMES;
    FOLLOWED BY EOF;
    PRECEDED BY HEX '01';
    :
    END EMP;
    GROUP PROJ:
            OCCURS FROM 0 TIMES;
            PRECEDED BY HEX '03';
    :
    END PROJ;
END DEPT;
```

For each user-written CONVERT statement, we can produce a customized program. Take the DEPT FORM from the above DEFINE statement:

```
T1 = SELECT (FROM DEPT WHERE BUDGET GT '100');
```

will produce the following program:

```
/* PROCESS LOOP FOR T1 */
DO WHILE (not end of file);
    CALL GET (DEPT);
    IF BUDGET > '100'
            THEN CALL BUFFER_SWAP (T1, DEPT);
END
```

However, this approach is proprietary, language oriented (not user friendly), and too expensive to adopt.

4.4 LOGICAL LEVEL TRANSLATION APPROACH

This approach is similar to the interpretive approach but proposes the reduction of storage and physical costs and without the need for specialized description languages. Instead, it considers only the logical level of data representation. For example, Shoshani (1975) used a source definition of the network database and the network DML to read the data from the network database and store it in a convenient, intermediate target. The intermediate target format was then read and stored in the relational database using the definition of the relational database and the relational DML as illustrated in Figure 4-6.

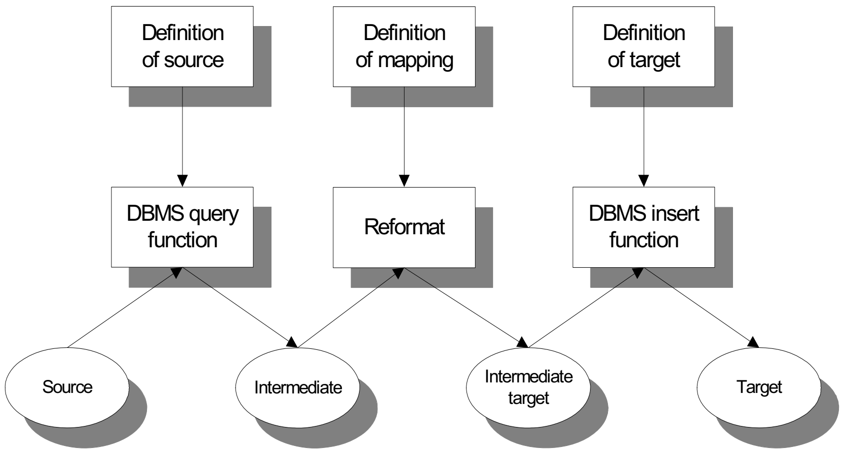


Figure 4-6 Logical level approach for data conversion

There are two parts to this problem: unloading the data from the nonrelational or relational database, and uploading the data into the relational database or from the relational to object-oriented or XML database. The two steps are independent, since most vendor load utilities accept a simple flat file as input. Any available utility that can read the source database and creates a flat output file can be used for this purpose. These output sequential files should be reorganized into a logical sequence for the uploading process after the generation of the new database definition. Generally the load utility can be applied in the upload process.

The logical level approach is more commonly used in the industry because it is easier to implement than the others. The later sections describe using the logical approach to convert data from a network database to a relational database, from a hierarchical database to a relational database, and from a relational database to an object-oriented or XML database.

4.5 DATA CONVERSION FROM NETWORK TO RELATIONAL

As described before, the logical approach consists of an unload step and an upload step. For the purpose of automation, we must convert data from a network database to a semantically richer relational database. The primitive semantics of record types and record keys in network schema can be mapped into relations and relation keys in relational schema. Other more advanced semantics such as generalization and categorization are considered not the main component of the database and can be handled later. Thus, a preprocess of direct schema translation from network to relational is needed before the data conversion. These steps are shown in Figure 4-7 (Fong & Bloor, 1994).

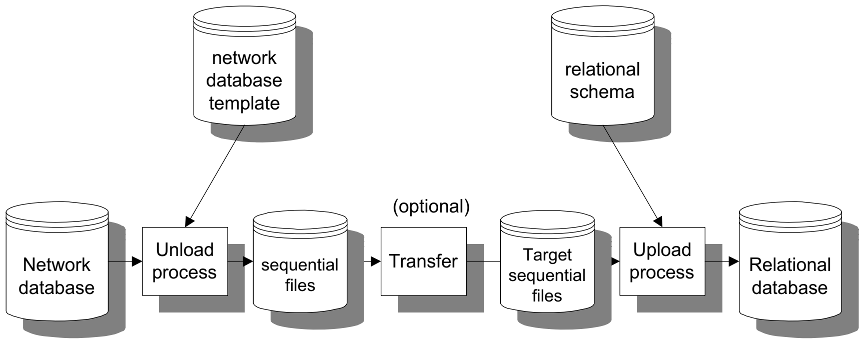


Figure 4-7 System flow diagram for data conversion from network to relational

Conversion is automated by database navigation. The process includes unloading the network database into sequential files. The unload process reads all the records of the network database, and writes them to the files.

The procedure to convert the network database into relational is:

Preprocess step 1 - Direct schema translation from network to relational.

- Rule 1. Map each record type to a relation.
- Rule 2. Map each record "Navigational" key (i.e., concatenate owner record key to member record key) to the relation key.

The translated relational schema will then be used as a template to map the network database content to a target relational database.

Step 1- Create a template file to define the network database and its translated relational schema.

A template file can be created from an input network schema together with user input to specify the record identifier. The template file consists of network schema record types, their linkages to each other through different set types, and their record identifier. The record identifiers will contain the concatenation of record keys and will be mapped into the relational database as primary keys or composite keys. The template file will be used to unload the network database into sequential files.

The following shows the structure of a template file.

Record type template file

Name	Key_1,.ey_n	Identifier Type	$Identifier_1$..$Identifier_n$	$Attr_1$..$Attr_n$

Name = network schema record type name
Key_1,.Key_n = record key of the record type
Identifier Type = record identifier type,'F' for fully internally
identified, 'P' for partially internally identified
and 'I' for internally unidentifier.
$Identifier_1$..$Identifier_n$= concatenated record keys with owner
record keys.
$Attr_1$..$Attr_n$ = attributes of the record type.

Besides the above template file, another template file is used to store all the set linkage information. The following is the structure of the set linkage template file.

Set linkage template file

Owner	Member	Set linkage Name

Owner = owner record type name within the set
Member = member record type within the set
Set Linkage = name of the set that connects the owner and member

Step 2. Unload network database into sequential files.

In the unload process, with the help of template files from step 1, an Unload program will read all record occurrences of each record type of the network database from the bottom up and map each record type into a sequential file. The Unload algorithm is as follows:

```
Program Unload network database to sequential files
begin
  /*     n = number of record types
         m = number of levels in each path expression
  */
  Get all record type $N_1$, $N_2$....$N_n$ within input network schema;
  For i = 1 to n do /* for each target record type $N_i$ */
     while $N_i$ record occurrence found do
       begin
         If it is first occurrence
           then obtain first record $N_i$ within area
           else obtain next record $N_i$ within area;
           For j = m-1 to 1 do
           /* read target record owner records by database navigation
           from level m-1 to level 1, a system-owned records */
           Obtain owner records keys $K_i(1)$, $K_i(2)$,...$K_i(j)$
            /* obtain the record keys of all owners of record $N_i$ along
           database access path from bottom up to the system owned
           record*/
          end-for;
      Case record identifier_type of
'F': begin
           If m = 1
           then output $N_i$ record with $K_i(m)$ as record identifier to
                        sequential  file i
            else output $N_i$ record with $K_i(1)$, $K_i(2)$....$K_i(m-1)$, $K_i(m)$
                        as foreign key to sequential file  i /*   $K_i(m)$ = key of
                        owner record key in level m */
      end;
 'P': output $N_i$  record with $K_i(1)$, $K_i(2)$,.., $K_i(m-1)$, $K_i(m)$ as
          record identifier to sequential file i;
 'I':  output $N_i$ record with $K_i(1)$, $K_i(2)$,.., $K_i(m-1)$,
         Sequence# as record identifier to sequential file i;
       end-case;
  end-while;
  end-for;
end;
```

The algorithm reads each record occurrence by database navigation. For each record occurrence of fully internally identified read, it reads its owner record occurrences from the bottom up to the system owned record types. It then concatenates the owner record keys for the record type of partially internally identified or internally unidentified. For owner record keys with record type of fully internally identified, the concatenation of owner record keys is not required. The objective is to concatenate owner record identifiers as foreign keys in the target record when mapped to the relational database.

Step 3 - Transfer sequential files to target computer (optional).

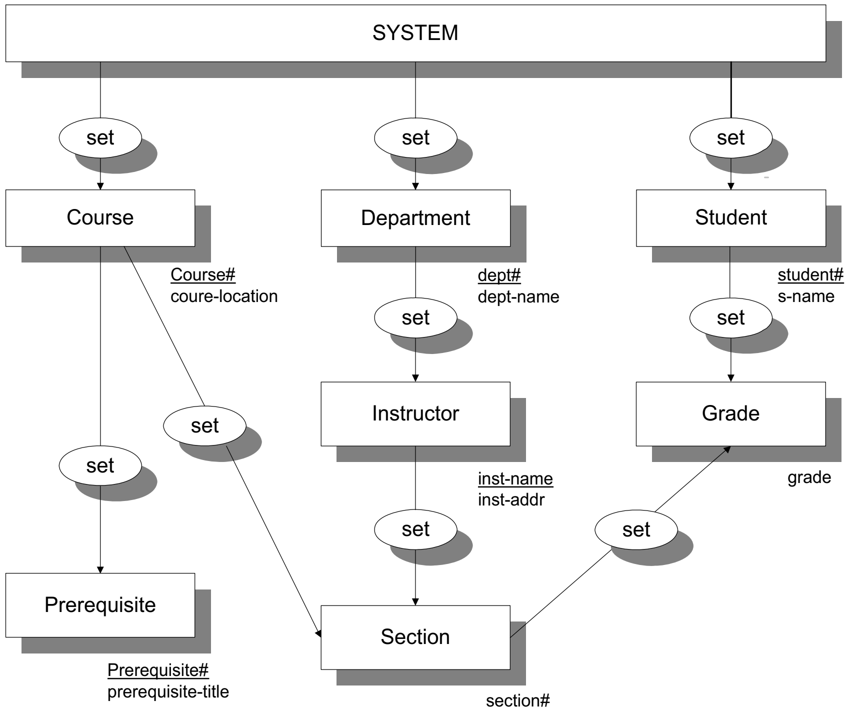
We must transfer the unloaded sequential files into another computer if the target relational database is residing in a different physical location or another machine. The data format may need to be changed due to different bit size per word and/or character size per record. This is a straightforward task for which many software utilities already exist.

Step 4 - Upload sequential files into a relational database.

Finally, we upload the sequential files into a relational database according to the translated relational schema. The relational schema must be created before the upload process.

Case Study of Data Conversion From Network to Relational

Before converting data from network to relational, a translated relational schema must be defined. We apply the previously described method to the university enrollment system for illustration. Figure 4-8 shows a network schema and its database.



Record Course

COURSE#	COURSE_LOCATION
CS101	LECTURE THEATRE1
IS201	LECTURE THEATRE2
IS301	ROOM P7818

Record Student

STUDENT#	STUDENT_NAME
025056	JOHN F. SMITH
312788	FRANK. H. FRAN
217228	JANE E. BUNDY

Record Prerequisite

PREREQUISITE#	PREREQUISITE_TITLE
IS201	SYSTEM ANALYSSIS

Record Section

SECTION
SECTION1
SECTION2

Record Department

DEPARTMENT#	DEPARTMENT_NAME
CS	COMPUTEER SCIENCE
IS	INFORMATION SYSTEM

Record Section

GRADE
A
B

Record Instructor

INSTRUCTOR_NAME	INSTRUCTOR_ADDRESS
A.B.ADAMS	WHITE PLAINS
J.S. FINK	BROOKLYN
A.M. JONES	LONG ISLAND

Figure 4-8 A network database for university enrollment system

The following steps show the different stages in the conversion process:

Step 1 - Create a template file to define the network databases and its translated relational schema:

During the template creation process, the user is prompted to input the record class of each entity. The following shows the user input for each entity type in the university enrollment system.

The identify type (F, P, I) of:	COURSE#	F
The identify type (F, P, I) of	PREREQUISITE	F
The identify type (F, P, I) of	DEPARTMENT	F
The identify type (F, P, I) of	INSTRUCTOR	P
The identify type (F, P, I) of	SECTION	P
The identify type (F, P, I) of	STUDENT	F
The identify type (F, P, I) of	GRADE	P

The template file is shown below with record name, existing record keys, record identifier type ('F' = fully internally identified, 'P' = partially internally identified, and 'I' = internally unidentified), derived record identifier, and attributes for each record type.

Record Name	Record Key	Identifier Type	Record Identifier	Attributes
course	course#	F	course#	course# course_location
prerequisite	prerequisite#	F	prerequisite#	prerequsite# prerequsite_title
department	department#	F	department#	department# department_name
instructor	instructor_name	P	department# instructor_name	instructor_name instructor_addres s
section		P	department# course# instructor_name section#	
student	student#	F	student#	student# student_name
grade		P	department# instructor_name course# student# section#	grade

The Set Linkage template file is shown below:

Owner	Member	Set Linkage Name
COURSE	PREREQUISITE	Course_Prerequisite
COURSE	SECTION	Course_Section
DEPARTMENT	INSTRUCTOR	Department_Instructor
INSTRUCTOR	SECTION	Instructor_section
STUDENT	GRADE	Student_grade
SECTION	GRADE	Section_grade

Step 2 - Unload records of each record type in the network database, with the record identifier into a sequential file.

Record COURSE

COURSE#	COURSE_LOCATION
CS101	LECTURE THEATRE 1
IS201	LECTURE THEATRE 2
IS301	ROOM P7818

Record PREREQUSITE

PREREQUISITE#	PREREQUISITE_TITLE	*COURSE#
IS201	SYSTEM ANALYSIS	IS301

Record DEPARTMENT

DEPARTMENT#	DEPARTMENT_NAME
CS	COMPUTER SCIENCE
IS	INFORMATION SYSTEM

Record INSTRUCTOR

DEPARTMENT#	INSTRUCTOR_NAME	INSTRUCTOR_ADDRESS
CS	A.B. ADAMS	WHITE PLAINS
CS	J.S. FINK	BROOKLYN
IS	A.M. JONES	LONG ISLAND

Record SECTION

DEPARTMENT#	COURSE#	INSTRUCTOR_NAME	SECTION#
CS	CS101	A.B. ADAMS	SECTION 1
CS	CS101	J.S. FINK	SECTION 2

Record STUDENT

STUDENT#	STUDENT_NAME
025056	JOHN F. SMITH
312788	FRANK H. FRAN
217228	JANE E. BUNDY

Record GRADE

DEPART MENT#	INSTRUCTOR _NAME	SECTION #	COURSE #	STUDENT #	GRADE
CS	A.B. ADAMS	Section 1	CS101	025056	A
CS	J.S. FINK	Section 2	CS101	312788	P

Step 3 - Upload the unloaded sequential files into the relational Database.

Relational schema will be created with one create statement for each relation. For example, the following is a create statement for the relation table DEPARTMENT. Each unloaded sequential file is loaded to a relation.

```
CREATE TABLE DEPARTMENT
                          (DEPARTMENT                  CHAR(2),
                           DEPARTMENT_NAME             CHAR (20))
CREATE TABLE COURSE
                          (COURSE#                     CHAR(5),
                           COUSE_LOCATION              CHAR (20))
CREATE TABLE PREREQUISITE
                          (PREREQUISITE#               CHAR(5),
                           PREREQUISITE_TITLE          CHAR (20),
                           COURSE#                     CHAR(5))
CREATE TABLE INSTRUCTOR
                          (DEPARTMENT                  CHAR(2),
                          INSTRUCTOR_NAME              CHAR(20),
                           INSTRUCTOR_ADDRESS          CHAR (40))
CREATE TABLE SECTION
                          (DEPARTMENT                  CHAR(2),
                           COURSE#                     CHAR(5),
                          INSTRUCTOR_NAME              CHAR(20),
                          SECTION#                     CHAR(10))
CREATE TABLE STUDENT
                          (STUDENT#                    INTEGER(5),
                           STUDENT_NAME                CHAR (40))
CREATE TABLE GRADE
                          (DEPARTMENT                  CHAR(2),
                           INSTRUCTOR_NAME             CHAR (20),
COURSE#                    CHAR (5),
STUDENT#                   INTEGER(5),
SECTION#                   CHAR(8),
GRADE                      CHAR (1))
```

4.6 DATA CONVERSION FROM HIERARCHICAL TO RELATIONAL

In a similar manner to the data conversion from network to relational, data conversion from hierarchical to relational requires some initial processing followed by a sequence of three steps, as shown in Figure 4-9.

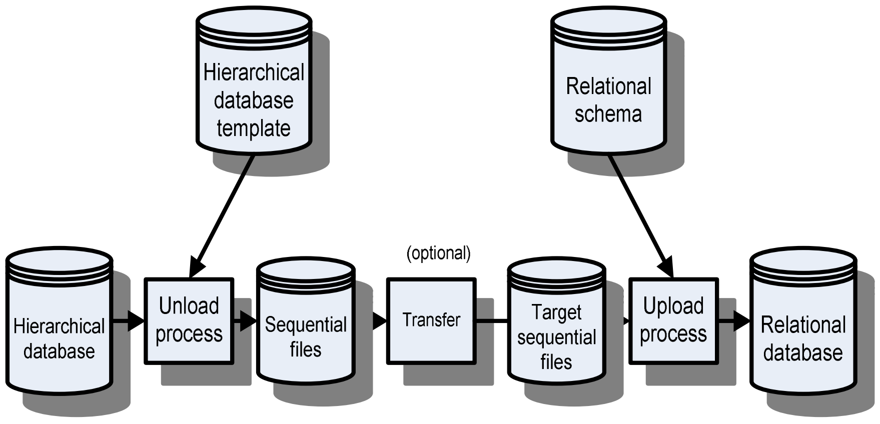


Figure 4-9 System flow diagram for data conversion from hierarchical to relational

Preprocess step 1 - Translate hierarchical schema to relational schema by mapping each segment type to a relation and each segment "Access path" key to a relation key.

Step 1 - Unloading the hierarchical database, writing each segment type data into a file.
The algorithm for this proces is shown below.

```
Program Unload hierarchical database to sequential files
Begin
  /* H = the number of segment types */
  Get all segment type $H_1$, $H_{2,..}H_h$ from the hierarchical input schema;
  For i = 1 to h do /* for each target segment type */
  begin
      Get $H_{i1}$, $H_{i2...}$ $H_{ii}$ segment types;
          /* get target segment $H_{ii}$ parent segments $H_{i1...}H_{i(i-1)}$ */
    Let j = 1 /* start from level 1 of root segment */
    While j > 0 do /* processing all target segment occurrences */
     begin
       case j of
    j=1: begin /* process all root segment occurrences */
          Get next $H_{i1}$ segment;
           If segment found
             then Let j = j + 1 /* go down toward target segment */
             else Let j = j - 1 /* go up to get out of the loop */
          end
   i>j>1: begin /* set up parentage position */
               Get next within parent $H_{ij}$ segment;
                If segment found
                 then Let j = j + 1 /*go down toward target segment*/
                  else Let j = j - 1; /* go up toward root segment */
              end;
    j=i: begin /* process target segment */
          while $H_{ii}$ segment found do
            begin
             Get next within parent $H_{ii}$ segment; /*set up parentage */
                case $H_{ii}$ segment identifier type of
                   "F": output $H_{ii}$ segment with its parent segment
                        keys $H_m$ to sequential file i;
                               /*$H_m$=the concatenation of parent
                                                segment keys of $H_i$ segment*/
                   "P": output $H_{ii}$ segment along with $H_{i1}$(key),
                         $H_{i2}$(key)...$H_{i(i-1)}$(key), $H_{ii}$(key)  to sequential file i;
                   "I": output $H_{i1}$ segment along with $H_{i1}$(key),
                         $H_{i2}$(key)......$H_{i(i-1)}$(key),.sequence# to sequential file i;
                  case-end;
               while-end;
               Let j = j - 1; /* go up toward root segment */
              end;
           case-end;
    while-end;
  for-end;
end;
```

Step 2 - (optional) Transfer sequential file to a target computer.

Step 3 - Upload sequential files to the relational database.

4.7 DATA CONVERSION FROM RELATIONAL TO OBJECT-ORIENTED

Similar to the procedure for data conversion from network to relational, we must perform schema translation from relational to object-oriented in preprocess, and then unload and upload the relational database to a target object-oriented database as shown in Figure 4-10.

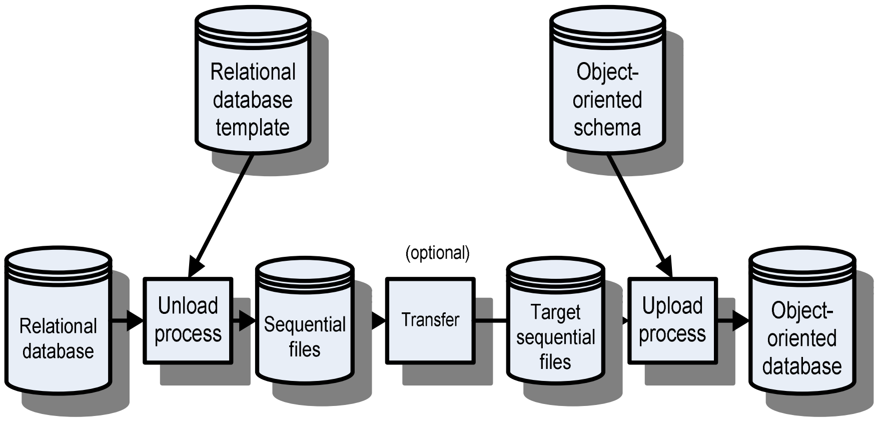


Figure 4-10 System flow diagram for data conversion from relational to object-oriented

There are four steps in converting data from relational to object-oriented. They are:

Preprocess step 1 - Translate relational schema into an object-oriented schema

Rule 1: Map relation to class object

This rule maps relations into class objects. The resulting classes contain all the attributes of the source relations.

Rule 2: Map foreign keys to association attribute

This mapping takes the value determined relationships of the relational model and maps them into association attributes in the object-oriented model. The foreign key attributes are then dropped from the class, leaving the class with semantically meaningful attributes and association attributes with other classes.

Rule 3: Map isa relationship to inheritance

The subclass-to-superclass (i.e., isa) relationships in a relational schema are represented by a class hierarchy in the object schema with inheritance statements.

Step 1 - Unload relations' tuples into sequential files.

According to the translated object-oriented schema, the tuples of each relation will be unloaded into a sequential file. The unload process is divided into three steps:

1. The first substep is to unload each relation tuple into a file using insert statements (Note: These statements will later be uploaded back to a target object-oriented database such that each class will be initially loaded from the tuples of a corresponding relation.)

2. In the second substep, for each foreign key, its referred parent relation tuple will be unloaded into another file with update statements. Then the referred child relation tuple will be unloaded into the same file (Note: The idea is to make use of the stored OID when uploading the insert statement in the first substep. The update statement is to place the correct value in the association attribute when they are uploaded to a target object-oriented database.)

3. In the third substep, for each subclass relation, its referred superclass relation tuple will be loaded into a third file with update statements. (Note: the idea is also to make use of the stored OID when uploading the insert statement in the first substep.)

The pseudo code for this process can be described as follows:

```
Begin
  Get all relation $R_1$, $R_2$....$R_n$ within relational schema;

For i = 1 to n do /* first substep: load each class with
                        corresponding relation tuple data */
```

```
 begin
  while $R_j$ tuple found do
    output non-foreign key attribute value to a sequential file $F_i$
         with insert statement;
  end;

For j = 1 to n do /* second substep: update each loaded class with
                  its association attribute value */
begin
  while $R_j$ tuple with a non-null foreign key value found do
  begin
     Get the referred parent relation tuple from $R_p$ where $R_p$ is
                a parent relation to $R_j$;
      Output the referred parent relation tuple to a sequential
                file $F_j$ with update statement;
       Get the referred child relation tuple from $R_j$;
       Output the referred child relation tuple to the same file
                $F_j$ with update statement;
  end;

  For k = 1 to n do /* third substep; update each subclass to
                  inherit its superclass attribute value */
  begin
     while a subclass relation $R_k$ tuple found do
      begin
        Get the referred superclass relation tuple from $R_s$
                         where $R_s$ is a superclass relation to $R_k$;
         Output the referred superclass relation tuple to a
                         sequential file $F_k$ with update statement;
       end;
  end;
```

Step 2 - (optional) Transfer sequential files to target computer.

The unloaded sequential file can be transferred to another computer if the target object-oriented database resides on another machine. The data format may need to be changed due to different bit size per word and/or character size per record. This is a straightforward task for which many software utilities already exist.

Step 3 - Upload sequential files to an object-oriented database.

As a prerequisite of the data conversion, a schema translation from relational to object-oriented schema will be carried out beforehand. Then, the translated object-oriented schema is mapped into the object-oriented databases DDL. The sequential file F_i will first be uploaded into object-oriented database to fill in the class attributes' values. The sequential file Fj will then be uploaded into the object-oriented database to fill in each class association attribute values. Lastly, the sequential file F_k will be uploaded to fill in each subclass inherited attributes values.

Step 4 - (optional). Normalize object-oriented database to normal form if necessary (Ling, 1994).

A poorly designed relation incurs the overhead of handling redundant data and the risk of causing update anormalies. We can decompose a relation into fully normalized relations. Similarly for an object-oriented schema, since complex attributes and multi-valued attributes make a class object in unnormal form, we must normalize them into normal form to avoid update anormalies. For example, the following is a class object with update anormalies.

```
Class Employee
        attr Employee#: integer
        attr Employee_name: string
        attr Salary: integer
        attr dept_name: string
        attr dept_budget: integer
        attr dept_location: set(string)
end
```

If we delete a department, we must update all the department employees' data. If we change data of a department, we must change all the department data of the employees working in the department. Such update anormalies create the need to normalize the object-oriented schema. The solution is to remove these update anormalies by decomposing a class object into two class objects so that they can function independently of each other. The procedure to perform a normalization is as follows:

- Create a referenced class if one does not exist.
- Introduce an object reference if one does not exist.
- Move decomposed attributes to the referenced class.

In the example, we can normalize the class Employee by decomposing into two classes: Employees and Department as follows:

```
Class Employee                              Class Department
 attr Employee#: integer                          attr Dept_name: string
 attr Employee_name: string                       attr Dept_budget: integer
 attr Salary: integer                             attr location: set(string)
 association attr hired_by ref Department          association attr hire ref
end                                                  set(Employee
                                                end
```

After the normalization, the update anormalies are eliminated since the decomposed two class objects can be updated independently.

Case Study of Data Conversion from Relational to Object-Oriented

To illustrate the application of the above methodology, we can use a modified university enrollment system as an example.

Relation Course

Course	Course_title	Location
CS101	Intro to Computer Science	Lecture Theatre 1
IS201	System Analysis	Lecture Theatre 2
IS301	Decision Support System	Room P7818

Relation Prerequisite

*Course#	Prerequisite	Prereq_title
IS301	IS201	System Analysis

Relation Instructor

SS#	Inst_name	Inst_addr
415223641	A.B.Adams	White Plains
613557642	J.S. Fink	Brooklyn
452113641	A.M.Jones	Long Island

Relation Section

SS#	*Course	Section#	Lecture_hour
415223641	CS101	1	30
613557642	CS101	2	30

Relation Graduate Student

Student#	Degree_to_be
012888	M.Sc.
120008	Ph.D.

Relation Student

Student#	Student_name	Sex
012888	Paul Chitson	M
120008	Irene Kwan	F
117402	John Lee	M

Relation Enroll

*Student	*Course	SS#	Section#	Year	Grade
012888	CS101	415223614	1	1995	A
120008	CS101	613557642	2	1996	B

Its semantic model can be represented by the following extended entity relationship model in Figure 4-11.

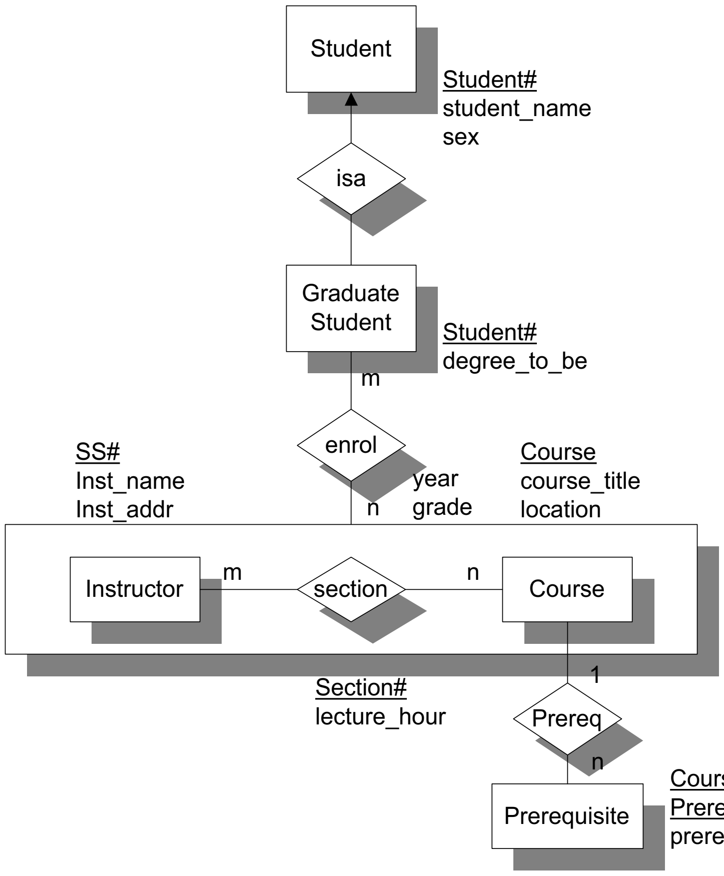


Figure 4-11 An EER model for the modified university enrollment system

By using the methodology in Chapter 3, we can convert these relations into class objects as follows:

Step 1 - Translate relational schema to object-oriented schema.

The result of translating the relational schema into the object-oriented model are shown in an UML diagram in Figure 4-12.

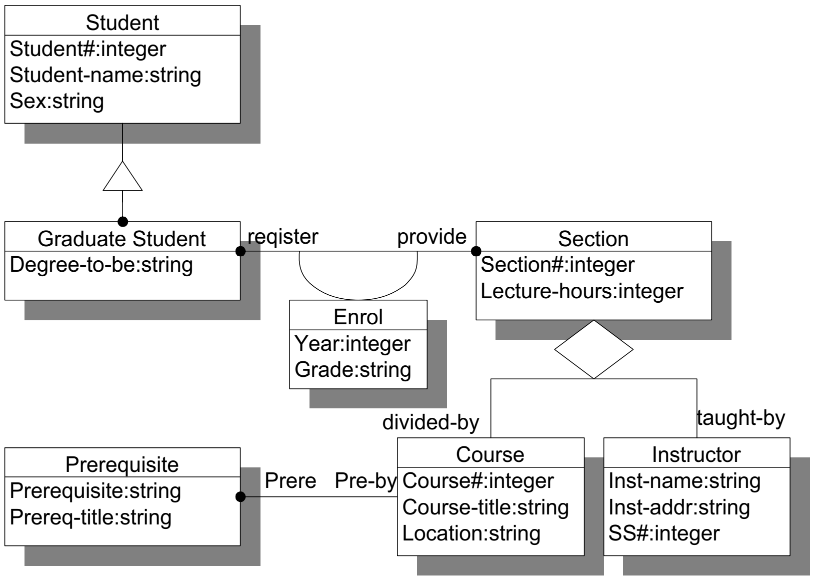


Figure 4-12 Translated object-oriented schema in UML

Its translated object-oriented schema is as follows:

```
Class Student
 attr student#: integer
 attr student_name: string
 attr sex: string
end

Class Graduate student
 inherit Student
attr degree_to_be: string
end

Class Section
 attr section#: integer
 attr lecture_hour: integer
 association attr divided_by ref course
 association attr taught_by ref instructor
end

Class Instructor
 attr inst_name: string
 attr ss#: integer
 attr inst_addr: string
end

Class Course
 attr course: string

Class Prerequisite
 attr course: string
 attr course_title: string                      attr prerequisite: string
 attr location: string                          attr prereq_title: string
 association attr prer_by ref set(prerequisite)  association attr prere ref course
end                                             end

Class Enrol
 attr year integer
 attr grade: string
 association attr register ref graduate_student
 association attr provide ref section
end
```

Step 2 - Unload data into sequential files.

By applying the algorithm specified, this step unloads data from each relation into a sequential file along with its association data from other relations.

The idea is to load the attribute data from the input relation, and the association attribute data from the loaded object-oriented database. The Select statement is to retrieve class occurrences that have been loaded into the object-oriented database with the stored OID. The association attributes are in italic.

For implementation, a foreign key will be loaded with referred data using the stored OID. The insert and select statements in the following are from a prototype written using UniSQL (UniSQL, 1993).

The content of file F_i after the first substep in unload process are the following insert statements:

insert into student (student#, student_name, sex) values (‘012888’, ‘Paul Chitson’, ‘M’)

insert into student (student#, student_name, sex) values (‘120008’, ‘Irene Kwan’, ‘F’)

insert into student (student#, student_name, sex) values (‘117402’, ‘John Lee’, ‘M’)

insert into graduate_student (student#, degree_to_be, *register*) values (‘012888’, ‘M.Sc.’, null)

insert into graduate_student (student#, degree_to_be, *register*) values (‘120008’, ‘Ph.D.’, null)

insert into section (section#, lecture_hour, *taught_by, divide, provide*) values (1, 30, *null, null*, *null*) insert into section (section#, lecture_hour, *taught_by, divide, provide*) values (2, 30, *null, null, null*)

insert into enrol (year, grade, *register_by*, *provide_by*) values (1995, 'A', *null, null*)

hinsert into enrol (year, grade, *register_by, provide_by*) values (1996, 'B', *null, null*)

insert into instructor (inst_name, ss#, inst_addr) values ('A.B.Adams', 415223641, 'White Plains')

insert into instructor (inst_name, ss#, inst_addr) values ('J.S.Fink', 613557642, 'Brooklyn')

insert into instructor (inst_name, ss#, inst_addr) values ('A.M.Jones', 452113641, 'Long Island')

insert into course (course, course_title, location, *pre-by*), values ('IS101', 'Introduction to Computer Science', 'Lecture Theatre 1', null)

insert into course (course, course_title, location, *pre-by*), values ('IS201', 'System Analysis', 'Lecture Theatre 2', null)

insert into course(course, course_title, location, *pre-by*), values ('IS301', 'Decision Support System', 'Room P7818', null)

insert into prerequisite (prerequisite, prereq_title, *pre*) values ('IS201', 'System Analysis', null)

The content of file F_j after second substep are:

update section
set *taught_by* = (select * from instructor where ss# = 415223641)
set *divided_by* = (select * from course where course = 'IS101')
where ss# = 415223614 and course = 'IS101' and section# = 1

update section
set *taught_by* = (select * from instructor where ss# = 613557642)
set *divided_by* = (select * from course where course = 'IS101')
where ss# = 613557642 and course = S101' and section# = 2)

update enroll
set *register_by* = (select * from graduate_student where student# = '012888')
set *provide_by* = (select * from section where ss# = 415223641 and course = 'IS101' and section# =1)
where ss# = 415223641 and course = S101' and section = 1 and year = 1995

update enroll
set *register_by* = (select * from graduate_student where student# = '120008')
set *provide_by* = (select * from section where ss# = 613557642 and course = 'IS101' and section# = 2)
where ss# = 613557642 and course = 'IS101' and section = 2 and year = 1996

update course
set *pre_by* = (select * from prerequisite where course = 'IS301')
where prerequisite = 'IS301'

update prerequisite
set *prereq* = (select * from course where course = 'IS301')
where prerequisite = 'IS201'

The content of file F_k after third substep are:

update graduate_student
set student_name = (select * from student where student# = '012888')
set sex = (select * from student where student# = '012888')
where student# = '012888'

update graduate_student
set student_name = (select * from student where student# = '120008')
set sex = (select * from student where student# = '1200008')
where student# = '1200008'

Step 3 - (optional). Transfer sequential files to target computer.
Not applied in this case study.

Step 4 - Upload sequential files into object-oriented database
The three files F_i, F_j and F_k are then uploaded into an object-oriented database to fill in the classes and their attributes' values.

Step 5-(optional) Normalize the translated object-oriented schema.
Since there is no redundant data in the object-oriented schema, this step can be skipped.

As a result, the converted object-oriented database is

Class Course

OID	Course	Course_title	Location
001	CS101	Intro to Computer Science	Lecture Theatre 1
002	IS201	System Analysis	Lecture Theatre 2
003	IS301	Decision Support System	Room P7818

Class Prerequisite

OID	Stored_OID	Course#	Prerequisite	Prereq_title
014	003	IS301	IS201	System Analysis

Class Instructor

OID	Inst_name	SS#	Inst_addr
004	A.B.Adams	415223641	White Plains
005	J.S. Fink	613557642	Brooklyn
006	A.M.Jones	452113641	Long Island

Class Section

OID	SS#	Stored OID	Section#	Lecture_hour
007	415223641	001	1	30
008	613557642	001	2	30

Class Graduate Student

OID	Student#	Degree_to_be
009	012888	M.Sc.
010	120008	Ph.D.

Class Student

OID	Student#	Student_name	Sex
009	012888	Paul Chitson	M
010	120008	Irene Kwan	F
011	117402	John Lee	M

Class Enrol

OID	Stored OID	Stored OID	SS#	Section#	Year	Grade
012	009	001	415223614	1	1995	A
013	010	001	613557642	2	1996	B

4.8 *DATA CONVERSION FROM RELATIONAL TO XML DOCUMENT*

As the result of the schema translation in Chapter 3, we translate an EER model into different views of XML schemas based on their selected XML view. For each translated XML schema, we can read its corresponding source relation sequentially by embedded SQL; that is, one tuple at one time, starting a parent relation. The tuple can then be loaded into an XML document according to the mapped XML DTD. Then we read the corresponding child relation tuple(s), and load them into an XML document. The procedure is to process corresponding parent and child relations in the source relational database according to the translated parent and child elements in the mapped DTD as follows:

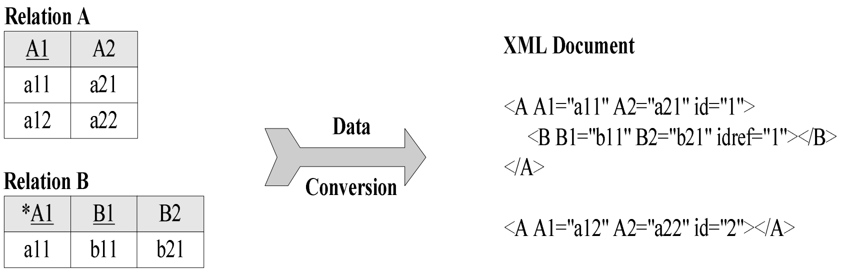
```
Begin
   While not end of element do
   Read an element from the translated target DTD;
   Read the tuple of a corresponding relation of the element from
   the source relational database;
   load this tuple into a target XML document;
   read the child elements of the element according to the DTD;
   while not at end of the corresponding child relation in the
             source relational database do
             read the tuple from the child relation such that the
             child's corresponding to the processed parent relation's
             tuple;
       load the tuple to the target XML document;
   end loop      //end inner loop
  end loop  // end outer loop
end
```

As a result, the data can be converted into an XML according to each preserved data semantic in the translated DTD as shown in the following rules:

Notice that each rule of data conversion must be processed after each rule of schema translation in Section 3.7 in Chapter 3.

Rule 1: Mapping weak entity from RDB to XML

In converting relational data of weak entity into an XML instance, we must ensure that each child element's IDREF refer to its strong element's ID.



Relation A

A1	A2
a11	a21
a12	a22

Relation B

*A1	B1	B2
a11	b11	b21

XML Document

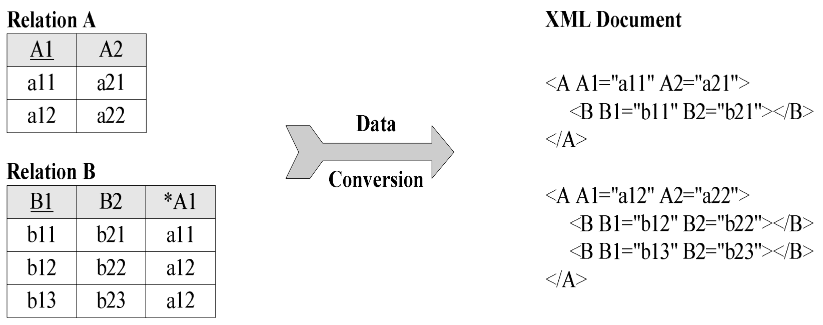
```
<A A1="a11" A2="a21" id="1">
   <B B1="b11" B2="b21" idref="1"></B>
</A>

<A A1="a12" A2="a22" id="2"></A>
```

Figure 4-13 Weak Entity: Data Conversion

Rule 2: Mapping participation from RDB to XML

In converting relational tuples with total participation into XML instances, we must ensure that each child elements (converted from child relation tuples) is under its corresponding parent element (converted from parent relation tuples). Similarly, we can convert partial participation tuples into XML instances. However, for those standalone (non-participating) child relation tuples, they can only be converted into child element instances under an empty parent element instance.

Case 1: Total / Mandatory Participation



Relation A

A1	A2
a11	a21
a12	a22

Relation B

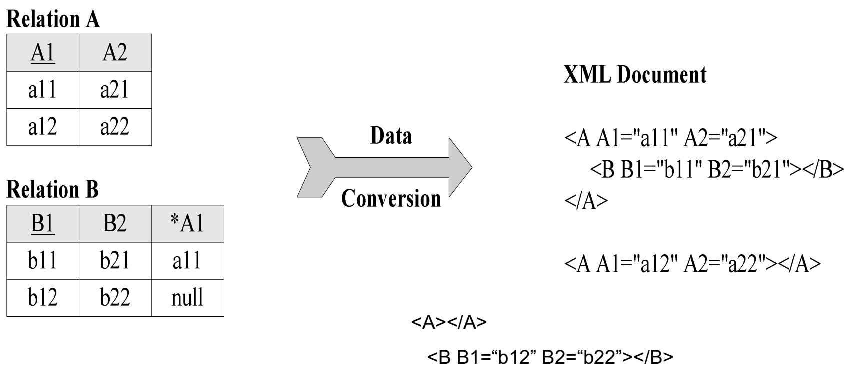
B1	B2	*A1
b11	b21	a11
b12	b22	a12
b13	b23	a12

XML Document

```
<A A1="a11" A2="a21">
   <B B1="b11" B2="b21"></B>
</A>

<A A1="a12" A2="a22">
   <B B1="b12" B2="b22"></B>
   <B B1="b13" B2="b23"></B>
</A>
```

Figure 4-14 Total participation: data conversion

Case 2: Partial / Optional Participation



Relation A

A1	A2
a11	a21
a12	a22

Relation B

B1	B2	*A1
b11	b21	a11
b12	b22	null

XML Document

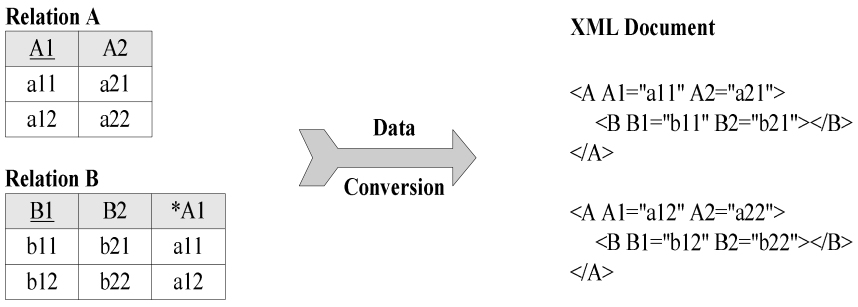
```
<A A1="a11" A2="a21">
   <B B1="b11" B2="b21"></B>
</A>

<A A1="a12" A2="a22"></A>

<A></A>
   <B B1="b12" B2="b22"></B>
```

Figure 4-15 Partial participation: data conversion

Rule 3: Mapping cardinality from RDB to XML

In converting one-to-one relational tuples into XML instances, we must ensure that each parent element instance consists of one child element instance only. In converting one-to-many relational tuples into XML instances, each parent element instance can have multiple child element instances. In converting many-to-many relational tuples into XML instances, a pair of ID and IDREF in two element types are applied such that they refer to each other in many-to-many associations.

Case 1: One-to-one Cardinality



Relation A

A1	A2
a11	a21
a12	a22

Relation B

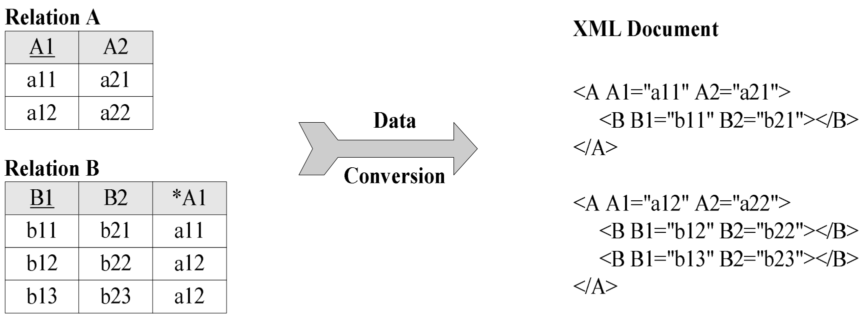
B1	B2	*A1
b11	b21	a11
b12	b22	a12

XML Document

```
<A A1="a11" A2="a21">
   <B B1="b11" B2="b21"></B>
</A>

<A A1="a12" A2="a22">
   <B B1="b12" B2="b22"></B>
</A>
```

Figure 4-16 One-to-one cardinality: data conversion

Case 2: One-to-Many Cardinality



Relation A

A1	A2
a11	a21
a12	a22

Relation B

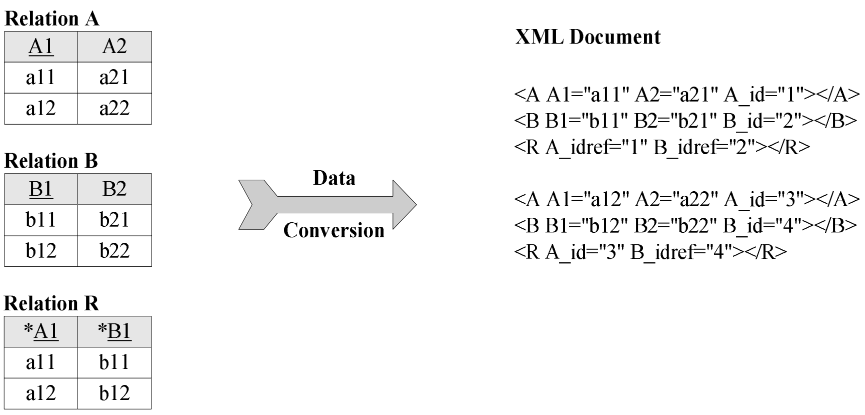
B1	B2	*A1
b11	b21	a11
b12	b22	a12
b13	b23	a12

XML Document

```
<A A1="a11" A2="a21">
   <B B1="b11" B2="b21"></B>
</A>

<A A1="a12" A2="a22">
   <B B1="b12" B2="b22"></B>
   <B B1="b13" B2="b23"></B>
</A>
```

Figure 4-17 One-to-Many cardinality: data conversion

Case 3: Many-to-Many Cardinality



Relation A

A1	A2
a11	a21
a12	a22

Relation B

B1	B2
b11	b21
b12	b22

Relation R

*A1	*B1
a11	b11
a12	b12

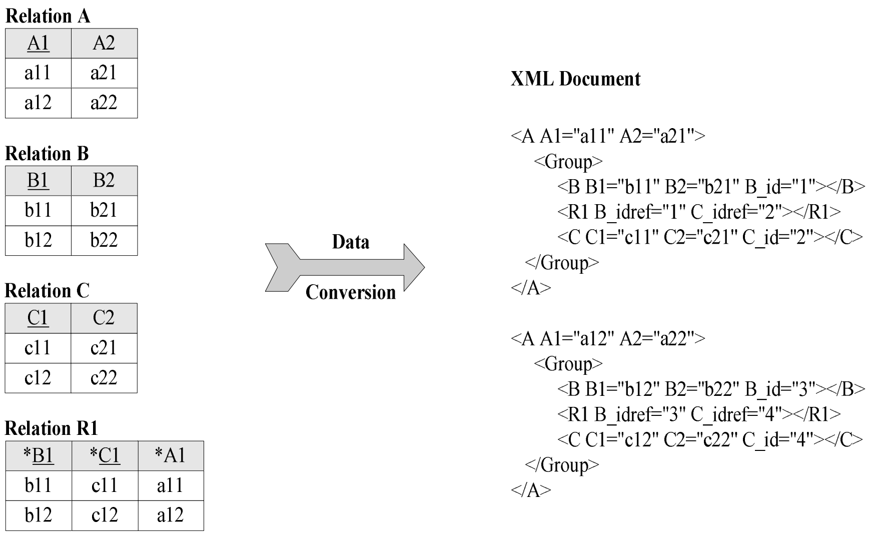
XML Document

```
<A A1="a11" A2="a21" A_id="1"></A>
<B B1="b11" B2="b21" B_id="2"></B>
<R A_idref="1" B_idref="2"></R>

<A A1="a12" A2="a22" A_id="3"></A>
<B B1="b12" B2="b22" B_id="4"></B>
<R A_id="3" B_idref="4"></R>
```

Figure 4-18 Many-to-many cardinality: data conversion

Rule 4: Mapping aggregation from RDB to XML

In converting aggregation relational tuples into XML instances, we must ensure the component relational tuples are converted into the component elements under a group element in an XML document.



Relation A

A1	A2
a11	a21
a12	a22

Relation B

B1	B2
b11	b21
b12	b22

Relation C

C1	C2
c11	c21
c12	c22

Relation R1

*B1	*C1	*A1
b11	c11	a11
b12	c12	a12

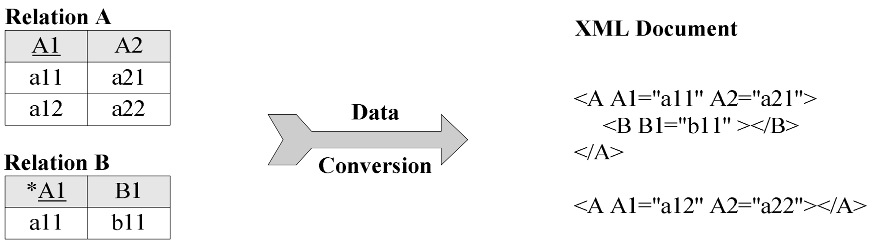
XML Document

```
<A A1="a11" A2="a21">
   <Group>
      <B B1="b11" B2="b21" B_id="1"></B>
      <R1 B_idref="1" C_idref="2"></R1>
      <C C1="c11" C2="c21" C_id="2"></C>
  </Group>
</A>

<A A1="a12" A2="a22">
   <Group>
      <B B1="b12" B2="b22" B_id="3"></B>
      <R1 B_idref="3" C_idref="4"></R1>
      <C C1="c12" C2="c22" C_id="4"></C>
  </Group>
</A>
```

Figure 4-19 Aggregation: data conversion

Rule 5: Mapping ISA relationship from RDB to XML

In converting isa relational tuples into XML instances, we must ensure that the subclass relational tuples are converted into child element instances without the duplication of superclass relational key.



Relation A

A1	A2
a11	a21
a12	a22

Relation B

*A1	B1
a11	b11

XML Document

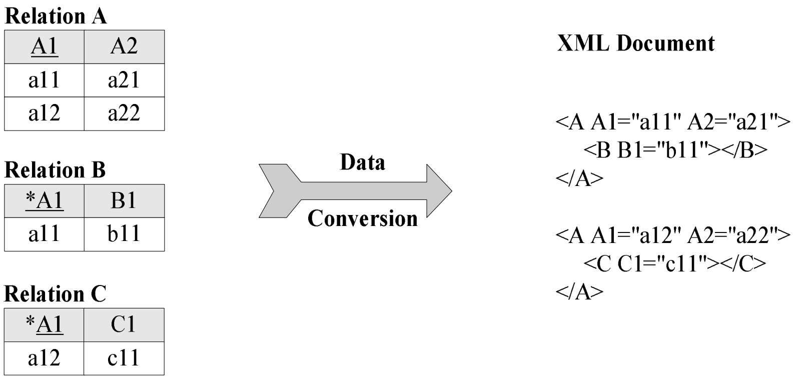
```
<A A1="a11" A2="a21">
   <B B1="b11" ></B>
</A>

<A A1="a12" A2="a22"></A>
```

Figure 4-20 ISA relationship: data conversion

Rule 6: Mapping generalization from RDB to XML

Case 1: Disjoint Generalization

Similar to an isa relationship, in converting generalization relational tuples into XML instances, we must ensure that the subclass relational tuples are converted into child element instances without the duplication of superclass relational key. However, in disjoint generalization, there are no duplicate element instances in two different element type instances under the same parent element instance. On the other hand, there is no such restriction in overlap generalization.



Relation A

A1	A2
a11	a21
a12	a22

Relation B

*A1	B1
a11	b11

Relation C

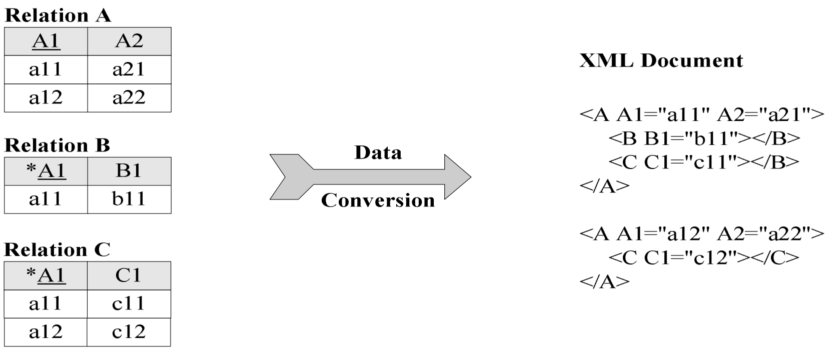
*A1	C1
a12	c11

XML Document

```
<A A1="a11" A2="a21">
   <B B1="b11"></B>
</A>

<A A1="a12" A2="a22">
   <C C1="c11"></C>
</A>
```

Figure 4-21 Disjoint generalization: data conversion

Case 2: Overlap Generalization



Relation A

A1	A2
a11	a21
a12	a22

Relation B

*A1	B1
a11	b11

Relation C

*A1	C1
a11	c11
a12	c12

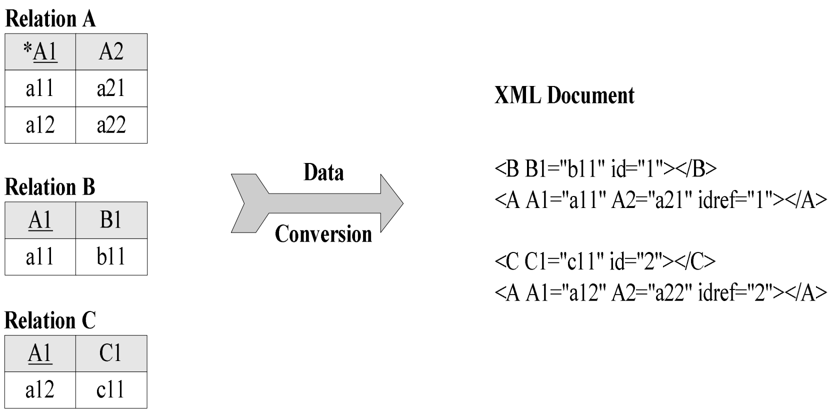
XML Document

```
<A A1="a11" A2="a21">
   <B B1="b11"></B>
   <C C1="c11"></B>
</A>

<A A1="a12" A2="a22">
   <C C1="c12"></C>
</A>
```

Figure 4-22 Overlap generalization: data conversion

Rule 7: Mapping categorization from RDB to XML

In converting categorization relational tuples into XML instances, we must ensure that each child tuple is converted into one only child element instance under a parent element instance.



Relation A

*<u>A1</u>	A2
a11	a21
a12	a22

Relation B

<u>A1</u>	B1
a11	b11

Relation C

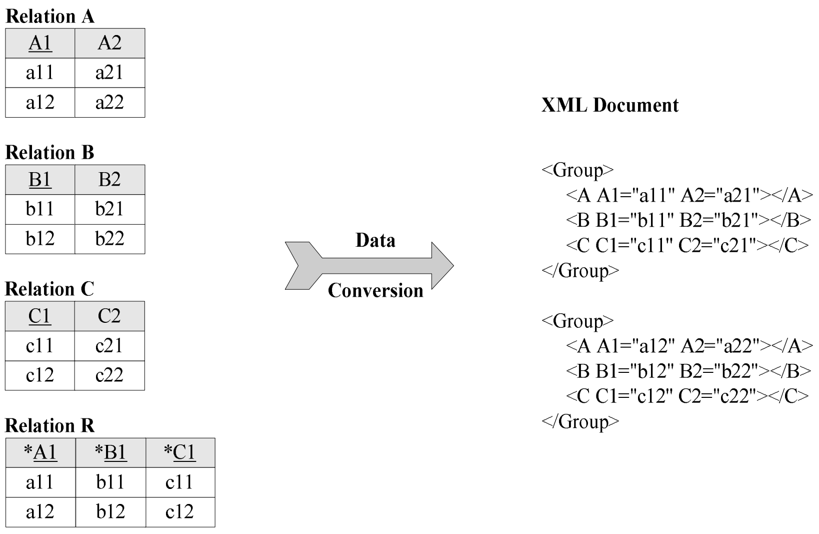
<u>A1</u>	C1
a12	c11

```
<B B1="b11" id="1"></B>
<A A1="a11" A2="a21" idref="1"></A>

<C C1="c11" id="2"></C>
<A A1="a12" A2="a22" idref="2"></A>
```

Figure 4-23 Categorization: data conversion

Rule 8: Mapping n-ary relationship from RDB to XML

In converting n-ary relational tuples into XML instances, we must ensure that the parent relations are converted into component element instances under a group element in an XML document.



Relation A

<u>A1</u>	A2
a11	a21
a12	a22

Relation B

<u>B1</u>	B2
b11	b21
b12	b22

Relation C

<u>C1</u>	C2
c11	c21
c12	c22

Relation R

*<u>A1</u>	*<u>B1</u>	*<u>C1</u>
a11	b11	c11
a12	b12	c12

```
<Group>
   <A A1="a11" A2="a21"></A>
   <B B1="b11" B2="b21"></B>
   <C C1="c11" C2="c21"></C>
</Group>

<Group>
   <A A1="a12" A2="a22"></A>
   <B B1="b12" B2="b22"></B>
   <C C1="c12" C2="c22"></C>
</Group>
```

Figure 4-24 n-ary relationship: data conversion

4.9 SUMMARY

This chapter shows the various methods of data conversions, which include customer program approach, interpretive transformer approach, translator generator approach, and logical level translation approach. Customer program approach is too costly because each customized program needs to be written for each file, and can only be used once. The interpretive transformer approach and the translator generator approach are language dependent and also very limited in their functions. They provide a simulator (or compiler) approach to convert from a file format to another. The users need to learn how to use their simulation language, and even so, the language cannot be used to serve for general database file conversion purpose. The logical level translation approach seems to be more general. Actually, many software utilities in the market apply this approach. However, these software tools are proprietary.

Algorithms have been developed by converting a hierarchical database to a relational database, a network database to a relational database, and a relational database to an object-oriented database. They all apply logical level translation approach by using unload source database to sequential files in the target database data structure sequence, and then upload them to the target database.

The algorithm of converting network databases to relational databases is to read through all the network database record types from the bottom up. Each record type accessed will be concatenated with its owner record keys. The objective is to create the record identifier in each unload process. The foreign keys can also be unloaded into the sequential file. They can then be uploaded into relational database.

The algorithm of converting a hierarchical database to a relational database is similar. The objective is also to create segment identifiers from each database access to each segment type.

The algorithm of converting a relational database to an object-oriented database is to make use of stored OID. In other words, the superclass is stored first. Its OID can then be used to store its subclass. Similarly, the composite class data is stored first, and then followed by their component (or associated) class by using the stored OID.

Data conversion must be done after schema mapping. The data conversion from relational into an XML document is to automate the data loading according to the translated XML schema in document type definition. For each rule of schema mapping for each data semantic, we can read the tuples from the relational database, and then load them into the XML elements and their sub-elements according to their translated XML schema. We can apply pair of ID and IDREF in DTD or pair of Key and Keyref in XSD to implement a many-to-many relationship in an XML document.

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Lochovsky, F. and Tsichritzis, D. (1982) Data Models, Prentice Hall, Inc., pp300-336.

Shoshani, A. (1975) A Logical-Level Approach to Data Base Conversion. 1975 ACM SIGMOD International Conference on Management of Data, pp112-122.

Shu, N., Housel, B. and Lum, V. (1975) CONVERT: A High Level Translation Definition Language for Data Conversion. Communication of the ACM, Volume 18 Number 10, pp557-567.

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QUESIONS

Question 4-1

Convert the following relational database into an object-oriented database:

Table Person

Ssn	Name
S1	A Kox
S2	P Chan
S3	B Chow

Table Course

Cno	cname	*ssn
Cs11	Algorithm	S1
Cs12	Database	S1

Table Staff

*ssn	Title	Hobby
S1	Professor	Ski
S2	Professor	Tennis

S3	Lecturer	Tennis

underlined words are primary keys and words with prefixes "*" are foreign keys.

Question 4-2

When we convert relational tuples into an XML document, can we avoid converting duplicate element instances in the XML document?

Question 4-3

Convert the following relational database into an XML document based on selection of XML view on Department.

Relation Car_rental

Car_model	Staff_ID	*Trip_ID
MZ-18	A002	T0001
MZ-18	B001	T0002
R-023	B004	T0001
R-023	C001	T0004
SA-38	A001	T0003
SA-38	A002	T0001

Relation People

Staff_ID	Name	DOB
A001	Alexander	07/01/1962
A002	April	05/24/1975
B001	Bobby	12/06/1984
B002	Bladder	01/03/1980
B003	Brent	12/15/1979
B004	Belandar	08/18/1963
C001	Calvin	04/03/1977
C002	Chevron	02/02/1974

Relation Car

Car_model	Size	Description
SA-38	165	Long car (Douglas)
MZ-18	120	Small sportier
R-023	150	Long car (Rover)

Relation Trip

Trip_ID	*Department_ID
T0001	AA001
T0002	AA001
T0003	AB001
T0004	BA001

Relation Department

*Department_ID	Salary
AA001	35670
AB001	30010

CHAPTER 5

DATABASE PROGRAM TRANSLATION

The concept of a relational database was first proposed by E.F. Codd in 1970. It was almost instantaneously recognized as a more user friendly model than the previous nonrelational (e.g., hierarchical or network model) database model. However, it was not adopted by the industry until the early 1980s because of its poor performance. Throughout the 1980s the performance of relational databases improved and gained wider industry acceptance. This created a need to convert existing databases into a relational structure. Yet database conversion is both a costly and time consuming process. The majority of time spent in such conversion projects is spent on the process of program translation.

To translate a program it is necessary to determine the functions and semantics of the program. Programmers often make assumptions about the state and ordering of the data in the database without stating these assumptions explicitly in their programs. Therefore, it will usually be necessary to provide more information about the semantics of the program than can be extracted from the program text and its documentation alone. Also needed in the program conversion process is information about the data structure of the program before translation, the new structure of the program after translation, and how the two are related.

In general, there are five basic approaches in program translation: emulation, software interface (bridge program), decompiling, co-existence, and rewriting. We develop a relational interface as the software interface for our proposed methodology. We have improved the performance by implementing an internal schema that lets both relational and nonrelational database programs access a common data structure *without* database navigation. Database navigation is not user friendly because the users can only access a record by following through its access path. It is also inefficient because each database access may take several I/Os.

The five basic approaches and our “enhanced interface” approach are described in the following sections.

5.1 REWRITING

This approach requires the entire database system be redeveloped from scratch in a relational format. One must translate the nonrelational schema into relational schema; rewrite all the application programs to run on the relational database; and throw away the old application programs.

5.2 SOFTWARE INTERFACE

Vendors may provide relational interface software to their nonrelational DBMSs. For example, LRF (Logical Record Facility), a software tool from Computer Associates (CA, 1992a), is a run-time facility that allows application programs to access IDMS (a network database) data without knowing the physical structure of the database. It converts IDMS into IDMS/R, a relational-like database. Under LRF, programmers do not use database navigation statements to access the database. It is possible to combine processes in a macro that acts like a relational DML statement. Views are defined by the relational operators select, project and join. A view is implemented as a logical record. Figure 5-1 shows a diagram of the processing retrieval paths of LRF.

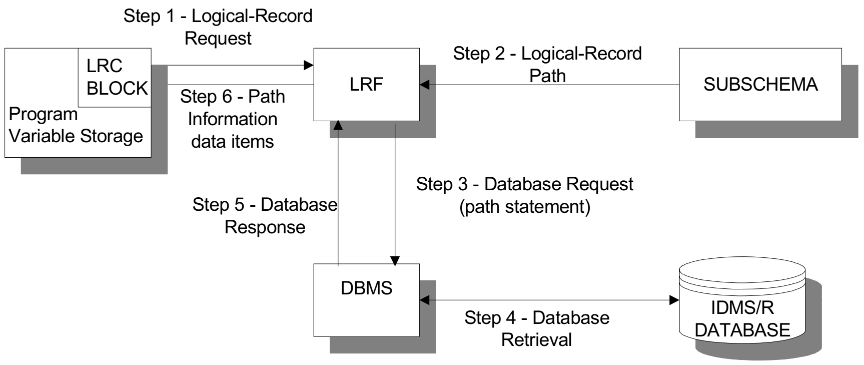

Step 1 - Logical-Record Request
LRC BLOCK
Program Variable Storage
Step 6 - Path Information data items
LRF
Step 2 - Logical-Record Path
SUBSCHEMA
Step 3 - Database Request (path statement)
Step 5 - Database Response
DBMS
Step 4 - Database Retrieval
IDMS/R DATABASE

Figure 5-1 LRF processing retrieval path (step 3, 4, 5 are repeated until all path-DML statements have been executed)

As an example, to implement a join operation for three records. (Department, Office and Employee) in a company's network database, using the foreign key, Employee-ID, the DBA must define the paths table as shown in Figure 5-2 (CA, 1992b). Only after this table has been defined in the subschema can the user retrieve the rows from the results of the join operation.

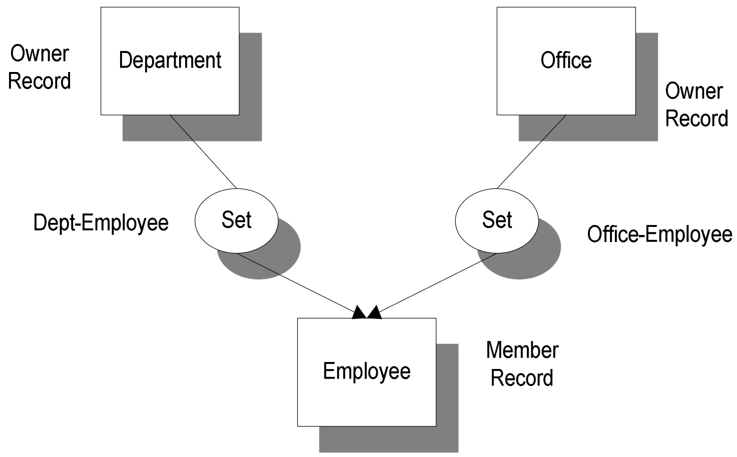


Figure 5-2 An employee system in network schema

A logical path EMP-LR using LRF is defined in subschema below:

PROGRAM REQUEST	SUBSCHEMA PATH GROUP
OBTAIN FIRST	ADD
EMP-LR	PATH-GROUP NAME IS OBTAIN
WHERE EMP-ID EQ	EMP-LR
‘1234’	SELECT FOR EMP-ID OF
	EMPLOYEE
	OBTAIN FIRST EMPLOYEE
	WHERE CALCKEY EQ
	EMP-ID OF LR
	ON 0000 NEXT
	ON 0326 ITERATE
	IF DEPT-EMPLOYEE MEMBER
	ON 0000 NEXT
	ON 1601 ITERATE
	OBTAIN OWNER WITHIN
	EPT-EMPLOYEE
	ON 0000 NEXT
	FIND CURRENT EMPLOYEE
	ON 0000 NEXT
	IF OFFICE-EMPLOYEE
	MEMBER
	ON 0000 NEXT
	ON 1601 ITERATE
	OBTAIN OWNER WITHIN
	OFFICE-EMPLOYEE
	ON 0000 NEXT

Path-group EMP-LR is the logical-record name. It enables users to retrieve Employee, Department, and Office records of the same employee. Database navigation is done in the subschema, retrieving a sequence Employee, Department, and Office records. The “Next” statement validates the return code of DML. 0000 indicates a successful operation. LRF locates an appropriate path by matching the selection criteria specified in the program request to the selectors specified in the path.

5.3 EMULATION

This approach includes auxiliary support software or firmware in the target system to map source program commands to functionally equivalent commands in the target system. Each nonrelational

DML is substituted by relational DML statements to access the converted relational database (Housel, 1977).

The DML emulation strategy preserves the behaviour of the application program by intercepting the individual DML calls at execution time and invoking equivalent DML calls to the restructured database. For example, Computer Associate's ESCAPE/DL1 (CA, 1992c) translates input-output statements in IMS (a hierarchical database) to IDMS/R (a relational-like database) DML. An IMS application program can access and update an IDMS/R database through a run-time interpreter.

In the run-time environment of Computer Associate's ESCAPE/DL1 package, two components are used to translate DL/1 to IDMS/R requests. One component, the ESCAPE DL/1 Run-time Interface, receives DL/1 requests from the application program; it then accesses the IDMS/R database and presents the appropriate IMS segments to the application program. The other component, the Interface Program Specification Block (IPSB) Compiler, describes the correspondence between the IDMS/R database structure and the simulated IMS database structure that the application program will view. The IPSB Source contains user-supplied control information that is compiled by the IPSB Compiler; the resulting IPSB Load Module is loaded by the ESCAPE/DL1 Run-time Interface as shown in Figure 1-4.

5.4 DECOMPILATION

This approach first transforms a program written in a low level language into an equivalent but more abstract version and then, based on this abstract representation, implements new programs to fit the new environment, database files, and DBMS requirements. Decompilation algorithms have been developed to transform programs written with the procedural operators of CODASYL DML into programs that interact with a relational system via a non-procedural query specification. This is done through the analysis of the database access path.

For example, Katz and Wong (1982) designed a decompilation method that proceeded in two phases. The first phase is analysis. During this phase, a network database program is partitioned into blocks of statements for which an entry can only occur at the first statement. The user then seeks to group together a sequence of FIND statements that reference the same logically definable set of records, and to aggregate these sets whenever possible. The result is the mapping of a DML program into access path expressions.

The second phase is embedding, where the access path expression is mapped into a relational query and interfaced with the original program.

For instance, consider a program that finds the departments for which accountants born after 1950 are assigned, using the following network schema in Figure 5-3.

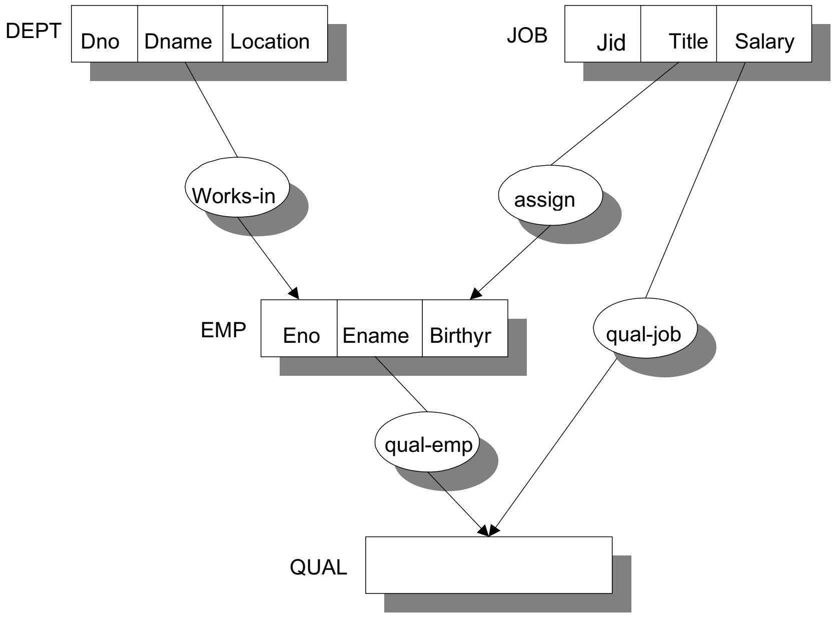


Figure 5-3 A sample network schema for decompilation

The corresponding relational schema is:

Relation DEPT (<u>Dno</u>, Dname, Location)
Relation JOB (<u>Jid</u>, Title, Salary)
Relation EMP (<u>Eno</u>, Ename, Birthyr, Dno, Jid)
Relation QUAL (*<u>Eno</u>, *<u>Jid</u>)

A sample network database program to be decompiled is as follows:

```
      MOVE 'ACCOUNTANT' TO TITLE IN JOB.
      FIND FIRST JOB USING TITLE.
 L.   IF NOT-FOUND GO TO EXIT.
      FIND FIRST EMP WITHIN ASSIGN.
 M.   IF EMP-OF-SET GO TO O.
      GET EMP.
      IF EMP.BIRTHYR ≤ 1950 GO TO N.
(other code that accesses emp in User Work Area)
      FIND OWNER WITHIN WORKS-IN.
      GET DEPT.
       :
 N. FIND NEXT EMP WITHIN ASSIGN.
         GO TO M.
 O. FIND NEXT JOB USING TITLE.
        GO TO L.
EXIT.
```

After the first phase, for each control block, we get a partition block as shown below:

```
MOVE 'ACCOUNTANT' TO TITLE IN JOB
(1)FIND FIRST JOB USING TITLE.
L.  IF NOT-FOUND GO TO EXIT.
    (2) FIND FIRST EMP WITHIN ASSIGN.
    M. IF END-OF-SET GO TO O.
      GET EMP.
      IF EMP.BIRTHYR ≤ 1950 GO TO N.
      (other code that accesses emp in User Work Area)
      (3)  FIND OWNER WITHIN WORKS-IN.
        GET DEPT.
    N.FIND NEXT EMP WITHIN ASSIGN.
    GO TO M.
O. FIND NEXT JOB USING TITLE.
    GO TO L.
     EXIT.
```

After the second phase, block 1 and 2 are translated into the first SQL select statement and block 3 is translated into secondary SQL select statements as shown below:

```
LET C1 BE
SELECT E.TID, E.ENO, E.ENAME, E.BIRTHYR FROM JOB, EMP
WHERE J.TITLE = JOB.TITLE AND E.ASSIGN = J.JID.
LET C2 BE
SELECT D.DNO, D.NAME, D.LOCATION FROM EMP, DEPT
WHERE E.TID = EMP.TID AND E.WORKS-IN = D.DNO.
MOVE 'ACCOUNTANT' TO TITLE IN JOB.
L.
  OPEN C1.
  SELECT C1.
M.  IF end of set GO TO EXIT.
     FETCH C1.
     IF EMP.BIRTHYR ≤ 1950 GO TO N.
------ other code ------
     OPEN C2.
     SELECT C2.
     FETCH C2.
        :
     CLOSE C2.
N. SELECT C1.
      GO TO L.
   EXIT.  CLOSE C1.
```

5.5 CO-EXISTENCE

This approach continues to support the nonrelational database while developing an information-capacity-equivalent relational database for the same application. Developers maintain an incremental mapping from the nonrelational database to the relational database. For example, Mark et al (1992) present an incrementally maintained mapping from a network to a relational database. At the beginning, the applications on the relational database are restricted to retrievals. Gradually, applications on the network database are rewritten and moved to the relational database, while the incremental mapping continues to maintain the relational database for the applications still running on the network database. The basic idea of the incremental maintained mapping is illustrated in Figure 5-4.

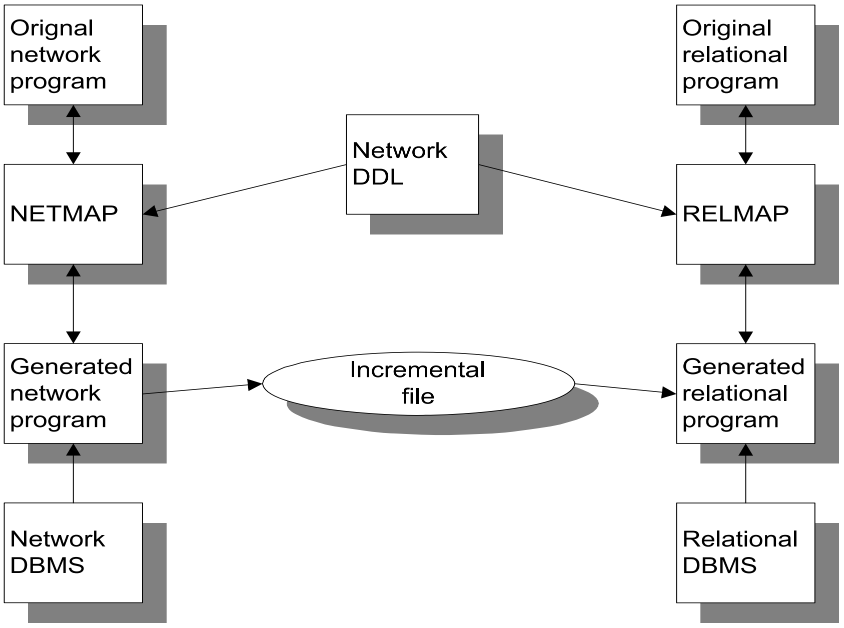


Figure 5-4 Incrementally converting network to relational database system

The initial network to relational database mapping algorithm takes as input the network schema defined in terms of the network DDL. The algorithm generates an equivalent relational schema definition in terms of the relational DDL, a program for unloading the network database to a temporary file and a program for uploading the temporary file to the relational database. After the relational database is defined using the generated relational DDL statements, the network database is mapped to the temporary file by using the generated unloading program. Finally, the uploading program reads the data in the temporary file and inserts them into the relational database.

At the network site, DML statements that update the database are monitored. Every time an update operation changes the database, the changes are also recorded in the differential file. This transformer is referred to as NETMAP.

At the relational site, all DML statements are monitored. Before a retrieval operation retrieves data from the database or an update operation changes the database, all changes recorded in the differential file, but not yet installed in the database, are first installed in the database. This transformer is referred to as RELMAP.

5.6 ADDING A RELATIONAL INTERFACE TO A NETWORK DATABASE

Emulation adds more workload to the database administrator because of the pre-compile macro call design of each database access. Decompilation is not feasible because of the nature of reverse engineering from lower level database management language to higher level database management language. Rewriting is very costly due to the number of bridge program(s) needed for each application program. Co-existence requires companies maintain two different database management systems at the same time, which requires much manpower. As a result, the relational interface approach is the preferred option.

Our approach applies a preprocess to map a network schema to an information-capacity-equivalent relational schema. This open schema includes derivation of primary and foreign keys in the transformed relational tables. Our objective is to implement the mapped relational schema over existing network schema to form an open internal schema that can be used concurrently by both relational and network database programs.

Before program conversion, we must translate the network schema to a relational schema without loss of information. Translation from network to relational schema involves a one-to-one mapping between the record type and the relation. The Set structure of the network schema is translated into the referential relationship between child and parent relations. For example, Zaniolo (1979) designed a set of relations that recast the network schema in terms of a relational model. In this structure, each network record type is mapped to a relation on a one-to-one basis. The record key of network schema is mapped to a primary key in the relational table. However, if the existing network record key is not unique, then we must concatenate it with its owner record key in order to create the primary key. The owner record key is also mapped as a foreign key in the relational table to link the parent and child records. If the set membership in the network schema is manual, then the record key of the member record will be mapped as a candidate key in the relational table.

Our approach enhances this schema translation by putting the translated relational record keys into secondary indices. The implementation of such secondary indices in each nonrelational record forms an open schema so that the access path of each record type takes only one I/O, the same as in the relational database primary indices. Secondary indices are composed of the record identifier that were derived from the primary keys of the owner records. The target of the secondary indices is each record type of the network database.

Basically, there are three types of record identifiers: fully internally identified, partially internally identified, and internally unidentified as described in Chapter 3. The record identifier is derived from the semantics of the existing network database. However, once a real-world situation has been modeled in a network schema, some of the semantics are irretrievable. We thus need user input to distinguish each type of record identifier so that we can recover its semantics. Figure 5-5 shows that such record identifiers are stored in the secondary indices in an existing nonrelational database (where F=fully internally identified, P=partially internally identified, I=internally unidentified, and IX=secondary indices).

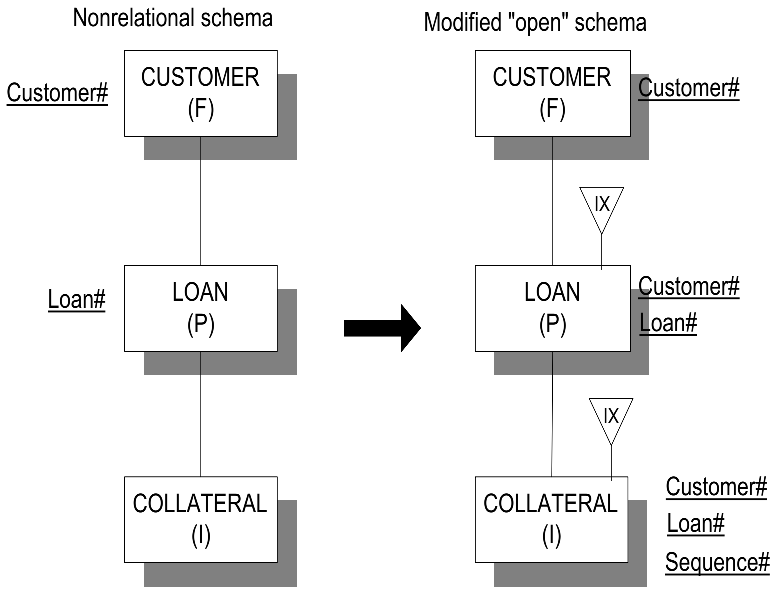
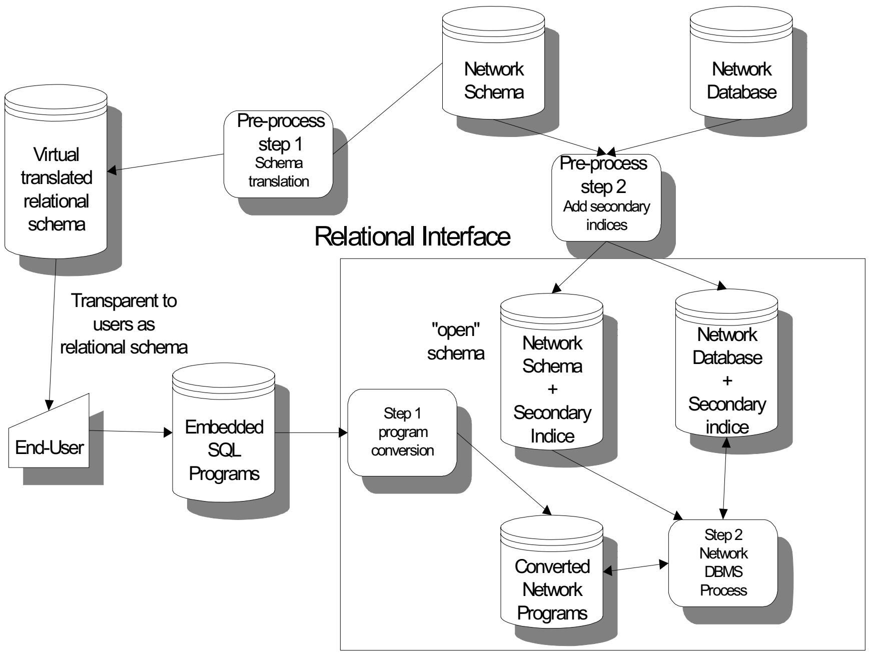


Figure 5-5 Add derived secondary indices

In Figure 5-6, we show a system flow diagram for an embedded SQL program that accesses the existing network database as an *open* database. Open in this context means that a network database with secondary indices can be accessed by both network and relational database programs.



Network Schema
Network Database
Virtual translated relational schema
Pre-process step 1 Schema translation
Pre-process step 2 Add secondary indices
Relational Interface
Transparent to users as relational schema
"open" schema
Network Schema + Secondary Indice
Network Database + Secondary indice
End-User
Embedded SQL Programs
Step 1 program conversion
Converted Network Programs
Step 2 Network DBMS Process

Figure 5-6 Relational interface provision for network databases

The overall procedure for creating this relational interface involves the following steps:

Preprocess step 1. Map network schema to a relational schema and derive secondary indices.

We first map the original network schema into a corresponding relational schema by:

- Deriving a corresponding relational record key for each network record type, confirmed with the users then

- Adding these derived record identifiers as secondary indices to the network schema

To implement these entity keys in the network schema, we must modify the existing network schema by adding the derived record identifiers as secondary indices to each record type so that each record type can act as a relational table. The modified schema can still be used by the network database program, because the additional secondary indices will not affect its operation. Since the translated schema is a network schema as well as a "Relational-like" schema to the user, we call it an "open" schema.

Preprocess step 2. Add the derived secondary indices into the network database.

We perform the data conversion at the logical level of data representation using an unload-and-upload technique. This technique converts the existing network database into an open database that embeds the derived secondary indices into each record. The conversion first unloads the data from each network database record type into a sequential file, adding the derived record identifier. Then it uploads each sequential file into the network database according to the modified "Relational-like" schema with secondary indices composed of the derived record identifiers.

Step 1. Translate SQL to network DML.

The main process of interface creation begins with program translation. To effect the translation process, we must define the algorithm and syntax for translating the relational DML (SQL, for example) to the network DML (IDMS, for example). After we complete the schema translation and create an open database by adding secondary indices to the internal schema, each SQL statement can be mapped to a series of IDMS statements.

The completed program translation will have a one-to-one mapping between each record type of the nonrelational database and each relation in the relational database, which ensures that the output of both DMLs will be the same. The following sections show the detail of the actual translation algorithms.

The user can now apply SQL statements to access the nonrelational database. Each SQL (the DML of relational database) statement is translated at the run time into the lower level DML of network database. The following are the major SQL statements for the Join, Select, Update, Insert, and Delete operations and their translation into the equivalent DML language of IDMS, a network DBMS (CA, 1992b).

Relational Operation Project

The general algorithm for projection translation follows, in which all attributes in a relation R, which corresponds to a record type N, are projected.

Algorithm Projection

```
1.  find first N record by secondary indices IX
2.  get $D_j$ values, j = 1, 2,..n /* get referenced data */
3.  find next N record
4.  exit if none
5.  continue from 2
```

The syntax for the algorithm Project is:

Relational	Network
Exec SQL Declare C cursor	Obtain first N within IX.
for	If return-code ≠ 0
Select * from Table-T	error-exit
End-Exec.	else
	Display N
Exec SQL Open C	Perform Loop until
end-exec.	end-of-record.
Exec SQL Fetch C into T.	Loop.
	Obtain next N within IX.
Display T.	Display N.

Relational Operation Join

In the relational model, a join operation is allowed between two relations if the joined attributes are compatible. Users may form joins from any two record types in the network database. In general, the Join operation for two record types N_i and N_k are as follows:

Algorithm Join

```
1.  find first $N_i$ record by secondary indices $IX_i$
2.  exit if none
3.  LOOP1: get referenced data item values in buffer
4.      LOOP2: find $N_k$ record by secondary indices $IX_k$
5.        evaluate compatible attributes /* if f1 = v1 and f2 = v2 */
6.        continue from 8 if evaluation fails
7.        get referenced data item values /* obtain joined record */
8.        find next $N_k$ record within secondary indices $IX_k$
9.        exit if none
10.       continue from LOOP2
11. find next $N_i$ record within secondary indices $IX_i$
12. exit if none
13. continue from LOOP1
```

The syntax for the algorithm Join is:

Relational	Network

Exec SQL Declare C
    cursor for
Select F1, F2....Fn
    from Table-T1,
    Table-T2.
End-exec.
 	
Exec SQL Open C
    end-exec.
 	
Exec SQL Fetch C into
T end-exec
	Find first N_i record within IX_i.
	  Find first N_k record within IX_k.
	  If record-found
	   perform LOOP1 until
	   end-of-record.
	
	LOOP1.
	  If f1=v1 and f2=v2
	    Obtain N_i record
	    Obtain N_k record.
	    Perform LOOP2 until
	    end-of-record.
	    Find next N_i record within IX_i.
	
	LOOP2.
	  Find next N_k record within IX_k.
	  If f1=v1 and f2=v2
	    Obtain N_i record
	    Obtain N_k record.

Relational Operation Insertion

Attribute values are specified for a tuple to be inserted in a relation R_k. We denote by $v_1, v_2 \ldots v_n$ the values for attributes corresponding to fields in N_k and with $V_1, V_2 \ldots V_f$ the values of the foreign keys in R_k.

Algorithm Insertion

1. locate the owner record type N_{k-1} of to-be-inserted record N_k within secondary indices IX_{k-1} using ID_{k-1}. /* ID_{k-1} = record identifier value in IX_{k-1} */
2. locate to-be-inserted record types N_k within secondary indices IX_k using ID_k ./* ID_k is the record identifier value in IX_k */
3. Establish contents of all N_k record data items in working storage ($v_1, v_2 \ldots v_n$, $V_1, V_2 \ldots V_f$).
4. store N_k record
5. connect N_k record to all owners record N_{k-1} in manual sets that have been established its currency in 2.

The syntax for the algorithm Insert is:

Relational	Network
Exec SQL Insert into	Find first N_{k-1} within Ix_{k-1} using
Table-T(F1, F2,....Fn)	ID_{k-1}.
Values (V1, V2.....Vn)	If return-code $\neq$ 0
End-Exec.	error-exit-1
	else
	Move V1 to F1
	Move V2 to F2
	...
	Move Vn to Fn
	Find first N_k within IX_k
	using ID_k
	If return-code = 0
	error-exit-2
	else
	Store N_k
	If set membership between
	N_k and N_{k-1} is manual
	connect N_k to N_{k-1}.

Relational Operation Deletion

A simple delete-only statement in the network database corresponds to the relational database delete statement for a given relational schema. The delete-record-N-only statement has the following properties:

- Remove record N_k from all set occurrences in which it participates as a member.

- Remove but do not delete all optional members N_{k+1}, for each set where N_k participates as an owner record.

- Do not delete record N_k if there are fixed or mandatory members record N_{k+1} for each set S where N_k participates as an owner record.

The syntax for the algorithm Delete is:

Relational	Network

Exec SQL Delete from
Table-T
where F1 = V1
  and F2 = V2
  and ...
  and Fn = Vn
End-Exec.
	Obtain first N_k within IX_k
	  using ID_k.
	If return-code ≠ 0
	  error-exit-1
	else
	  Find current N_{k+1} within S
	  If return-code = 0
	    error-exit-2
	  else
	    Erase N_k.

Relational Operation Update

Suppose we want to replace the value of an attribute A in the relation R with the value V. Basically, we consider two cases. In the first case, A is not a foreign key. It corresponds to a data item in the corresponding record type N and thus we need a modify network command to perform the replacement. In the second case, A is a foreign key. Replacing a value in this case involves changing the set linkages, rather than the attribute value. Value (A) is the content of attribute A in the record type N before update.

Algorithm Update

```
If A ∈ {A1, A2,...   An} /* A is a non-foreign key attribute */
 then if A = K(R) /* K(R) = key field in record R */
        then drop the update /* disallow update record key */
        else do
              get $N_k$ record by secondary indices $IX_k$
              modify $N_k$ record /* update non-key field by A=V */
             end
  else if V ≠ null and value(A) = null /* A is a foreign key */
        then connect $N_k$ to new-owner-record $N_n$ /* insert $N_k$ into
                                                   new owner record set */
  else if V = null and value(A) ≠ null
        then disconnect $N_k$ from old-owner-record $N_{k-1}$
                         /* remove $N_k$ from old owner record set */
  else if V≠ null and value(A) ≠ null
        then reconnect $N_k$ from old-owner-record $N_{k-1}$ to new-
                         owner-record $N_n$. /* change $N_k$ owner */
```

Other functions implied by the network IDMS include:

- Mandatory or fixed set membership will disallow the disconnect operation in order to preserve original inherent constraint of network database.

- Fixed set membership will disallow foreign key change.

The syntax for the algorithm Update is:

Relational	Network
Exec SQL Update Table-T	Obtain first N_k within IX_k using ID_k.
set F1 = V1	If return-code $\neq 0$
and F2 = V2	error-exit
and Fn = Vn	else
End-Exec.	if A $\neq$ foreign key
	Move V1 to F1
	.....
	Move Vn to Fn
	Modify N_k
	else
	if V $\neq$ null and value(A) = null
	Find first N_n within Ix_n
	Connect N_k to N_n
	else
	if V = null and value(A) $\neq$ null
	Find first N_{k-1} within IX_{k-1}
	Disconnect N_k from N_{k-1}
	else
	if V$\neq$ null and value (A) $\neq$ null
	Find first N_{k-1} within IX_{k-1}
	Find first N_n within Ix_n
	Reconnect N_k from N_{k-1} to $N_{n.}$

Step 2. Processing network database data manipulation language.

The translated network database program is now ready for processing. From the users' point of view, they are executing an embedded-SQL program. However, from the system point of view, the embedded SQL program has been translated into a network database program, to access the network DBMS. Because of the equivalent translated network DML statements (compared with the embedded SQL statements), the result of the translated network database program is the same as the result of the embedded SQL program. Such processing can be successful if accomplished by changing the execution environment, i.e., mapping the relational schema of the embedded SQL program to the network schema of the translated network database program in the pre-process step 1 and adding secondary indices to the translated network schema and the network database in the pre-process step 2.

On the other hand, even with the secondary indices added to the network database, the existing network database program, after recompilation with the modified secondary-indices-add network schema, can still access the modified network database as it did before the addition, as Figure 5-7 shows (Figure 5-7 is an extension of Figure 5-6). As a result, the modified network DBMS acts as a relational interface to relational database program and as a network DBMS to the network database program. The benefit of this relational interface is that the users can write new programs using an embedded-SQL (relational database) program while the existing (out-of-dated) network database programs are still in use. The out-of-dated network database programs should be gradually phased out or rewritten to use an embedded-SQL program.

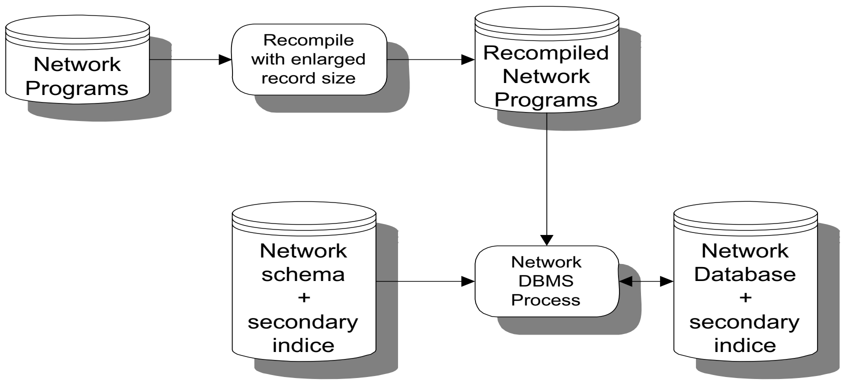

Network Programs
Recompile with enlarged record size
Recompiled Network Programs
Network schema + secondary indice
Network DBMS Process
Network Database + secondary indice

Figure 5-7 Existing network database programs access "open" database

Case Study of Translating Embedded SQL to Network Database Program

To illustrate the emulation algorithm in a case study, the following is an embedded SQL program that will be able to access the network database for the manufacturer's part supplier system of Figure 5-8.

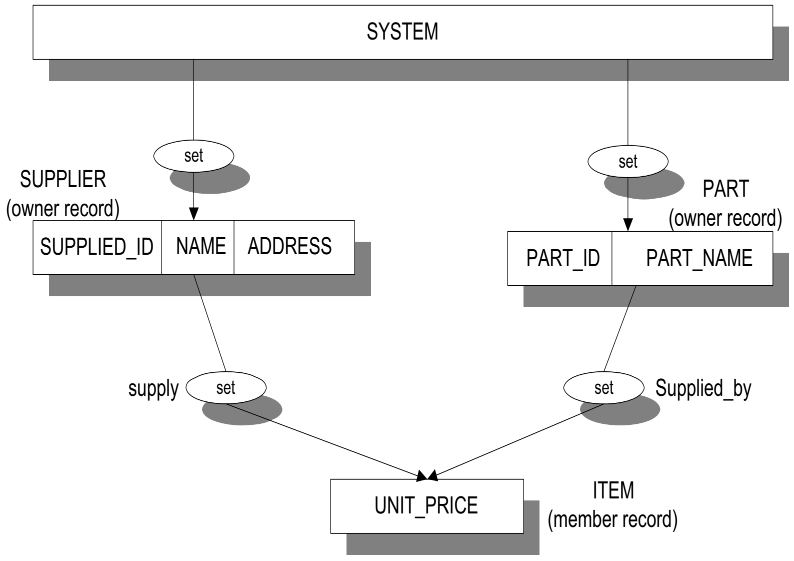


Figure 5-8 Network schema

Sample data from the Network database could be as follows:

SUPPLIER

SUPPLIER_ID	SUPPLIER_NAME	ADDRESS
S1	John’s Co.	32 Ivy Road
S2	Michael Lee	61 Clark Road
S3	Jack's Store	90 Dicky Road
S4	Michael Lee	61 Clark Road

PART

PART_ID	PART_NAME
P1	Sugar
P2	Orange Juice
P3	Beer
P4	Chocolate

ITEM

UNIT_PRICE
4
5
6

After schema transformation, the modified network schema acting as an “open” internal schema is as shown in Figure 5-9.

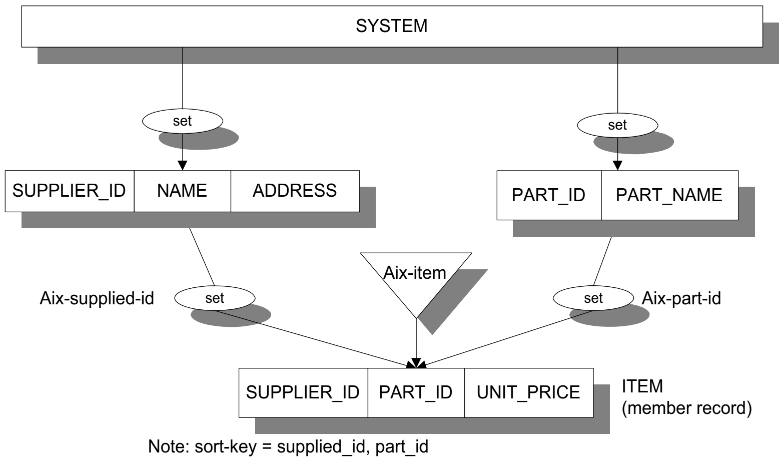


Figure 5-9 Network schema with secondary indices as "open" schema

The data of the converted database are:

SUPPLIER

SUPPLIER_ID	SUPPLIER_NAME	ADDRESS
S1	John’s Co.	32 Ivy Road
S2	Michael Lee	61 Clark Road
S3	Jack’s Stare	90 Dicky Road
S4	Michael Lee	61 Clark Road

PART

PART_ID	PART_NAME
P1	Sugar
P2	Orange Juice
P3	Beer
P4	Chocolate

ITEM

SUPPLIER_ID	PART_ID	UNIT_PRICE
S1	P1	4
S2	P3	6
S3	P1	5

SUPPLIER_ID, PART_ID together will be used as secondary indices in the network schema. The network schema has also been converted to a relational schema as follows:

Relation SUPPLIER (<u>SUPPLIER_ID</u>, NAME, ADDRESS)
Relation PART (<u>PART_ID</u>, PART_NAME)
Relation ITEM (<u>SUPPLIER_ID</u>, <u>PART_ID</u>, UNIT_PRICE)

We can thus write an embedded-SQL program with two SQL statements (Select and Insert) to access the translated relational schema as follows:

```
ID DIVISION.
PROGRAM-ID.  RELATIONAL-DATABASE-PROGRAM.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. DG MV10000.
OBJECT-COMPUTER. DG MV10000.
DATA DIVISION.
WORKING-STORAGE SECTION.
  EXEC SQL DECLARE C1 CURSOR FOR
      SELECT * FROM SUPPLIER
  END-EXEC.
01 SUPPLIER.
      05  SUPPLIER-ID          PIC X(4).
      05  SUPPLIER-NAME        PIC X(20).
      05  ADDRESS              PIC X(20).
01 PART.
      05  PART-ID              PIC X(4).
      05  PART-NAME            PIC X(20).
01 ITEM.
      05  SUPPLIER-ID          PIC X(4).
      05  PART-ID              PIC X(4).
      05  UNIT-PRICE           PIC 9(4).
01 PRICE                       PIC ZZ9.
77 NO-DATA                     PIC S9(9) COMP VALUE +100.
77 END-OF-SET                  PIC S9(9) COMP VALUE +100.
77 ACCESS-OK                   PIC S9(9) COMP VALUE +0.
PROGRAM DIVISION.
000-MAIN-ROUTINE.
      PERFORM 100-SELECT-ITEM.
      PERFORM 300-INSERT-ITEM.
      EXEC SQL CLOSE C1 END-EXEC.
      STOP RUN.
100-SELECT-ITEM.
   EXEC SQL OPEN C1 END-EXEC.
   EXEC SQL FETCH C1 INTO :ITEM END-EXEC.
   IF SQLCODE = NO-DATA
     DISPLAY 'NO SELECTED RECORD IN ITEM TABLE'
   ELSE
     MOVE UNIT-PRICE TO PRICE
     DISPLAY 'SUPPLIER ' ITEM.SUPPLIER-ID
          ',  PART  ' ITEM.PART-ID, ':  PRICE ' PRICE
     PERFORM 150-SELECT-NEXT-ITEM
        UNTIL SQLCODE = END-OF-SET.
150-SELECT-NEXT-ITEM.
   EXEC SQL FETCH C1 INTO :ITEM END-EXEC.
   IF SQLCODE = ACCESS-OK
     MOVE UNIT-PRICE TO PRICE
     DISPLAY 'SUPPLIER ' ITEM.SUPPLIER-ID
          ', PART '   ITEM.PART-ID, ': PRICE '  PRICE.
300-INSERT-ITEM.
   MOVE 'S3' TO SUPPLER-ID.
   MOVE 'P1' TO PART-ID.
   MOVE 5 TO UNIT-PRICE.
   EXEC SQL INSERT INTO ITEM
       (SUPPLIER-ID, PART-ID, UNIT-PRICE)
       VALUES (:SUPPLIER-ID, :PART-ID, :UNIT-PRICE)
   END-EXEC.
   IF SQLCODE = NO-DATA
     DISPLAY 'NO RECORD INSERTED'
   ELSE
     MOVE UNIT-PRICE TO PRICE
     DISPLAY 'SUPPLIER ' ITEM.SUPPLIER-ID
          ', PART   ' ITEM.PART-ID
          ': PRICE  ' PRICE ' INSERTED'.
```

After program translation, the above embedded-SQL program will be translated into a network database program containing the emulated Network DML statements of OBTAIN and STORE as shown below:

```
IDENTIFICATION DIVISION.
PROGRAM-ID. CONVERTED-NETWORK-DATABASE-
          PROGRAM.
ENVIRONMENT DIVISION.
  CONFIGURATION SECTION.
  SOURCE-COMPUTER. DG MV10000.
  OBJECT-COMPUTER. DG MV10000.
DATA DIVISION.
SUBSCHEMA SECTION.
COPY "SUBSUPPLY.COB"
WORKING-STORAGE SECTION.
```

```
77 TXT-NO              PIC 9(10).
01 PRICE               PIC ZZ9.
77 NO-DATA             PIC S9(9) COMP VALUE +100.
77 END-OF-SET          PIC S9(9) COMP VALUE +100.
77 ACCESS-OK           PIC S9(9) COMP VALUE +0.
PROCEDURE DIVISION.
MAIN-CNV SECTION.
INIT.
    READY UPDATE.
    INITIATE TRANSACTION TX-NO USAGE UPDATE.
000-MAIN-ROUTINE.
      PERFORM 100-SELECT-ITEM.
      PERFORM 300-INSERT-ITEM.
      COMMIT.
      FINISH.
      STOP RUN.
100-SELECT-ITEM.
    OBTAIN FIRST ITEM WITHIN AIX-ITEM.
    IF DBMS-STATUS NOT = 00000
      DISPLAY 'NO RECORD IN ITEM TABLE'
    ELSE
      MOVE UNIT-PRICE TO PRICE
      DISPLAY 'SUPPLIER ' AIX-SUPPLIER-ID
            ', PART   ' AIX-PART-ID
            ': PRICE  ' PRICE
      PERFORM 150-SELECT-NEXT-ITEM
        UNTIL DBMS-STATUS = 17410.
150-SELECT-NEXT-ITEM.
   OBTAIN NEXT ITEM WITHIN AIX-ITEM.
   IF DBMS-STATUS = 00000
     MOVE UNIT-PRICE TO PRICE
     DISPLAY 'SUPPLIER ' AIX-SUPPLIER-ID
           ', PART   ' ,AIX-PART-ID, ': PRICE  ' PRICE.
300-INSERT-ITEM.
   MOVE 'S3' TO SUPPLIER-ID.
   MOVE 'P1' TO PART-ID.
   MOVE 5    TO UNIT-PRICE.
   FIND FIRST PART WITHIN AIX-PART USING SORT KEY.
   IF DBMS-STATUS NOT = 00000
    DISPLAY 'NO RECORD INSERTED - MISSING OWNER
        IN PART'
   ELSE
     FIND FIRST SUPPLIER WITHIN AIX-SUPPLIER
        USING SORT KEY
     IF DBMS-STATUS NOT = 00000
```

```
        DISPLAY 'NO RECORD INSERTED -
          MISSING OWNER IN SUPPLIER'
    ELSE
      MOVE SUPPLIER-ID TO AIX-SUPPLIER-ID.
    MOVE PART-ID TO AIX-PART-ID.
    OBTAIN FIRST ITEM
          WITHIN AIX-ITEM USING SORT KEY.
    IF DBMS-STATUS = 00000
      DISPLAY 'NO RECORD INSERTED'
    ELSE
      STORE ITEM
      MOVE UNIT-PRICE TO PRICE
      DISPLAY 'SUPPLIER ' AIX-SUPPLIER-ID
            ', PART   ' AIX-PART-ID
            ': PRICE  ' PRICE ' INSERTED'.
```

5.7 *ADDING A RELATIONAL INTERFACE TO A HIERARCHICAL DATABASE*

The hierarchical to relational schema mapping is based on key-propagation, which is very similar to the process of normalising a relational schema. There is a one to one correspondence between segment types and relations. In addition, the key fields of higher level segment types are propagated to lower level segment types. Because of database navigation, the user needs to use a parent segment key in order to access its child segment. As a result, the parent segment key is concatenated with the child segment key to identify the child segment. When we map hierarchical schema to relational schema, the parent segment key will appear in both the parent relation and child relation, which leads to the existence of redundant data. For example, the CUSTOMER# in Figure 5-5 will appear in both relation Customer and relation Loan when mapping the left-hand-side hierarchical schema to right-hand-side relational schema. However, semantically, if CUSTOMER# is not needed to identify the relation Loan, then the relation Customer and relation Loan are not normalized.

Any hierarchical link is an inherent integrity constraint, which ensures that a child segment occurrence is connected automatically to a parent segment occurrence and may not be removed unless deliberately deleted. Following the DBTG (database task group, a database committee in 60s and 70s) terminology, the hierarchical link is of type: fixed-automatic.

To illustrate the program translation from relational to hierarchical, we must show the syntax for translating each SQL to a hierarchical database management language of IMS (Information Management System, a hierarchical DBMS). There are four parameters in IMS database management language. They are:

- Function Code, which defines the database access function
- Program Control Block, which defines the external subschema access path
- I-O-Area, which is a target segment address
- Segment Search Argument, which defines the target segment selection criteria as follows:

```
CALL "CBLTDLI" USING FUNCTION-CODE
                     PCB-MASK
                     I-O-AREA
                     SSA-1
                     ...
                     SSA-n.
```

After the schema translation, we create an open database by adding secondary indices to the IMS schema. Next, at runtime, we map an SQL statement to a series of IMS DML statements. The overall methodology for program translation from a relational to a hierarchical model can be described with a procedure similar to those previously described for converting from the network model to the relational model:

Preprocess step 1. Schema translation.

Preprocess step 2. Data conversion.

Step 1. Translate SQL to hierarchical database DML:

Program translation can be completed in a similar manner to the network database. By the addition of secondary indices we can translate the relational SQL into the hierarchical database DML.

The algorithms and procedures are similar, except for the Update operation. An update operation that alters the value of a foreign key in the relational database cannot be directly translated to a hierarchical database such as IMS. This is because the linkages between parent and child segments are fixed and the parentage, once established, cannot be changed. To change the linkage, we must write a special program that copies the child segment and its dependent segments to a new child segment, and then deletes the old child segment. On the other hand, if we update a non-key field, the process is simple. The Update operation in a relational database can be translated to the hierarchical database using the following algorithm:

Algorithm Update

```
1. Set up position of target segment H.
2. Set up new values of target segment H.
3. Update target segment H.
```

The syntax for the algorithm Update is:

Relational	Hierarchical
Exec SQL Update	Move Vk1 to Fk1.
Table-T	Move Vk2 to Fk2.
set F1 = V1 and	……
F2 = V2 and	Move Vkn to Fkn.
……	Exec DLI GHU using PCB(1)
Fn = Vn	Segment T
End-Exec.	into Segment-area
	where S1=Fk1
	and S2=Fk2
	…
	and Sn=Fkn.
	If return-code = space
	Move V1 to F1
	…..
	Move Vn to Fn
	Exec DLI REPLACE
	else
	error-exit.

Step 2. Processing hierarchical database DML.

The translated hierarchical database programs are now ready for processing. The result of processing the translated hierarchical database program will be the same as the result of processing the embedded SQL program before translation. Similarly, Figure 5-6 shows (if we substitute all occurrences of "network" with "hierarchical") that even with the secondary indices added to the hierarchical database, the existing hierarchical database program, after recompilation with the modified secondary-indices-added hierarchical schema, can still access the modified hierarchical database as it did before. As a result, the modified hierarchical DBMS acts as a relational interface to the relational database program and as a hierarchical DBMS to the hierarchical database program. The out-of-date hierarchical database programs should be phased out or rewritten to the embedded SQL programs.

5.8 IMPLEMENTATION OF THE RELATIONAL INTERFACE

We can implement the relational interface by translating an embedded SQL Cobol program source to DL/1 Cobol program source code. The types of relational operations addressed include Select, Join, Update, Insert, and Delete. Figure 5-10 shows the data flow diagram of the relational interface.

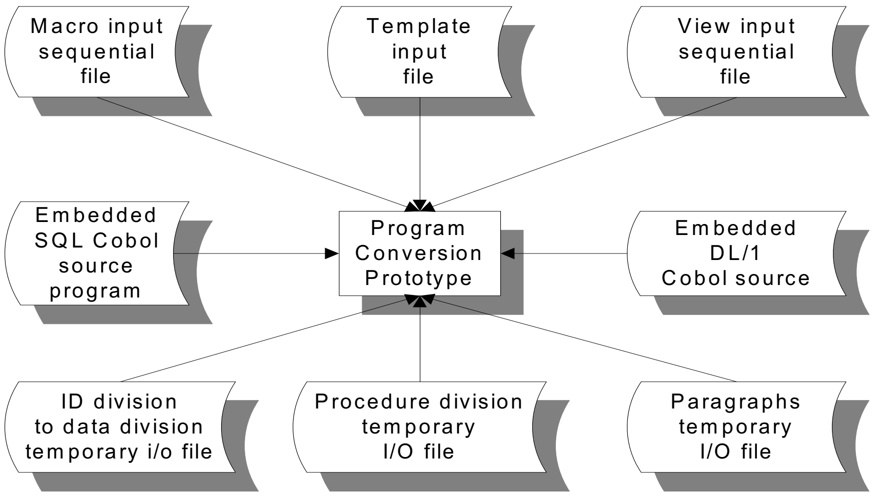

Macro input sequential file
Template input file
View input sequential file
Embedded SQL Cobol source program
Program Conversion Prototype
Embedded DL/1 Cobol source
ID division to data division temporary i/o file
Procedure division temporary I/O file
Paragraphs temporary I/O file

Figure 5-10 System diagram of the program translation

The relational interface software scans the Cobol source program, filtering embedded SQL commands and passing them to the SQL command analyzer. The software determines the type of operation in the extracted SQL command by analyzing the command tokens. Some tokens, such as Table Name, Field Name, Conditions, and Host Variable, are saved. The recognised relational operation type is used to find the corresponding template macro in the macro file.

The macro file contains the embedded DL/1 (Data Language I, IMS database management language) in Cobol statements for emulating one embedded SQL Cobol command. Each operation has its own macro for the segment and field to be changed depending on the operation. The use of the macro variables lets the segment names be substituted when the macro is expanded. Each variable indicates where a parameter is required. The variable name is preceded by ! and delimited by ^ and has a maximum length of eight as required by DL/1. For example, TAB_NAME on the first line of the following sample macro is the name of a variable that is replaced, in this case, by a table name.

The template macro then generates the emulation source code, with the dummy variable being replaced by the saved tokens selected earlier.

A sample macro is shown below:

```
UPDATE PERFORM !TAB-NAME^-REPLACE-!SERIALNO^
                        !FULLSTOP^
UPDTWH !TAB-NAME^-REPLACE-!SERIALNO^.
    EXEC DLI GHU USING PCB(1)
                               SEGMENT (!TAB-NAME^)
                               INTO (!TAB-NAME^-AREA)
                               SEGLENGTH (!TAB-NAME^-LEN)
                               WHERE (!WHERE-CL^)
                               FIELDLENGTH(!FLD-NAME^-LEN)
   END-EXEC.
   IF DIBSTAT = 'E'
      MOVE +100 TO DLICODE
   ELSE
      COMPUTE !SET-CLUA^
      EXEC DLI REPLACE
    END-EXEC.
```

5.9 REENGINEERING RELATIONAL DATABASE PROGRAMS INTO OBJECT-ORIENTED DATABASE METHODS

Our methodologies can reengineer traditional record-based database systems into table-based database systems, and to integrate a database system with an expert system into an object-oriented system. As object-oriented paradigm is the trend of computer technologies for better productivity, we must reengineer existing database systems into object-oriented databases too. We have described the schema translation and data conversion from a relational database to an object-oriented database. This section is to describe how to translate relational database programs (i.e., embedded SQL programs) into object-oriented database programs.

Relational database programs can be defined as program logic with non-procedural call of embedded-SQL statements. In general, object-oriented database programs are encapsulated methods in each object. The participated boundary of relational database programs are more general. However, the participated boundary of object-oriented database methods is bounded by each object. As a result, the functional specification of relational database programs are multi-threaded with many outputs (i.e., many inputs and many outputs), while the functional specification of object-oriented database methods are one in, one out (i.e., one input, one output). To convert a relational database program into object-oriented methods, we must therefore break down the relational database into modules such that each module accesses only one object. The program logic of a relational database program can be converted into program logic of messages among objects.

The translation steps can be as follows:

The Relational Database

Relation Supplier (supplier-id, supplier-name, address)
Relation Part (part-id, part-name)
Relation Item (supplier-id, part-id, unit-price)

Step 1. Schema translation from relational into object-oriented as described in Chapter 3.

Step 2. Data conversion from relational into an object-oriented database as described in Chapter 4.

Step 3. Break down the logic of each relational database program into messages logic such that each message invokes an object by translating each module into an object's method and translating the other program logic into message processing logic among objects.

For example, the example of the following embedded-SQL program can be translated into the following object-oriented methods using UniSQL as a sample (UniSQL, 1992):

Step 1. Relational tables SUPPLIER, PART, and ITEM are translated into the following objects:

```
create supplier                      create part
(supplier_id string,                 (part_id string,
 supplier_name string,               part_name string));
  address string));

create unit_price
(unit_price integer,
 supplied_by supplier,
 supplemented_by part));
```

Step 2. Data on relational tables SUPPILER, PART, and UNIT_PRICE are unloaded and uploaded into data of object student under an object-oriented database management system.

Step 3.1. The relational database programs to select and insert items is translated into messages that access object ITEM in different methods using UniSQL, an object-oriented database.

As an example, an embedded SQL program is as follows:

```
ID DIVISION.
PROGRAM-ID. Relational-DATABASE-PROGRAM.
ENVIRONMENT DIVISION.
DATA DIVISION
WORKING-STORAGE SECTION.
    EXEC SQL DECLARE TEST1 CURSOR FOR
      SELECT * FROM SUPPLIER
    END-EXEC.
01 SUPPLIER.
    05    SUPPLIER-ID   PIC X(4).
    05 SUPPLIER-NAME PIC X(20).
    05    ADDRESS       PIC x(20).
01  PART.
    05    PART-ID       PIC X(4).
    05    PART-NAME     PIC X(20)
01  ITEM.
    05    SUPPLIER-ID   PIC X(4).
    05    PART-ID       PIC X(4).
    05    UNIT-PRICE    PIC 9(4).
01  PRICE               PIC Z99.
77  NO-DATA          PIC S9(9) COMP VALUE +100.
PROGRAM DIVISION.
000-MAIN-ROUTINE.
    MOVE 'S3' TO SUPPLIER-ID.
    MOVE 'P1' TO PART-ID.
```

```
            MOVE 5 TO UNIT-PRICE.
            EXEC SQL INSERT INTO ITEM
              (SUPPLIER-ID, PART-ID, UNIT-PRICE)
            VALUES (:SUPPLIER-ID, :PART-ID, :UNIT-PRICE)
            END-EXEC.
        IF SQLCODE = NO-DATA
              DISPLAY 'NO RECORD INSERT'
            ELSE
              MOVE UNIT-PRICE TO PRICE
              DISPLAY 'SUPPLIER' ITEM.SUPPLIER-ID
              ', PART ' ITEM.PART-ID
              ': PRICE ' PRICE ' INSERTED'.
```

Step 3.2. The emulation method of this embedded-SQL program can be converted into an UniSQL C program as follows:

```
void
in_info(DB_OBJECT *class_object, DB_VALUE *return_arg,
DB_VALUE *supplier_id, DB_VALUE *supplier_name,
DB_VALUE *supplier_address, DB_VALUE *part_id,
DB_VALUE *part_name, DB_VALUE *unit_price)

{
 EXEC SQLX BEGIN DECLARE SECTION;
 DB_OBJECT *class_obj = class_object;
 const char *supplier_id;
 const char *supplier_name;
 const char *supplier_address;
 const char *part_id;
 const char *part_name;
 const char *unit_price;
 DB_OBJECT *new_instance = NULL;
 EXEC SQLX END DECLARE SECTION;
 DB_MAKE_NULL(return_arg);

 supplier_id = DB_GET_STRING(supplier_id);
 supplier_name = DB_GET_STRING(supplier_name);
 supplier_address = DB_GET_STRING(supplier_address);
 part_id = DB_GET_STRING(part_id);
 part_name = DB_GET_STRING(part_name);
 unit_price = DB_GET_STRING(unit_price);

if (supplier_id != NULL && part_id != NULL && unit_price !=
NULL)
 EXEC SQLX INSERT INTO item(supplier_id, supplier_name,
supplier_address, part_id, part_name, unit_price) VALUES
(::supplier_id, ::suplier_name, ::supplier_address, ::part_id, ::part_
name, ::unit_price) TO :new_instance;

 if (new_instance != NULL)
   DB_MAKE_OBJECT(return_arg, new_instance);
};
```

Step 3.3 Message of invoking this object can be translated into the following message command file.

Call main

5.10 TRANSACTION TRANSLATION FROM SQL TO OSQL

To translate transactions from RDB to OODB, we can apply a symbolic transformation technique that contains syntax translation and semantic translation for SQL. For syntax translation, an SQL statement will be modified. For semantic translation, navigational syntax will be modified. For example, the join operation in RDB can be replaced by class navigation (association) in OODB. Queries of source language are built in our model. We navigate the query graph (QG) of SQL and then map it to the QG of OSQL (object-oriented SQL or OQL) (Cattell, 1997) with reference to the intermediate result of schema translation. Semantic rules (transformation definition) for query transformation from source language to target language will be applied. Then, query of target language will be produced. The output query OSQL should be the syntactic and semantic equivalent to the source SQL.

The OSQL, the object-oriented extension to SQL, allows data retrieval using path expressions, and data manipulation using methods. In query transformation, a syntax-directed parser converts the input OSQL into multi-way trees. The transformation process is then performed, based on the subtree matching and replacement technique. The process of SQL to OSQL transformation is in Figure 5-11.

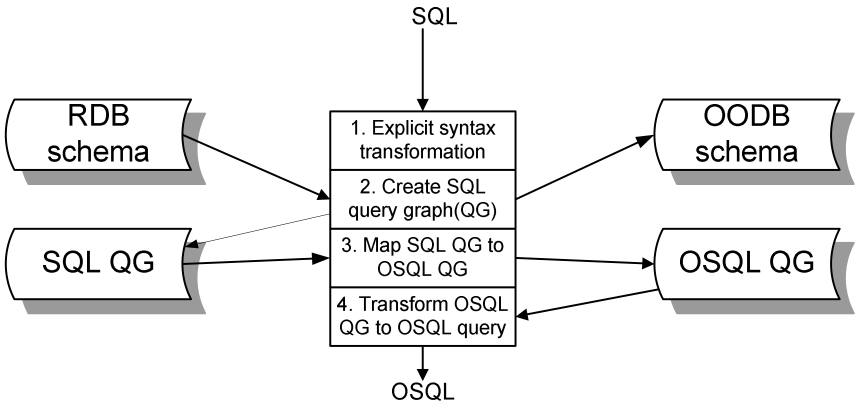

SQL
RDB schema
1. Explicit syntax transformation
2. Create SQL query graph(QG)
3. Map SQL QG to OSQL QG
4. Transform OSQL QG to OSQL query
OODB schema
SQL QG
OSQL QG
OSQL

Figure 5-11 Process for SQL to OSQL translation

After schema mapping from RDB to OODB, we can transform an RDB transaction (SQL) to an OODB transaction (OSQL). The following sections detail the major SQL statements for the Join, Update, Insert, and Delete operations and their translation into the equivalent OSQL statements.

Relational Operation Join

In the relational model, a join operation is allowed between two relations if the joined attributes are compatible. Users may transform a join operation in RDB to class navigation in OODB. The technique is to convert the database access path from SQL's query graph of joining relations: $R_1,R_2,\ldots\ldots R_n$ to the OSQL's query graph of navigating classes: C_{anchor}, $C_2,\ldots\ldots C_n$. The join operation can be transformed to class navigation for class C_{anchor} (first class in class navigation path) (Fong, 1997) as:

Step 1. Decompose SQL query transaction.

During this step, the SQL query transaction is decomposed into groups by parsing its syntax as:

SELECT {attribute-list-1} FROM {$R_1,R_2,\ldots\ldots R_n$}
WHERE {join-condition} AND/OR {search-condition-1}
ORDER BY {attribute-list-2} GROUP BY {attribute-list-2} HAVING {search-condition-2}

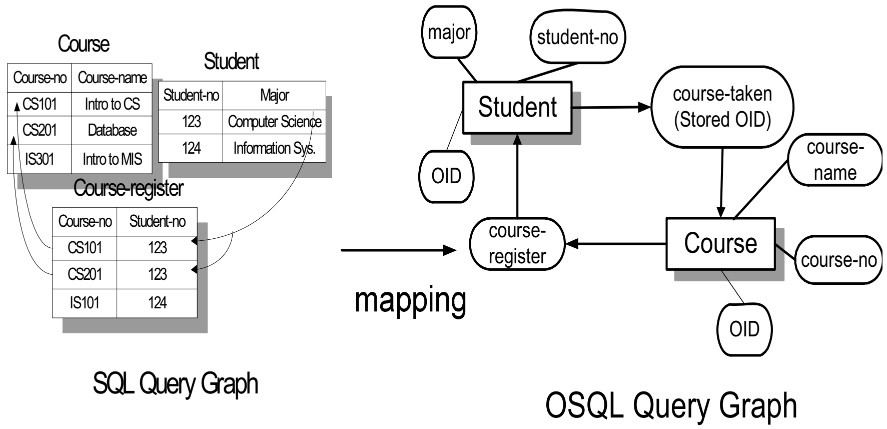
Step 2. Create the query graph of SQL through input relations join path. Based on the input relations, a join graph can be created to indicate the join condition from one relation to another. The join condition can be based on the natural join, i.e., the value match of common attributes of the input relations, or, based on the search condition specified in the SQL statement. The join path can be described as:

$R_1 \xrightarrow[J_1]{} R_2 \xrightarrow[J_2]{} \ldots\ldots \xrightarrow[J_n]{} R_n$ where $J_1, J_2 \ldots\ldots J_n$ are join and search conditions

Step 3. Map the SQL query graph to OSQL query graph.
We can map each relation to a corresponding class from the pre-process. The first relation in the join graph (in step 2) can be mapped to an anchor class. We can then form a class navigation path to follow from the anchor class to its associated class, and so on until all the mapped classes are linked. The class navigation graph is the mapped OSQL query graph as shown below:

$C_{anchor} \xrightarrow[P_1]{} C_2 \xrightarrow[P_2]{} .. \xrightarrow[P_n]{} C_n$ where $P_1, P_2 .. P_n$ are aggregate attributes of class $C_{anchor}, C_2 .. C_n$

For example, Figure 5-12 shows how a SQL query graph among three relations' join query graph is mapped into an OSQL query graph among two classes associated by the Stored OID of class Student addressing to the OID of class Course. Note that query graphs are in the direction of the arrows.



Course

Course-no	Course-name
CS101	Intro to CS
CS201	Database
IS301	Intro to MIS

Student

Student-no	Major
123	Computer Science
124	Information Sys.

Course-register

Course-no	Student-no
CS101	123
CS201	123
IS101	124

Figure 5-12 A SQL query graph is mapped to an OSQL query graph

Step 4. Transform SQL to OSQL query transaction
From the query graph of SQL, a corresponding OSQL transaction can be

constructed by

- Replacing the target attribute of relations by the target attribute of classes in navigation path
- Replacing the input relations in the FROM clause by the anchor class

The translated OSQL statement can be described as:

SELECT {attributes in classes navigation path into OID} FROM {C_{anchor}}
WHERE {transformation of join-condition} AND/OR {transformation of search-condition-1}
ORDER BY {transformation of attribute-list-2} GROUP BY {transformation of attribute-list-2}
HAVING {transformation of search-condition-2}

Refer to the case study for an example.

Relational Operation Insertion

Attribute values are specified for a tuple to be inserted in a relation R_k. We denote by v_1, $v_2 \ldots v_n$ the values corresponding to attributes in R_k and, if any, with V_{f1}, $V_{f2} \ldots V_{fm}$ corresponding to the foreign keys in R_k. The transformation technique is to preserve the referential integrity between parent relations and child relations through foreign keys V_{f1}, $V_{f2} \ldots V_{fm}$ in RDB to the association between class C_k and its associated class through aggregate attributes $^P{}_{c1}$, $^P{}_{c2} \ldots {}^P{}_{cm}$ in OODB as follows (Fong, 2000):

Step 1. Locate the to-be-inserted object
According to the pre-process, we can map the to-be-inserted tuple in RDB to a corresponding to-be-inserted object in OODB as follows:

SQL: INSERT into R (v_1, $v_2 \ldots v_n$, V_{f1}, $V_{f2} \ldots V_{fm}$) value ($V(v_1)$, ..$V(v_n)$, $V(V_{f1}) \ldots V(V_{fm})$)

Pre-process(schema translation): Relation R_k ($v_1, v_2 \ldots v_n, V_{f1}, V_{f2} \ldots V_{fm}$)$\rightarrow$ Class C_k (A_1, $A_2 \ldots A_n$, P_{c1}, $P_{c2} \ldots P_{cm}$)

Step 2. (optional). Locate composite objects that contain the to-be-inserted object.

The aggregate attributes of a composite object contains the stored OID of another object. We can locate, if any, the parent relations R_{p1}, R_{p2}…R_{pm} of the relation R_k with the to-be-inserted tuple by matching its foreign keys V_{f1}, V_{f2}…V_{fm} against their parent relations' primary keys. We can map these parent relations to the associated class C_{a1}, C_{a2}…C_{am} class of the to-be-inserted class C_k by matching the values of foreign keys as follows:

*SELECT * from C_{a1} where $A_{a1} = V_{f1}$ into :* $OID_{C_{a1}}$

…..

SELECT * from C_{am} where $A_{am} = V_{fm}$ into : $OID_{C_{am}}$

Step 3. Insert the to-be-inserted object.
We can then put the OID of the composite objects (in step 2) into the aggregate attributes of the to-be-inserted object and insert it as:

INSERT into C_k (A_1,…A_n, P_{c1},…P_{cm}} values ($V(v_1)$,…$V(v_n)$, $OID_{C_{a1}}$,…. $OID_{C_{am}}$) into : OID_{Ck}

Note: $OID_{C_{a1}}$,…. $OID_{C_{am}}$ exist only if there are foreign keys in to-be-inserted tuple.

Relational Operation Deletion
A simple delete statement in the object-oriented system corresponds to the relational delete on the given relational schema. The transformation technique is to delete a to-be-deleted object and remove, if any, the relationship that the to-be-deleted object has with its composite objects as:

<u>Algorithm</u> Delete

Step 1. Locate the to-be-deleted object.
We can map a to-be-deleted tuple in relation R_k to a corresponding to-be-deleted object in class C_k as:

SQL: DELETE from R_k where v_1=$V(v_1)$ and v_2=$V(v_2)$… v_n=$V(v_n)$

Pre-process (schema translation): Relation R_k (v_1, $v_2 \ldots v_n$, V_{f1}, $\ldots V_{fm}$) $\rightarrow$ Class C_k (A_1,$A_2 \ldots A_n$, $^P{}_{c1}$, $\ldots {}^P{}_{cm}$)

Step 2 (optional). Delete aggregate attribute of composite objects containing the to-be-deleted object.
We can locate the parent relation R_{p1}, $R_{p2} \ldots R_{pm}$ of the relation R_k of the to-be-deleted tuple by matching its foreign keys V_{f1}, $V_{f2} \ldots V_{fm}$ against the parent relations' primary keys. Similarly, there may be an aggregate attribute P_k in the to-be-deleted object that points to a set of associated class C_{b1}, $C_{b2} \ldots C_{bp}$. We can then delete the aggregate attribute of these composite objects in the associated class C_{a1}, $C_{a2} \ldots C_{am}$, C_{b1}, $C_{b2} \ldots C_{bp}$.

SELECT P_k from C_k where $A_1=V(v_1)$ and...$A_n=V(v_n)$ into **:** OID_{C_k}
UPDATE C_{a1} set $P_{a1} = P_{a1}$ - { OID_{C_k} } where $A_{a1} = V(V_{f1})$

.....

UPDATE C_{am} set $A_{am} = A_{am}$ - { OID_{C_k} } where $A_{am} = V(V_{fm})$
UPDATE C_{b1} set $P_{b1} = P_{b1}$ - { OID_{C_k} }

.....

UPDATE C_{am} set $P_{bp} = P_{bp}$ - { OID_{C_k} }

Step 3. Delete the to-be-deleted object.
We can then delete the to-be-deleted object from its class C_k as:

DELETE ALL from C_k where $A_1=V(v_1)$ and… $A_n=V(v_n)$

Note: ALL is needed to delete all the subclasses' objects only if deleting a superclass object.

Relational Operation Update
Suppose we want to replace the value of an attribute v_k from value $V(v_{k1})$

to $V(v_{k2})$ in the relation R_k (which maps to class C_k). Basically, we consider two cases. In the first case, v_k if not a foreign key. It corresponds to an attribute in the corresponding object, and thus we need an update statement of OSQL to perform the replacement. In the second case, v_k is a foreign key. Replacing a value in this case involves changing the aggregate attributes of its composite as shown below:

Step 1. Locate the to-be-updated object.
We can map a to-be-updated tuple in relation R_k to a corresponding to-be-updated object in class C_k as:

SQL: UPDATE R_k set $v_k = V(v_{k2})$ where $v_1=V(v_1)$ and $v_2=V(v_2)$… $v_n=V(v_n)$

Pre-process(schema translation): Relation R_k (v_1, v_2…v_n, V_{f1}, …V_{fm}) $\rightarrow$ Class C_k (A_1,A_2…A_n, P_{c1}, …P_{cm}, P_p)

Step 2 (optional). Update aggregate attribute of composite objects containing to-be-updated object.

If the to-be-updated attribute is an aggregate attribute (P_c or P_p), we can locate the aggregate attribute P_c or P_p in the to-be-updated object, and then delete (the existing) and insert (the new) aggregate attribute of these composite objects in the associated class C_{a1}, …C_{am}, C_{b1}, …C_{bp} as.

SELECT P_{c1},..P_{cm}, P_p from C_k where $A_1=V(v_1)$ and...$A_n=V(v_n)$ into : OID_{C_k}

UPDATE C_{ak} set $P_{ak} = P_{ak} - OID_{C_k}$
UPDATE $C_{a'k}$ set $P_{a'k} = P_{a'k} + OID_{C_k}$

UPDATE C_{bk} set $P_{bk} = P_{bk} - OID_{C_k}$

UPDATE $C_{b'k}$ set $P_{b'k} = P_{b'k} + OID_{C_k}$

Step 3. Update the to-be-updated object.
We can then update the to-be-updated object from its class C_k as:

UPDATE C_k set $v_k = V(v_{k2})$ where $v_1=V(v_1)$ and $v_2=V(v_2)$… $v_n=V(v_n)$

Case Study of Transaction Translation From SQL to OSQL

Suppose we have an enrollment system with the following RDB schema:

Relation PERSON (<u>SS#</u>, Name)
Relation COURSE (<u>Course-no</u>, Course-name)
Relation STUDENT (<u>SS#</u>, @Student#, Major)
Relation COURSE-REGISTER (*<u>Course-no</u>, *<u>Student#</u>)
Relation DEPARTMENT (<u>Dept-name</u>, Faculty)
Relation STAFF (<u>SS#</u>, @Staff#, *Dept-name, Position)
Relation OFFICE (<u>Office#</u>, Office-name, Office-loc, *Staff#)

where underlined words are primary keys, words with @ prefixes are candidate keys, and words with * pprefixes are foreign keys.

By following the pre-process step 1, we map each relation to a class such that each primary key of a tuple is transformed into an OID and an attribute in an object. In step 2, each attribute of a tuple is mapped to an attribute in an object. In step 3, the foreign keys Dept-name and Staff# are mapped to aggregate attribute P_{dept}, P_{staff} with values pointing to the OID of DEPARTMENT and STAFF. In step 4, the relationship relation COURSE-REGISTER is mapped to aggregate P_{course} and $P_{student}$ with set values pointing to the OID of COURSE and STUDENT. In step 5, the subclasses STUDENT and STAFF copy the attributes of superclass PERSON. The translated OODB schema can be shown below:

Class PERSON (OID, SS#: integer, Name: string)

Class COURSE (OID, Course-no: integer, Course-name: string, $P_{student}$: set(STUDENT))

Class STUDENT (OID, Student#: integer, Major: string, P_{course}: set(COURSE)) as subclass of PERSON

Class DEPARTMENT (OID, Dept-name: string, Faculty: string, P_{staff}: set(STAFF))

Class STAFF (OID, Staff#: integer, Position: string, $P_{department}$: DEPARTMENT, P_{office}: set (OFFICE)) as subclass of PERSON

Class OFFICE (OID, Office#: integer, Office-name: string, Office-loc: string, $P_{occupant}$: STAFF)

Assume we are to hire a new staff 'John Doe' for the Computer Science Department. The SQL transaction for the insert statement is:

INSERT PERSON (SS#, Name) value (452112345, 'John Doe')

INSERT STAFF (Dept-name, Position) value (CS, Professor)

By following the algorithm insert, we can translate the SQL statement to the following OSQL statement by locating the composite objects that contain the to-be-inserted object, and insert the to-be-inserted object with the aggregate attributes pointing to the composite objects as:

INSERT into PERSON (SS#, Name) value (452112345, 'John Doe')

SELECT * from DEPARTMENT where Dept-name = 'CS' into :OID_{cs}

INSERT into STAFF (Staff#, Position, $P_{department}$) value (123, Professor, OID_{cs})

However, if John Doe resigns, we need to remove his record from the CS department. The SQL for the delete statement is:

DELETE from STAFF where Staff# = 123

By following the algorithm delete, we can translate the SQL statement to the following OSQL statements by deleting the aggregate attribute of the composite objects that contain the to-be-deleted object, and also by deleting the set of OFFICE that John Doe occupies, and then delete the to-be-deleted object with the aggregate objects pointing to the composite objects as:
SELECT $P_{department}$, P_{office} from STAFF where SS# = 452112345 into :OID_{staff}

UPDATE DEPARTMENT set $P_{staff} = P_{staff} - OID_{staff}$
UPDATE OFFICE set $P_{occupant} = P_{occupant} - \{OID_{staff}\}$
DELETE ALL from PERSON where SS# = 452112345

Now, suppose John Doe actually wants to transfer from the CS department to the IS department. The SQL for the update statement is:
UPDATE STAFF set dept-name = 'IS' where SS# = 452112345
By following the algorithm update, we can translate the SQL statement to sets of OSQL statements as:

SELECT P_{office} from STAFF where SS# = 452112345 into :OID_{staff}
UPDATE DEPARTMENT set P_{staff} = P_{staff} - OID_{staff} where Dep="CS"
UPDATE OFFICE set P_{staff} = P_{staff} - {OID_{staff}} where Dep="CS"
UPDATE DEPARTMENT set P_{staff} = P_{staff} + OID_{staff} where Dep="IS"
UPDATE OFFICE set P_{staff} = P_{staff} + {OID_{staff}} where Dep="IS"
UPDATE STAFF set dept-name = 'IS' where SS# = 452112345

5.11 QUERY TRANSLATION FROM SQL TO XQL

An XQL (XML Query Language) is a query language for XML documents, and can be implemented by XPath. The SQL allows data retrieval using table join and data manipulation using methods. In query transformation, a syntax-directed parser converts the SQL into multi-way trees. The transformation process is performed, based on the subtree matching and replacement technique. The process of SQL query transformation is given in Figure 5-13.

Translation of SQL Query to XPath Query
After the schema is done, SQL query can be translated to XPath query by the following steps:

1. Decompose SQL query transaction
The basic syntax SQL SELECT statement is in the form of:

SELECT {attribute-list-1} FROM {relation-list} WHERE {join-condition} AND / OR {search-condition-1} ORDER BY {attribute-list-2} GROUP BY {attribute-list-3}
HAVING {search-condition-2}

The SQL query is decomposed into groups by parsing its syntax into the identifier-list, relation-list, and search conditions from the SQL query.

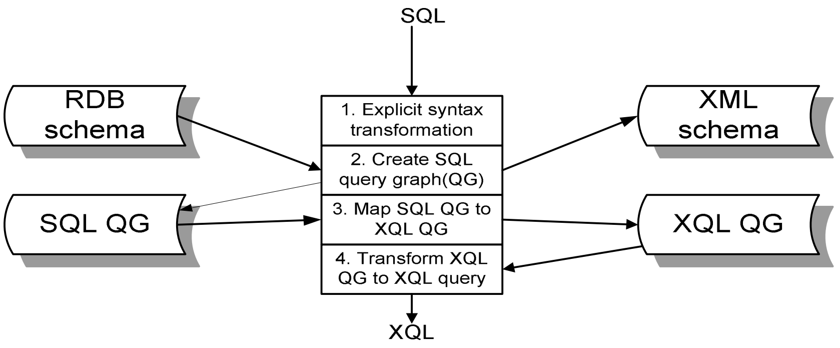

SQL
RDB schema
SQL QG
1. Explicit syntax transformation
2. Create SQL query graph(QG)
3. Map SQL QG to XQL QG
4. Transform XQL QG to XQL query
XML schema
XQL QG
XQL

Figure 5-13 Process for SQL to XQL transformation

2. Create the SQL query graph
Based on the relation-list and the join-condition in the SQL query transaction, the SQL query graph is created. The join condition is based on the natural join or based on the search condition specified in the SQL query.

3. Map the SQL query graph to XPath query graph
The SQL query graph is mapped to the XPath query graph. The table joins from the SQL query graph forms the XPath location path, which are the steps for navigating down the document tree from root node.

4. Transform SQL to XPath query
In this step, the SQL query is transformed into XPath syntax as:

/root/node1[@attribute1=condition]/…/node2[@attribute2=condition]/ @attribute3

The attribute-list in the SQL query is mapped to the leaf attribute node at the bottom of the document tree. If all the attributes of the element node are selected, "@*" is mapped to select all the attributes from the leaf element node.
If more than one attributes are selected, union operator is used to get the result. For example:

/root/node1/@attribute1 | /root/node1/@attribute2

The search-conditions in the SQL query are transformed to predicates to refine the set of nodes selected by the location step.

5. Transform XPath query data into SQL query data

The XML document returned from XMLDB is formatted into tabular format before return to user. The format of the result is based on the data stored in the table *table_column_seq* (prepared in pre-processed schema translation). The following shows the pseudo code for translating SQL query to XPath query:

```
PROCEDURE BreakdownSQLQuery (SQL-Query)
Initialize the array identifier-array,
Initialize the array relation-array to empty array
Initialize the array search-condition-array to empty array
Initialize the array XQL-query-array to empty array
Extract the portion of the SQL-Query from keyword
        'SELECT' to keyword 'FROM' into variable identifiers
Extract the portion of the SQL-Query from keyword
        'FROM' to keyword 'WHERE' into variable relations
Extract the portion of the SQL-Query from keyword
        'WHERE' to then end of the query into variable search-
conditions

Identify each search condition from the variable search-conditions and
put them into the array search-condition-array.

FOR EACH search-condition-array element DO
BEGIN
        Remove the search-condition from search-condition-
                array if it is a table join.
        IF search-condition is the function 'EXISTS( )' THEN
                Break down the subquery within 'EXISTS( )' by
                recursively calling procedure BreakdownSQLQuery
        Replace 'EXISTS' with XPath function 'count( ) > 0'
        END IF
END

Identify each identifier from the variable identifier and put them into
array identifier-array

FOREACH identifier-array element DO
BEGIN
        Locate the element node which the identifier belongs to
                construct the XQL query from the root node to the
                element node the identifier belongs to
        IF the identifier is '*' THEN
            Append '@*' to the end of the XQL query
        ELSE
            Append the identifier to the end of the XQL query
        END IF
        Store the XQL query to the array XQL-query-array
        END
                Concatenate the elements of the array XQL-query-array
                with the union sign '|' to form a single XQL query
        RETURN the concatenated XQL query.
END PROCEDURE

PROCEDURE mainProcedure  (User input SQL query)
XQL-Query = EXEC PROCEDURE  BreakdownSQLQuery (User input
QL query)
Submit the XQL-Query to the XMLDB Server
    IF no XML document returned THEN
        RETURN
    ELSE
        Retrieve the corresponding column headers
        Format the returned XML document into tabular format
        RETURN the data to user
     END IF
END PROCEDURE
```

Case Study of Translating an SQL Query Into XPath Query

Case studies of queries for security trading client statement are used to illustrate query translation between XPath and SQL.

Table record sequence number column

For any table to be used for query translation, an extra column – *seqno* is required.These columns are used by the XML gateway and therefore the following paragraphs first explain the usage and maintenance of these columns.

For each table, the last column is *seqno*. This *seqno* columns are used to ensure the records returned from database is in right order and this column is used for translation XQL location index functions (e.g., position( )).

These *seqno* columns are incremented by one for each new record. For

example, for the CLIENTACCOUNTEXECUTIVE table. The *seqno* is 1 and 2 for clientid 600001 (Fong, 2006).
On inserting a new record to a table, the insert trigger first finds out which column is used for counting *seqno* from the node_tablecolumn_mapping table. Then, the trigger selects the maximum *seqno* value for the new record. The maximum *seqno* value plus one will be assigned as the *seqno* value of the new record. For example, a new record inserted to the table CLIENTACCOUNTEXECUTIVE on the next page for clientid 600001 gets a new *seqno* value 3 since the maximum *seqno* for clientid 600001 already in the table is 2.

There is no need to update the seqno value in case record is deleted. In XQL, the location index function (e.g., position()) counts the order of the record relative to the parent node.
Client Table

Clientid	**Title**	**lastname**	**firstname**
600001	Mr	Chan	Peter
600002	Mrs	Wong	Ann
600003	Miss	Lee	Jane
Phone	**fax**	**email**	**seqno**
27825290	27825291	Peter@tom.com	1
24588900	21588200	Ann@ibm.com	1
27238900	36225555	Jane@msn.com	1

Clientorder table

clientid	**orderid**	**Tradedate**	**stockid**	**Inputquantity**
600001	300001	20020403	000003	10000
600002	300002	20020403	000004	10000
600003	300003	20020404	000003	20000
600003	300004	20020405	000004	6000
600002	300005	20020405	000941	6000
Action	**ordertype**	**Allornothing**	**inputdatetime**	**Seqno**
Buy	Limit	N	200204031001	1
Buy	Limit	N	200204031002	2
Sell	Limit	N	200204041101	1
Buy	Limit	N	200204051408	2
buy	Limit	N	200204051506	1

Balance Table

Clientid	**Stockid**	**Bookbalance**	**seqno**
600001	000001	10000	1
600001	000941	1000	2
600002	000001	1000	1
600003	000011	1000	1
600003	000012	500	2

AccountExecutive Table

aeid	Lastname	firstname	Seqno
AE0001	Franky	Chan	1
AE0002	Grace	Yeung	1
AE0003	Paul	Ho	1

The relational schema is pre-processed and translated to XML schema. From the relational tables above, the EER model is created:

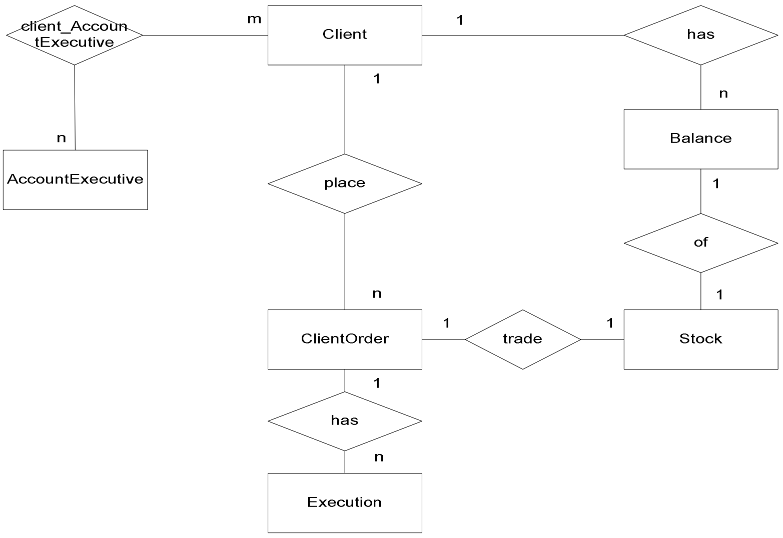


Figure 5-14 EER Model of the relational tables

An XML view of the relational schema on the selection of Client as root is translated from the EER model into a DTD Graph as follows:

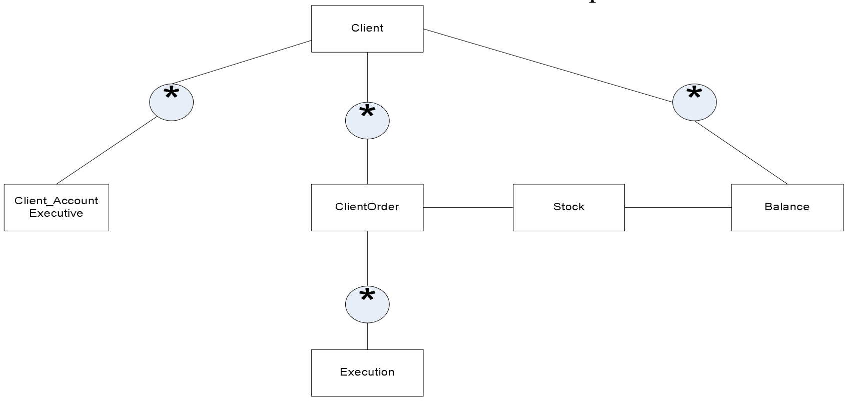


Figure 5-15 An XML client view in EER model is mapped to a DTD

Query for selecting all the *ClientID* and *OrderID*
SQL Query:

```
SELECT Client.ClientID, Order.OrderID
FROM       Client, Order
WHERE      Client.ClientID = Order.ClientdID
```

Translated XPath query:

```
/ClientStatement/Client/@ClientID                          |
/ClientStatement/Client/Order/@OrderID
```

Result from XPath Result:

```
<Client ClientID="600001"
    <Order OrderID="300001"></Order>
</Client>
<Client ClientID="600002">
    <Order OrderID="300002"
    <Order OrderID="300005"
</Client>
<Client ClientID="600003">
    <Order OrderID="300003"
    <Order OrderID="300004"
</Client>
```

5.12 SUMMARY

This chapter describes techniques in program translation, including rewriting, software interface, emulation, decompilation, and co-existence. Rewriting is to redevelop a new program, and is too costly. Software interface is to add a software layer atop of DBMS to translate source DML to target DML before run time processing. This technique results in additional work for DBA (database administrator).

Decompilation translates a lower level DML to higher level DML, not feasible due to the nature of reverse engineering. Co-existence adds a target DBMS running parallel with the source DBMS. It is too labour intensive and complicated for companies to support two DBMSs at the same time. Emulation translates source DML to target DML during run time. The technique is attractive due to its simplicity.

As a result of the above analysis, we decide, not to translate the hierarchical or network database DML to a relational database DML directly. Such translation is not possible at present. Instead, we adopt an indirect program translation to solve the problem. We will emulate embedded-SQL programs to hierarchical or network database programs. The benefit is for the users to write embedded-SQL programs to run against a hierarchical or network database. Such a process can let the users develop new programs in SQL while letting the old hierarchical or network database programs slowly get phased out.

The emulation includes transaction translation of Select, Join, Update, Modify, Insert, and Delete DML statements from SQL to IMS (hierarchical database DML) or IDMS (network database DML). The technique expands the non-procedural SQL to a series of procedural IMS or IDMS DMLs. Secondary indices are imposed on the hierarchical or network database for the purpose of eliminating database navigation in the translation process.

For transaction translation from SQL to OSQL or XQL, the query can be processed by mapping a non-procedural SQL DML to a navigational procedural OSQL DML or XQL according to the mapped OSQL or XQL query graph. The transaction translation can be processed by replacing foreign key update to Stored OID (an OID stored in the database) update in OSQL, or to a navigation path in XPath.

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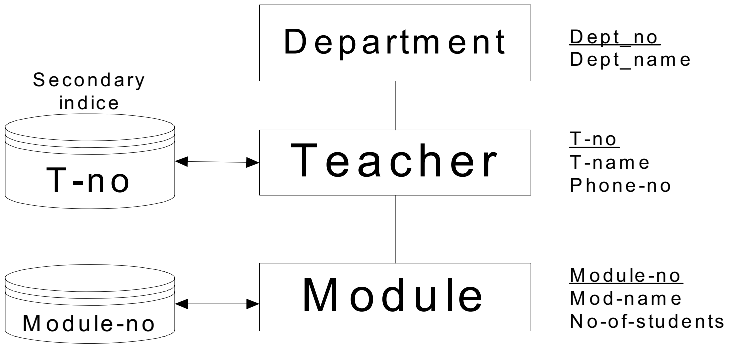
QUESTIONS

Question 5-1

Convert the following embedded SQL program to its corresponding embedded DL/1 program. The source relational database schema and its corresponding hierarchical database schema are as follows:

Relational database schema:
Relation Department (Dept-no, Deptname)
Relation Teacher (T-no, T-name, Phone-no, *Dept-no)
Relation Module (Module-no, Mod-name, No-of-students, *T-no)

Corresponding hierarchical schema:



The source embedded SQL program to be translated is:

```
IDENTIFICATION DIVISION.
PROTGRAM-ID. SQLPROJ.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. IBM-4381.
OBJECT-COMPUTER. IBM-4381.
DATA DIVISION.
WORKING-STORAGE SECTION.
COPY SQLCA.
77 NO-DATA                          PIC S9(9)       COMP
VALUE +100.
77 SUCCESS                          PIC S9(9)       COMP
VALUE +0.
01 HOST-VARIABLES.
    05 M-NO                     PIC X(20)       VALUE
SPACES.
    05 NO-OF-STUDENT  PIC S9(4)       COMP VALUE +0.
01 MODULE-AREA.
    COPY MODULE.
PROCEDURE DIVISION.
000-MAIN-PROCEDURE.
    PERFORM 400-DELETE-ROUTINE.
    PERFORM 500-UPDATE-ROUTINE.
    STOP RUN.
400-DELETE-ROUTINE.
    MOVE 'M01' TO M-NO.
    EXEC SQL DELETE FROM MODULE WHERE MODULE-
NO = :M-NO
```

```
    END-EXEC.
    IF SQLCODE = NO-DATA
            DISPLAY 'DELETION ERROR: NO SUCH ROW
FOUND.'.
    IF SQLCODE = SUCCESS
            DISPLAY 'DELETE MODULE ', M-NO,
'SUCCESSFULLY.'.
500-UPDATE-ROUTINE.
    MOVE 'M02' TO M-NO.
    MOVE 133 TO NO-OF-STUDENTS.
    EXEC SQL UPDATE MODULE
            SET NO-OF-STUDENTS = :NO-OF-STUDENT
            WHERE MODULE-NO = :M-NO
    END-EXEC.
    IF SQLCODE = NO-DATA
            DISPLAY 'UPDATING ERROR: NO SUCH ROW
FOUND.'.
    IF SQLCODE = SUCCESS
            DISPLAY 'UPDATED THE NUMBER OF STUDENT
OF MODULE',
                    M-NO, 'WITH', NO-OF-STUDENTS.
```

Question 5-2

Perform a query translation from the following SQL to OSQL:

Given the relational schema:
Relation Motor (Policy#, Insurance#, Premium)
Relation Vehicle (Vehicle#, Description)
Relation Cover (Policy#, Vehicle#)
Given the SQL query:

```
Select Vehicle.Description, Vehicle.Vehicle#, Motor.Policy#,
 Motor.Premiu
From      Vehicle, Cover, Motor
Where     Vehicle.Vehicle# = Cover.Vehicle#
And       Motor.Policy# = Cover.Policy#
And       Motor.Premium > 500.00
```

Question 5-3

Translate the following update transaction from SQL to OSQL so that a student with HKID of E123456 can change from his/her department from ‘IT’ to ‘CS’.

Given the relational schema as follows:

Relation PERSON (HKID, Name)
Relation STUDENT (*HKID, Major, *Dept_name)
Relation STAFF (*HKID, Position)
Relation COURSE (Course#, Course_name)
Relation COURSE-ENROL (*Course#, *HKID)
Relation DEPARTMENT (Dept_name, Faculty)
Relation OFFICE (Room#, Office_location, *HKID)

Given the SQL update transaction:

```
Update STUDENT set dept_name = ‘CS’ where HKID =
E1234546
```

CHAPTER 6

DATABASE CONVERSION METHODOLOGY

As database technologies evolve from hierarchical and network (nonrelational) to relational and object-oriented models, and as relational databases grow in power and popularity, developers face pressure to convert legacy databases to this newer model. In this chapter, as part of database reengineering, the problem of reusing a nonrelational database system is explored. Direct database systems conversion from nonrelational to relational is not feasible due to the nature of reverse engineering, i.e., translating from low level procedural DML of a nonrelational database to an equivalent but higher abstract level non-procedural DML of a relational database. The approach of adding a relational interface to a nonrelational database is preferred. The relational interface is constructed by mapping a nonrelational schema to an equivalent relational schema. Secondary indices are added to the nonrelational schema and database so that relational DML does not require database navigation to access nonrelational database. The modified schema and database can be accessed by both nonrelational and relational database programs. Such capability can help companies to extend the life of their nonrelational DBMSs by making them "Relational-like" DBMSs. The nonrelational database programs can be phased out or rewritten to use embedded-SQL. After all of the nonrelational database programs are eliminated, then we can complete the database conversion process by converting the data of the nonrelational database to a relational database replacing the nonrelational DBMS (i.e., a "Relational-like" DBMS with a relational interface) by a relational DBMS.

6.1 METHODOLOGY FOR ADDING A RELATIONAL INTERFACE INTO NONRELATIONAL DATABASES

The above database conversion technique, converting a nonrelational database system to a relational database system, is described in detail in a methodology, namely, Relational-like-database, RELIKEDB, that can be summarized as follows (Fong, 1993):

Phase I. Schema translation - map nonrelational schema to the EER model, and then map from EER model to relational schema.

Step 1.1. Map nonrelational schema to the EER model.

1. Derive implied relationship.
2. Derive multiple (alternative) relationship.
3. Derive unary relationship.
4. Derive binary relationship.
5. Derive n-ary relationship.
6. Derive aggregation, generalization and categorization.
7. Derive entities keys and other constraints.

Step 1.2. Map from the EER model to a relational schema.

1. Map entities into relations.
2. Map n-ary relationship into relationship relation.
3. Map aggregation, generalization and categorization into relations.

Phase II. Relational interface - Restructure nonrelational schema and database by adding record identifiers as secondary indices into each record type, and pre-compile embedded-SQL programs into nonrelational database programs to access the restructured nonrelational database by using following steps.

Step 2.1. Schema restructure - Add secondary indices by record identifiers into the nonrelational schema (from schema translation).

Step 2.2. Database restructure - Add secondary indices by record identifiers into the nonrelational database (from data conversion).

Step 2.3. Translate embedded-SQL programs into nonrelational database programs (from database program translation, i.e., logically we are processing an embedded-SQL program).

Step 2.4. Process the translated nonrelational database programs to access the restructured nonrelational database through the nonrelational DBMS (i.e., physically, we are processing a nonrelational database program).

Phase III. Data conversion - Convert data from a source database to a target database by restructuring the source database sequence to the structure of the target database sequence.

Step 3.1. Unload - The Unload program applies database navigation in a program that reads all nonrelational database records logically and unloads them with derived record identifiers. The record identifiers can be mapped to the relational schema as primary keys and/or foreign keys.

Step 3.2 (optional). Transfer - Transfer unloaded sequential files from the source computer to the target computer if they are different.

Step 3.3. Upload - The Upload program/utilities can then be used to upload the unloaded sequential files into the target relational database.

Figure 6-1 shows a diagram representation of the methodology. For more detail, refer to Chapter 3, 4, and 5.

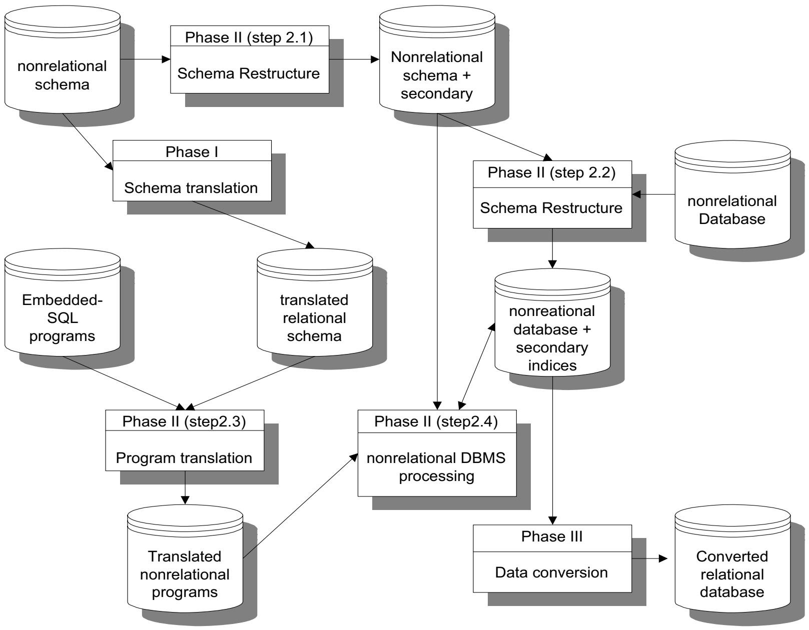


Figure 6-1 Methodology "RELIKEDB" data flow diagram

6.2 CASE STUDY OF CONVERTING A HIERARCHICAL DATABASE TO RELATIONAL

The case used is a patient information system for a group of public hospitals. The History of the patient stay in the hospital is stored including the ward, their symptoms and treatments. The facilities of the hospital are also stored. The hierarchical schema of the patient information system and source hierarchical database are as follows:

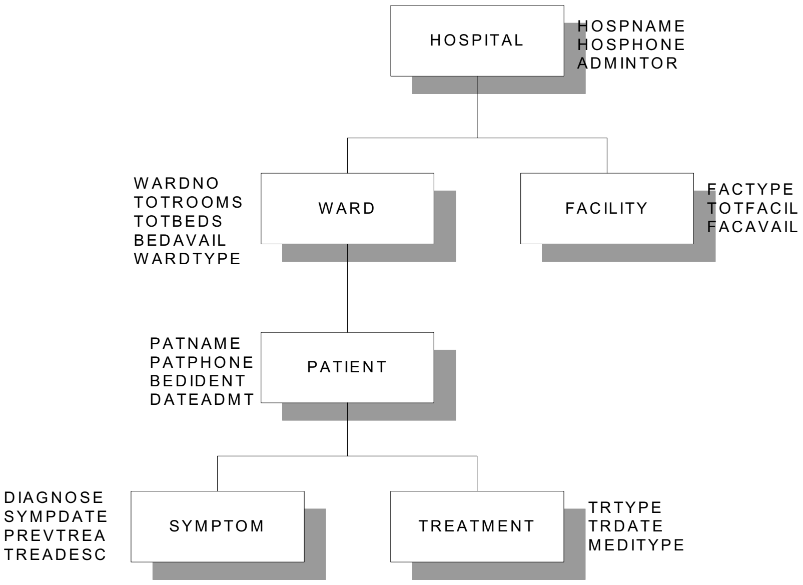


Figure 6-2 Hierarchical schema for the patient information system

The source hierarchical database for the Patient Information System is:

Segment HOSPITAL

<u>HOSPNAME</u>	HOSPHONE	ADMINTOR
MAC NEAL	123-7890	SHU MAKE
RIVEREDGE	654-3210	PAYNE

Segment WARD

WARDNO	TOTROOMS	TOTBEDS	BEDAVAIL	WARDTYPE
01	20	30	018	CARDIOVASC
04	15	36	017	GERIATRIC
05	10	10	008	ORTHOPEDIC

Segment PATIENT

PATNAME	PATPHONE	BEDIDENT	DATEADMT
MORIARTY	221-4123	0003	860823
ALLISON	222-2938	0008	860714
TEBO	223-2356	0017	860913
MORIARTY	321-7890	0004	860514
ALLISON	322-4878	0009	860602
TEBO	654-4213	0001	860721

Segment SYMPTOM

DIAGNOSE	SYMPDATE	PREVTREA	TREADESC
CHEST PAIN	860824	Y	HEART
FAINT	860701	N	SURGE
ULCER	860513	N	SURGE
BLEEDING	860601	N	SURGE
FAINT	860602	N	SURGE
BROKEN LEG	860720	N	SURGE

Segment TREATMNT

TRTYPE	TRDATE	MEDITYPE
CHEST PAIN	860823	HEART DRUG
REST	860714	NIL
REST	860514	ZANTAC
BANDAGE	860602	NIL
REST	860603	INFLUENZA
LEG SURGE	860721	NIL

Segment FACILITY

FACTYPE	TOTFACIL	FACAVAIL
CARDIOGRAPHIC M/C	10	9
X-RAY M/C	3	3
OXYGEN SUPPLY	90	81
CARDIOGRAPHIC M/C	10	9
X-RAY M/C	3	3
OXYGEN SUPPLY	90	81

Phase I. Schema translation.

Step 1. Map hierarchical schema to the EER model.

In this case study, certain substeps are skipped because of the following:

- There are no implied relationships (i.e., no duplicate key fields in segments)
- No alternative relationship exists (i.e., no loopy database access path exists),
- No unary or n-ary relationship exists (i.e., there are no cardinality in segment related to itself or more than two segments semantically related to each other)
- No aggregation, generalization or categorization exists (i.e., no such advance semantics exist among the segments)

We can derive entities' relationship by mapping each segment type into a relation, and each parent and child segment relationship into the entities' relationship in the EER model. We can also derive the entity key by deriving the default partial internally identifier for each segment type. However, since there is no segment key in segment type FACILITY, we must specify this segment as internally unidentified. Also the users specify segment WARD and segment PATIENT as fully internally identified. Figure 6-3 shows the resultant EER model.

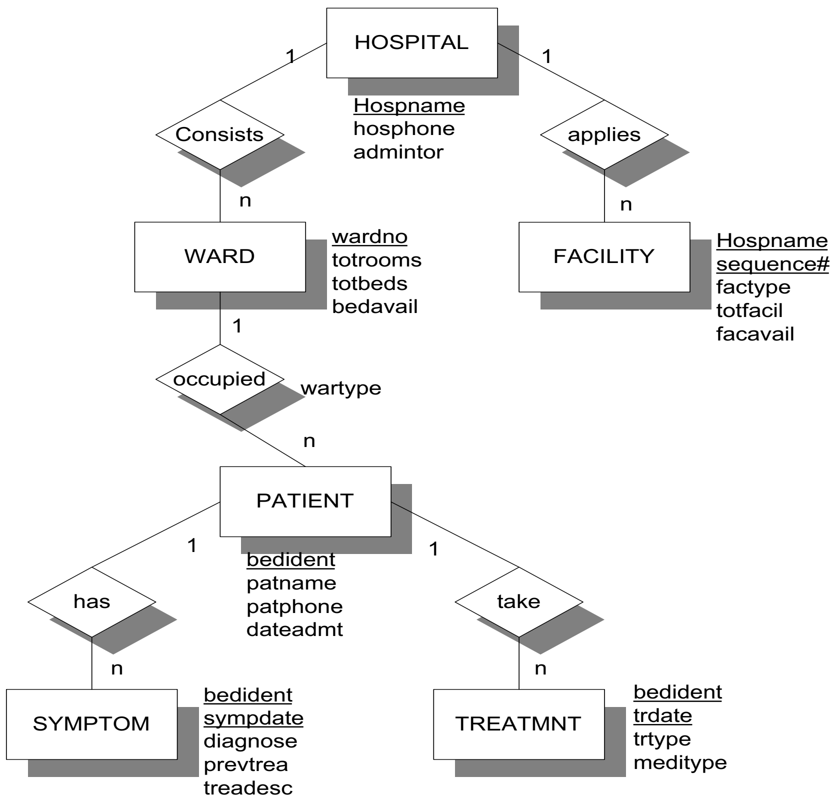


Figure 6-3 Mapped EER model for the patient information system

Step 2. Map the EER model to relational schema.

Map each entity to a relation and each entity key to the relation key. Map the 1:n relationship to a foreign key on the "many" side. The resulting relational schema is:

Relation HOSPITAL (<u>Hospname</u>, Hosphone, Admintor)
Relation WARD (<u>Wardno</u>, *Hospname, Totrooms, Totbeds, Wardtype)
Relation PATIENT (<u>Bedident</u>, *Wardno, Patname, Patphone, Dateadmt)
Relation SYMPTOM (*<u>Bedident</u>, <u>Sympdate</u>, Diagnose, Prevtrea, Treddesc)
Relation TREATMNT (*<u>Bedident</u>, <u>Trdate</u>, Trtype, Meditype)
Relation FACILITY (*<u>Hospname</u>, <u>Sequence#</u>, Factype, Totfacil, Facavail)

Phase II. Relational interface.

Step 2.1. Restructure the schema by adding record identifiers as secondary indices.

As a result of schema translation in phase I, we can derive the record identifiers for each segment (except the root segment) as follows:

Segment Type	Identifier Type	Secondary Indices(record identifier)
WARD	F	WARDDO
PATIENT	F	BEDIDENT
SYMPTOM	P	BEDIDENT, SYMPDATE
TREATMNT	P	BEDIDENT, TRDATE
FACILITY	I	HOSPNAME, SEQUENCE#

where F=fully internally identified, P=partially internally identified, and I = internally unidentified.

The restructured hierarchical database for the patient information system is:

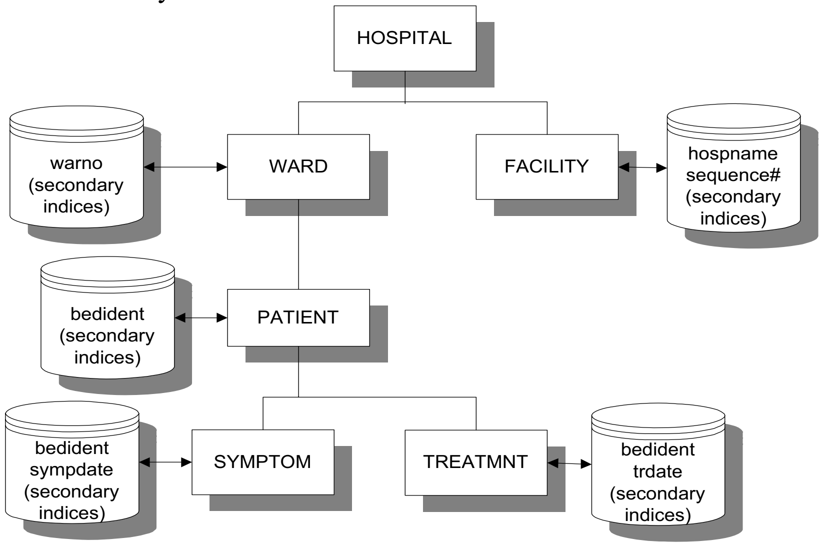

HOSPITAL
warno (secondary indices)
WARD
FACILITY
hospname sequence# (secondary indices)
bedident (secondary indices)
PATIENT
bedident sympdate (secondary indices)
SYMPTOM
TREATMNT
bedident trdate (secondary indices)

Figure 6-4 Secondary indexed hierarchical schema for the patient information system

Step 2.2. Database restructure by adding secondary indices into segments.

Next we create template files from the hierarchical schema in order to store the parent child segments linkages and their attributes in a working file for later processing. The segment template file is as follows:

Logical Segment	Physical Database	Physical Segment	Parent Segment	Segment Field
HOSPITAL	HOSPITAL	HOSPITAL	0	HOSPNAME
WARD	HOSPITAL	WARD	HOSPITAL	WARDNO
PATIENT	HOSPITAL	PATIENT	WARD	BEDIDENT
SYMPTOM	HOSPITAL	SYMPTOM	PATIENT	SYMPDATE
TREATMNT	HOSPITAL	TREATMNT	PATIENT	TRDATE
FACILITY	HOSPITAL	FACILITY	HOSPITAL	

Hierarchical level	Segment Number	Segment Length	Segment Type	Number of Fields	Cumulative Key Length
000	000	050	F	003	020
001	001	031	F	005	022
002	002	040	F	004	026
003	003	047	P	004	032
003	004	046	P	003	032
001	005	031	I	003	020

Create Field template file as follows:

Seg. No.	Field No	Field Name	Field Type	Start Byte	Field Length	Key Flag	Target Length	Decim Places
000	001	hospname	C	001	020	U	020	000
000	002	hosphone	C	021	010	N	010	000
000	003	admintor	C	031	020	N	020	000
001	001	wardno	C	001	002	U	002	000
001	002	totrooms	F	003	004	N	008	000
001	003	totbeds	H	007	002	N	004	000
001	004	bedavail	C	009	003	N	003	000
001	005	wardtype	C	012	020	N	020	000
002	001	patname	C	001	020	N	020	000
002	002	patphone	C	021	010	N	010	000
002	003	bedident	C	031	004	U	004	000
002	004	dateadmt	C	035	006	N	006	000
003	001	diagnose	C	001	020	N	020	000
003	002	sympdate	C	021	006	Y	006	000
003	003	prevtrea	C	027	001	N	001	000
003	004	treadesc	C	028	020	N	020	000
004	001	trtype	C	001	020	N	020	000
004	002	trdate	C	021	006	Y	006	000
004	003	meditype	C	027	020	N	020	000
005	001	factype	C	001	020	N	020	000
005	002	totfacil	P	021	003	N	006	000
005	003	facavail	D	024	008	N	008	002

We then unload the occurrences of each segment type of the hierarchical database with its record identifier into a sequential file. Each sequential file contains the data for each segment type. We then upload each sequential file back to the hierarchical database. The resultant hierarchical database (added with secondary indices) will be as follows:

Segment HOSPITAL

HOSPNAME	HOSPHONE	ADMINTOR
MAC NEAL	123-7890	SHU MAKE
RIVEREDGE	654-3210	PAYNE

Segment WARD

WARDNO	TOTROOMS	TOTBEDS	BEDAVAIL	WARDTYPE
01	20	30	018	CARDIOVASC
04	15	36	017	GERIATRIC
05	10	10	008	ORTHOPEDIC

Segment PATIENT

PATNAME	PATPHONE	BEDIDENT	DATEADMT
MORIARTY	221-4123	0003	860823
ALLISON	222-2938	0008	860714
TEBO	223-2356	0017	860913
MORIARTY	321-7890	0004	860514
ALLISON	322-4878	0009	860602
TEBO	654-4213	0001	860721

Segment SYMPTOM

*BEDIDENT	DIAGNOSE	SYMPDATE	PREVTREA	TREADESC
0003	CHEST PAIN	860824	Y	HEART
0008	FAINT	860701	N	SURGE
0004	ULCER	860513	N	
0009	BLEEDING	860601	N	
0009	FAINT	860602	N	
0001	BROKEN LEG	860720	N	

Segment TREATMNT

*BEDIDENT	TRTYPE	TRDATE	MEDITYPE
0003	CHEST PAIN	860823	HEART DRUG
0008	REST	860714	NIL
0004	REST	860514	ZANTAC
0009	BANDAGE	860602	NIL
0009	REST	860603	INFLUENZA
0001	LEG SURGE	860721	NIL

Segment FACILITY

*HOSPNAME	SEQUENCE#	FACTYPE	TOTFACIL	FACAVAIL
MAC NEAL	000001	CARDIOGRAPHIC M/C	10	9
MAC NEAL	000002	X-RAY M/C	3	3
MAC NEAL	000003	OXYGEN SUPPLY	90	81
RIVEREDGE	000001	CARDIOGRAPHIC M/C	10	9
RIVEREDGE	000002	X-RAY M/C	3	3
RIVEREDGE	000003	OXYGEN SUPPLY	90	81

Step 2.3.Translate embedded-SQL into a hierarchical database program.

Each embedded-SQL program is then translated into a hierarchical database program. In this case study, an embedded-SQL program for deleting ward data and/or updating a patient phone number can be translated into an information-capacity-equivalent hierarchical database program as follows:

The embedded SQL programs to be translated is:

```
IDENTIFICATION DIVISION.
PROGRAM-ID. SQLPROJ.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. DG MV10000.
OBJECT-COMPUTER. DG MV10000.
DATA DIVISION.
WORKING-STORAGE SECTION.
COPY SQLCA.
77 NO-DATA           PIC S9(9) COMP VALUE +100.
77 SUCCESS           PIC S9(9) COMP VALUE +0.
01 HOST-VARIABLES.
  05 WS-WARDNO       PIC X(2) VALUE SPACES.
  05 WS-PATPHONE     PIC X(10) VALUE SPACES.
  05 WS-BEDIDENT     PIC X(4) VALUE SPACES.
01 MODULE-AREA.
  COPY MODULE.
PROCEDURE DIVISION.
000-MAIN-PROCEDURE.
   PERFORM 400-DELETE-ROUTINE.
   PERFORM 500-UPDATE-ROUTINE.
   STOP RUN.
400-DELETE-ROUTINE.
   DISPLAY ‘WARDNO TO BE DELETED=’.
   ACCEPT WS-WARDNO.
   EXEC SQL DELETE FROM WARD WHERE WARDNO =
                                          :WS-WARDNO.
```

```
    END-EXEC.
    IF SQLCODE = NO-DATA
      DISPLAY 'DELETION ERROR: NO SUCH ROW FOUND.'.
    IF SQLCODE = SUCCESS
      DISPLAY 'DELETE MODULE ', WS-WARDNO, 'SUCCESSFULLY.'
500-UPDATE-ROUTINE.
    DISPLAY ’PHONE NUMBER TO BE UDATED=’.
    ACCEPT WS-PATPHONE.
    DISPLAY ‘ WARD BEDIDENT=’.
    ACCEPT WS-BEDIDENT.
    EXEC SQL UPDATE MODULE
           SET PATPHONE = :WS-PATPHONE
           WHERE BEDIDENT = :WS-BEDIDENT.
    END-EXEC.
    IF SQLCODE = NO-DATA
      DISPLAY 'UPDATING ERROR: NO SUCH ROW FOUND.'.
    IF SQLCODE = SUCCESS
      DISPLAY 'UPDATED THE PHONE NUMBER OF PATIENT
      TO’ ,WS-PATPHONE, ' FOR BEDIDENT ', WS-BEDIDENT.
```

The translated hierarchical database program in IMS DL/I is:

```
    IDENTIFICATION DIVISION.
    PROGRAM-ID. DLIPROJ.
    ENVIRONMENT DIVISION.
    CONFIGURATION SECTION.
    SOURCE-COMPUTER. IBM-4381.
    OBJECT-COMPUTER. IBM-4381.
    DATA DIVISION.
    WORKING-STORAGE SECTION.
    COPY DLILIB.
    77  NO-DATA                PIC S9(9) COMP VALUE +0.
    77  SUCCESS                PIC S9(9) COMP VALUE +0.
    01  HOST-VARIABLES.
        05  WS-WARDNO          PIC X(2) VALUE SPACES.
        05  WS-PATPHONE        PIC X(10) VALUE SPACES.
        05  WS-BEDIDENT        PIC X(4) VALUE SPACES.
    01  SDTMMODU-AREA.
        COPY CDTMMODU.
    PROCEDURE DIVISION.
        ENTRY 'DLITCBL'.
000-MAIN-PROCEDURE.
    PERFORM 400-DELETE-ROUTINE.
    PERFORM 500-UPDATE-ROUTINE.
    STOP RUN.
```

```
400-DELETE-ROUTINE.
     DISPLAY ‘WARDNO TO BE DELETED=’.
     ACCEPT WS-WARDNO.
      PERFORM 410-SDDDMODU-DELETE-01.
      IF DLICODE = NO-DATA
        DISPLAY 'DELETION ERROR: NO SUCH ROW FOUND.'.
      IF DLICODE = SUCCESS
         DISPLAY 'DELETED MODULE ', M-NO, ' SUCCESSFULLY.'.
410-SDDDMODU-DELETE-01.
      EXEC DLI GHU USING PCB(1)
                                 SEGMENT (WARD)
                                 INTO (SDDDMODU-AREA)
                                 SEGLENGTH (SDDDMODU-LEN)
                               WHERE (WARDNO = WS-WARDNO)
                                 FIELDLENGTH (EDDDMNO-LEN)
      END-EXEC.
      IF DIBSTAT = ' '
        EXEC DLI DELETE
        END-EXEC.
500-UPDATING-ROUTINE.
        DISPLAY ‘PHONE NUMBER TO BE UDATED=’.
        ACCEPT WS-PATPHONE.
        DISPLAY ‘WARD BEDIDENT=’.
        ACCEPT WS-BEDIDENT.
      PERFORM 550-SDDDMODU-REPLACE-01.
      IF DLICODE = NO-DATA
         DISPLAY 'UPDATING ERROR: NO SUCH ROW FOUND.'.
      IF DLICODE = SUCCESS
        DISPLAY 'UPDATED PHONE NUMBER OF PATIENT ',
          WS-PATPHONE, ' WITH BEDIDENT', WS-BEDIDENT.
550-SDDDMODU-REPLACE-01.
      EXEC DLI GHU USING PCB(1)
                                     SEGMENT (PATIENT)
                                     INTO (SDDDMODU-AREA)
                                     SEGLENGTH (SDDDMODU-LEN)
                              WHERE (BEDIDENT = WS-BEDIDENT)
                                     FIELDLENGTH (EDDDMNO-LEN)
      END-EXEC.
      IF DIBSTAT = 'GE'
        MOVE +100 TO DLICODE
      ELSE
        MOVE WS-PATPHONE TO PATPHONE.
      EXEC DLI REPLACE
      END-EXEC.
```

Step 2.4. Process the translated program to access a hierarchical database.

The translated IMS database program can then be used to update the DL/1 database with the same information capacity as the embedded-SQL database program. The users can now view the nonrelational database as a relational database.

Phase III. Data conversion.

Step 3.1. Unload reconstructed hierarchical database into sequential files.

Since this phase converts the data to a relational database, a relational schema is needed. For each partially internally identified and internally unidentified record type, the record identifiers are composite keys that include foreign keys. For the fully internally identified record type, the foreign keys are their immediate parent segment identifiers. The unloaded sequential files are thus:

Segment HOSPITAL

HOSPNAME	HOSPHONE	ADMINTOR
MAC NEAL	123-7890	SHU MAKE
RIVEREDGE	654-3210	PAYNE

Segment WARD

*HOSPNAME	WARDNO	TOTROOMS	TOTBEDS	BEDAVAIL	WARDTYPE
MAC NEAL	01	20	30	018	CARDIOVASC
MAC NEAL	04	15	36	017	GERIATRIC
RIVEREDGE	05	10	10	008	ORTHOPEDIC

Segment PATIENT

*WARDNO	PATNAME	PATPHONE	BEDIDENT	DATEADMT
01	MORIARTY	221-4123	0003	860823
01	ALLISON	222-2938	0008	860714
01	TEBO	223-2356	0017	860913
04	MORIARTY	321-7890	0004	860514
04	ALLISON	322-4878	0009	860602
05	TEBO	654-4213	0001	860721

Segment SYMPTOM

*BEDIDENT	DIAGNOSE	SYMPDATE	PREVTREA	TREADESC
0003	CHEST PAIN	860824	Y	HEART
0008	FAINT	860701	N	SURGE
0004	ULCER	860513	N	
0009	BLEEDING	860601	N	
0009	FAINT	860602	N	
0001	BROKEN LEG	860720	N	

Segment TREATMNT

*BEDIDENT	TRTYPE	TRDATE	MEDITYPE
0003	CHEST PAIN	860823	HEART DRUG
0008	REST	860714	NIL
0004	REST	860514	ZANTAC
0009	BANDAGE	860602	NIL
0009	REST	860603	INFLUENZA
0001	LEG SURGE	860721	NIL

Segment FACILITY

*HOSPNAME	SEQUENCE#	FACTYPE	TOTFACIL	FACAVAIL
MAC NEAL	000001	CARDIOGRAPHIC M/C	10	9
MAC NEAL	000002	X-RAY M/C	3	3
MAC NEAL	000003	OXYGEN SUPPLY	90	81
RIVEREDGE	000001	CARDIOGRAPHIC M/C	10	9
RIVEREDGE	000002	X-RAY M/C	3	3
RIVEREDGE	000003	OXYGEN SUPPLY	90	81

Step 3.2 is not applied since the source program and target program are in the same platform.

Step 3.3. Upload database.

The unloaded sequential files are loaded to a relational database based on the translated relational schema. The translated relational schema will include one create statement for each relation. The following are the create statements for the relational schema.

```
CREATE TABLE HOSPITAL
        (HOSPNAME   CHAR(20)      NOT NULL,
         HOSPHONE   CHAR(10)      NOT NULL,
        ADMINTOR    CHAR(20)      NOT NULL,
        PRIMARY KEY (HOSPNAME))
```

```
CREATE TABLE WARD
        (HOSPNAME    CHAR(20)       NOT NULL,
         WARDNO      CHAR(2)        NOT NULL,
        TOTROOMS     CHAR(4)        NOT NULL,
        TOTBEDS      CHAR(2)        NOT NULL,
        BEDAVAIL     CHAR(3)        NOT NULL,
        WARTYPE      CHAR(20)       NOT NULL,
        PRIMARY KEY (WARDNO),
         FOREIGN KEY (HOSPNAME))

CREATE TABLE PATIENT
        (WARDNO      CHAR(2)        NOT NULL,
         PATNAME     CHAR(20)       NOT NULL,
        PATPHONE     CHAR(10)       NOT NULL,
        BEDIDENT     CHAR(4)        NOT NULL,
        DATEADMT     CHAR(6)        NOT NULL,
        PRIMARY KEY (BEDIDENT),
         FOREIGN KEY (WARDNO))

CREATE TABLE SYMPTOM
        (BEDIDENT    CHAR(4)        NOT NULL,
         DIAGNOSE    CHAR(20)       NOT NULL,
        SYMPDATE     CHAR(6)        NOT NULL,
        PREVTREA     CHAR(1)        NOT NULL,
        TREADESC     CHAR(20)       NOT NULL,
        PRIMARY KEY (BEDIDENT, SYMPDATE),
         FOREIGN KEY (BEDIDENT))

CREATE TABLE TREATMNT
        (BEDIDENT    CHAR(4)        NOT NULL,
         TRTYPE      CHAR(20)       NOT NULL,
        TRDATE       CHAR(6)        NOT NULL,
        MEDITYPE     CHAR(20)       NOT NULL,
        PRIMARY KEY (BEDIDENT, TRDATE),
         FOREIGN KEY (BEDIDENT))

CREATE TABLE FACILITY
        (HOSPNAME    CHAR(20)       NOT NULL,
         SEQUENCE#   NUM(6)NOT NULL,
        FACTYPE      CHAR(20)       NOT NULL,
        TOTFACIL     NUM(3)NOT NULL,
        FACAVAIL     NUM(8)NOT NULL,
        PRIMARY KEY (HOSPNAME, SEQUENCE#),
         FOREIGN KEY (HOSPNAME))
```

6.3 METHODOLOGY FOR ADDING AN OBJECT-ORIENTED INTERFACE INTO NONRELATIONAL DATABASES

A frame model metadata is presented to add operations of data to RDBMS. It can be utilized as an object-oriented interface to RDB. With an object agent, it is used to implement an OODBC (Open Object-Oriented Database Connectivity) which acts as a common interface in the heterogeneous RDBs system. The users can access RDB with frame model meta-data via an OODB API (Application Program Interface) by OSQL. The OSQL is a query transaction of OODB and is navigational from class to class. It allows programming of data operations stored in the database and reduces application program workload. The method call enables users develop application program in stored procedure inside the frame model metadata. The result is an object-oriented view for RDB. To meet users' requirements, there is a need to support various RDBs using OODB API. Interoperability means the ability of independently developing systems to operate with each other. An interoperable database system is defined as a loosely coupled federated database architecture using a platform and vendor independent language and protocol. A standard OODB API is needed to transform a heterogeneous RDB systems to a homogeneous Object Relational DataBase systems.

Object-Oriented Database Application Program Interface

Because of OODB API, users can issue OSQL to access each other's RDB via frame model metadata. After schema mapping from OODB to RDB, OSQL query transaction can be translated into SQL query transaction. The technique is to convert the database access path from OSQL's navigational query graph to the SQL's relations join query graph. As shown in Figure 6-5, the Object Frame Model Agent (OFMA) is divided into three parts: the command scanner, the method interpreter, and the Data Manipulation Language (DML) interpreter. The server API process will first scan the incoming commands, identify the kind of command: DML or Method. If the command is DML, the server API will parse the DML command to the RDBMS. The execution and error checking will be performed by RDBMS. The error or result set will be returned to the caller after execution. If the incoming command is Method, the stored procedure defined in the method class of the frame model will be invoked, and the error or result set will be returned after execution is performed.

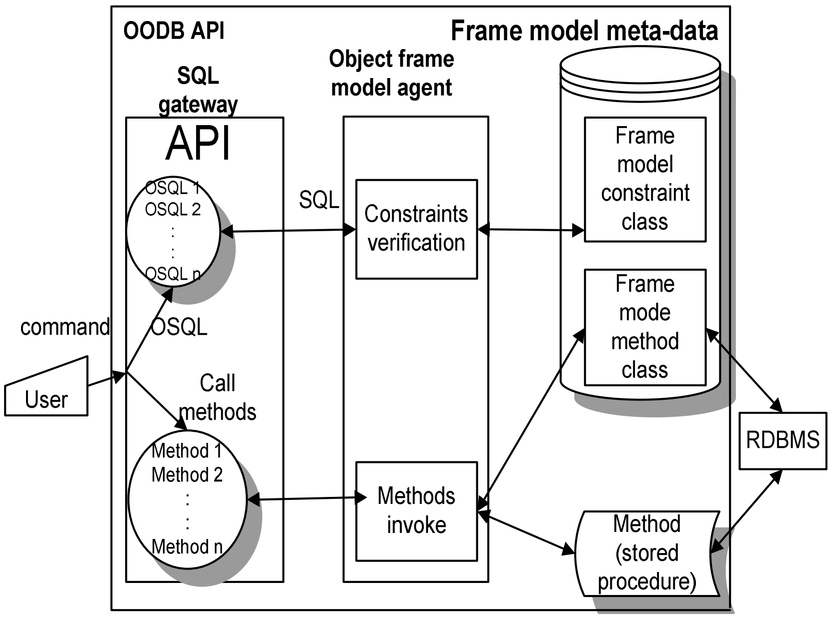


Figure 6-5 The architecture of OFMA (object agent)

The algorithm of command scanner is:

```
Begin   Get input COMMAND;
        Get COMMAND identifier from symbol table;
        Compare COMMAND to identifier;
        If COMMAND is DML
        Then call DML interpreter
        Else    Begin   Verify COMMAND syntax;
                If syntax error
                THEN return with error
                ELSE call METHOD interpreter;
        End;
End;
```

The algorithm of DML interpreter is:

```
Begin   If DML perform data modification
  Then begin    Query constraint definition for 'BEFORE' action;
                While not at end of Constraint definition do
                Begin   Query Constraint Method;
                        Execute Constraint Method;
                        If execution error
                        Then return with error;
                End;
                Execute DML command;
                If execution error
                Then return with error;
                Query Constraint definition for 'AFTER' action;
                While not at end of Constraint definition do
                Begin   Query Constraint Method;
                        Execute Constraint Method;
                        If execution error
                        Then return with error;
        End
    Else    Execute DML command;
        If execution error
        Then return with error
        Else return result;
End;
```

The algorithm of method interpreter is:

```
Begin   Query Method definition from Method class;
        If Method is DML command
        Then call DML interpreter
        Else begin      Execute Method definition;
                        If execution error
                        Then return with error
                        Else return with result
                End;
End;
```

Frame Model Metadata

The frame model metadata consists of two classes: static classes and active classes. Static classes represent factual data entities and active classes represent rule entities. An active class is event driven, obtaining data from the database when invoked by a certain event. The static class stores data in its own database. The two classes use the same structure. Combining these two types of objects within the inheritance hierarchy structure enables the frame model to represent heterogeneous knowledge. With database gateways translating OSQL to SQL, the frame model metadata system runs through OSQL to access heterogeneous RDBs. The frame model captures the semantics of heterogeneous RDB schemas after schema translation. With the help of an object agent, frame model metadata can be processed with an object-oriented view. The frame model metadata handles complex data such as class, constraints and methods. The object agent pre-compiles methods and stores methods as stored procedures, and invokes method and constraint class in the frame model metadata. The users, the object agent, the frame model metadata and the RDBMS form an OODBC. The users issue an OSQL to access a RDB via the OODBC. The RDBMS linked with an OODBC can inter-operate with each other through OSQL. Frame model metadata is a metadata consisting of four main parts: header, attributes, methods, and constraints (Huang, 1994). The detail can be referred to Figure 8.2 in Chapter 8.

Translate Query Transaction From OSQL to SQL

After schema mapping from OODB to RDB, we can translate OSQL query transaction to SQL query transaction. The technique is to convert the database access path from OSQL's query graph of classes navigation to the SQL's query graph of relations join. Its procedure can be described as follows (Fong, 2002):

Step 1. Decompose OSQL query transaction.

During this step, the OSQL query transaction is decomposed into groups by parsing its syntax as:

SELECT {attributes-list-1} FROM {class-list}
WHERE {data-navigation-path}AND/OR {search condition-1}
ORDER BY {attribute-list-2} GROUP BY {attribute-list-3} HAVING {search-condition-2}

Step 2. Create the query graph of OSQL through its classes' navigation paths.

Based on the input OODB schema, an navigation path can be created to indicate the relationship between an association attribute and the OID of its associated classes, i.e., to express the pointer structure between two associated classes. The OID in OSQL is implemented by the Attribute_type field of Attribute Class in Frame mode. The pointer structure is actually the OID of the associated classes, and the stored OID of the association attribute. The navigation path can be expressed in the following pointer structure:

Navigation path: Root Class (Association attribute) = Associated Class (OID)

In the case of class inheritance, the same object can appear in the

superclass and its subclass. There will be no pointer structure between them. Instead, the subclass's object will contain all the information of its superclass. As a result, for any query transaction involving a subclass, we can use subclass as a root class for navigation.
Navigation path: Root class (subclass) = Associated class (superclass)

Step 3. Map the OSQL query graph to SQL query graph.
From the navigation path of OSQL, we can locate the root class and its associated class through its association attribute. For each class, we can also locate its corresponding relations in RDB from the result of the pre-process of mapping OODB schema to RDB schema. The corresponding query graph of SQL is the path of the join of the mapped relations.

Step 4. Translate OSQL query transaction to SQL query transaction.
From the query graph of SQL query transaction, a corresponding SQL transaction can be constructed by:

- Replacing the navigation path of classes in the target attributes by target attributes only.
- Replacing the source class by their corresponding relations

For set expression, we can translate the same set operation of OSQL to SQL. For example,

$\text{Query}_{\text{OSQL}}$	Intersect	$\text{Query}_{\text{OSQL}}$	$\rightarrow$
$\text{Query}_{\text{SQL}}$	Intersect	$\text{Query}_{\text{SQL}}$	
$\text{Query}_{\text{OSQL}}$	Union	$\text{Query}_{\text{OSQL}}$	$\rightarrow$
$\text{Query}_{\text{SQL}}$	Union	$\text{Query}_{\text{SQL}}$	
$\text{Query}_{\text{OSQL}}$	Except	$\text{Query}_{\text{OSQL}}$	$\rightarrow$
$\text{Query}_{\text{SQL}}$	Minus	$\text{Query}_{\text{SQL}}$	

Exists identifier in $\text{Query'}_{\text{OSQL}}$: $\text{Query''}_{\text{OSQL}} \rightarrow$
$\text{Query'}_{\text{SQL}}$ where exists Identifier $\text{Query''}_{\text{SQL}}$

For all identifier in $\text{Query'}_{\text{OSQL}}$: $\text{Query''}_{\text{OSQL}} \rightarrow$
$\text{Query'}_{\text{SQL}}$ where exists All Identifier $\text{Query''}_{\text{SQL}}$

For all identifier in $\text{Query'}_{\text{OSQL}}$: $\text{Query''}_{\text{OSQL}} \rightarrow$ $\text{Query}_{\text{SQL}}$ where exists $\text{Query'}_{\text{SQL}}$ in $\text{Query''}_{\text{SQL}}$

Method Call Statement

To add the data operation into RDB, Method Call is implemented into OODBC as follows:

Call phrase	Substitutions for Call phrase
Call_statement	CALL method_call
Method_call	Method_name ([argument_value_comma_list]) on call_target [to_variable]
Call_target	Variable, metaclass_specification
Argument_value	Value_specification

6.4 CASE STUDY OF CONVERTING A RELATIONAL DATABASE TO OBJECT-ORIENTED

An existing RDBMS database application is used to demonstrate the ability of Object Frame Model Agent (OFMA). The application describes the relationship of staff, student and course of college departments. The RDBMS schema is re-engineered, and was redefined in Object schema. New instances of Header Class were created for each table of the RDBMS schema and class operation. A new instance was created for Method Class for the method that was defined in Header Class, Attribute Class, or Constraint Class. The case study demonstrates the possibility of employing frame model metadata to implement OODBC. Object behaviours such as encapsulation, inheritance, polymorphism, abstract data type, constraint, and Path Expression for OODBC will be shown using examples. In addition to the object behaviours, the relational behaviours such as relational query (SQL) and referential integrity will also be demonstrated using examples (Fong and Cheung, 2001):

The RDB Schema

Relation Department (<u>dept_name</u> , dept_no)
Relation Office (<u>office_no</u> , length , width , location, *dept_name)
Relation Person (<u>person_id</u>, name, birth_date, height, weight , address, phone_no, fax_no, email)
Relation Student (*<u>person_id</u>, student_id_no , *dept_name)
Relation Course_register (*<u>person_id</u> , *<u>course_no</u>)
Relation Course (<u>course_no</u> , course_name , credit , *staff_id_no)
Relation Staff (*<u>person_id</u>, staff_id_no , post, *dept_name , *office_no)
Relation Part_time_student (*<u>person_id</u>, *staff_id_no)
Relation Full_time_student (*<u>person_id</u>)

Object-Oriented Schema

```
CLASS department
ATTRIBUTE
Dept_name         varchar2(100)
Dept_no  integer            NOT NULL UNIQUE,
P_staff           set of staff
P_student         set of student
P_office          set of office
ATTRIBUTE METHOD
Staffs            set_of_staffs (dept_no),
Students          set_of_students (dept_no),
Offices           set_of_office (dept_no),
CLASS METHOD
Department        new(integer, varchar2(100),staff),
Department        find(dept_no),
Void              del(dept_no),
Void              show_all_instance(),
Void              change_head(staff),
Void              add_a_staff(staff),
Void              drop_a_staff(staff),
Void              add_a_student(student),
Void              drop_a_student(student),
Void              add_a_office(office),
Void              drop_a_office(office),
CONSTRAINT METHOD
Boolean  head_of_other_department(staff),

CLASS office
ATTRIBUTE
Office_nointeger            NOT NULL UNIQUE,
Length            float,
Width             float,
location          varchar2(100),
P_dept   department
ATTRIBUTE METHOD
Staffs            set_of_staffs (office_no),
CLASS METHOD
Office            new(integer, float, float, varchar2(100)),
Office            find(office_no),
Void              del(dept_no),
Void              change_length(float),
Void              change_width(float),
Void            change_location(float),
Void            add_a_user(staff_id_no),
Void            drop_a_user(staff_id_no),
CLASS person
ATTRIBUTE
Person_id       integer         NOT NULL UNIQUE,
Name            varchar2(50),
Brith_date      date,
Height          float,
Weight          float,
Address         varchar2(100),
Phone_no        integer,
Fax_no          integer,
Email           varchar2(50),
CLASS METHOD
Person    new(integer, varchar2(50), date, float, float, varchar2(100),
integer, integer, varchar2(50)),
Person    find(person_id),
Void            show_all_instance(),
Void            del(person_id),
Void            change_name(varchar2(50)),
Void            change_brith_date(date),
Void            change_address(varchar2(100)),
Void            change_phone_no(integer),
Void            change_fax_no(integer),
Void            change_email(varchar2(50)),

CLASS staff AS SUBCLASS of person
ATTRIBUTE
Staff_id_no     integer         NOT NULL UNIQUE,
Post            varchar2(50),
Dept_no         integer,
Office_no       integer,
P_dept    department
CLASS METHOD
Staff     new(integer, varchar2(50), date, float, float, varchar2(100),
integer, integer, varchar2(50), integer, varchar2(50), varchr2(100),
integer),
Staff           find(staff_id_no),
Void            change_post(varchar2(50)),
Void            change_dept(varchar2(100)),
Void            change_office(integer),
CLASS student AS SUBCLASS of person
ATTRIBUTE
Student_id_no    integer          NOT NULL UNIQUE,
Dept_no          integer
P_course         set of course
P_dept    department
ATTRIBUTE METHOD
Course           set_of_course(student_id_no);
CLASS METHOD
Student   new(integer, varchar2(50), date, float, float, varchar2(100),
integer, integer, varchar2(50), integer, integer),
Student   find(Student_id_no),
Void             change_dept(integer),
Void             add_a_course(course),
Void             drop_a_course(course),

CLASS ft_student AS SUBCLASS of student
CLASS METHOD
Student   new(integer, varchar2(50), date, float, float, varchar2(100),
integer, integer, varchar2(50), integer, integer),
CONSTRAINT METHOD
Boolean   not_pt_student(student_id_no);

CLASS pt_student AS SUBCLASS of student,staff
CLASS METHOD
Student   new(integer, varchar2(50), date, float, float, varchar2(100),
integer, integer, varchar2(50), integer, integer),
CONSTRAINT METHOD
Boolean   not_ft_student(student_id_no);

CLASS course
ATTRIBUTE
Course_no               integer  NOT NULL UNIQUE;
Course_name             varchar2(50);
Credit                  integer;
Teacher_name            varchar2(50)
P_student               set of student
ATTRIBUTE METHOD
Student                 set_of_student_registered (course_no);
CLASS METHOD
Course    new(integer, varchar2(50));
```

Grade	*find(course_no);*
Void	*del(course_no);*
Void	*Show_all_instances()*
Void	*change_course_name(varchar2(50));*
Void	*change_credit(integer);*
Void	*change_teacher(varchar2(50));*
Void	*add_a_registrant(student);*
Void	*drop_a_regustrant(student);*

Object-Oriented Behaviour of OODBC

Encapsulation

Attributes and methods of an object are bound within an object; attributes and methods can only be accessible through external function (method) call. For example,

Frame model metadata

Method Class

Class_name	Method_name	Parameters	Sequence_no	Method_type	Condition	Action	Next_sequence_no
DEPARTMENT	NEW	3		PLSQL		BEGIN NEW_DEPARTMENT (:1, :2, :3); END	

will display values of attributes of all i

Call new (10, Computer Science, 20) on class department;

will create an new instance of class department. The example is passing a message to DEPARTMENT class object without directly operating on their attribute values.

Inheritance

Attributes and methods were inherited from its superclass, and adding new attributes and methods for the inherited object. For example,

Call show_all_instances() on class ft_student;

will display all instances which belong to class ft_student.

Frame model meta-data

Header Class

Class_Name	Primary_key	Parents	Operation	Class_type
PART_TIME_STUDENT		STUDENT, STAFF	NEW	ACTIVE

Polymorphism

The same method call will give different result on different class object. For example,

call show_all_instance() on class department;

call show_all_instance() on class person;

will have different results. The following result will be displayed on the screen:

Abstract Data Type and Multiple Values

The type of an attribute can be defined as any predefined class or as a set of objects. For example, in the prototype CLASS course, the attribute method

Fame model metadata

Method Class

Class_name	Method_name	Parameters	Sequence_no	Method_type	Condition	Action	Next_sequence_no
SHOW_ALL_INSTANCE	DEPARTMENT	0		SQL		SELECT * FROM DEPARTMENT	

Method Class

Class_name	Method_name	Parameters	Sequence_no	Method_type	Condition	Action	Next_sequence_no
SHOW_ALL_INSTANCE	PERSON	0		SQL		SELECT * FROM PERSON	

Call set_of_student_registered(course_no)

will return the student instance that has registered the course.

Class Constraint

Frame model metadata

Attribute Class

Class_name	Attribute_name	Method_name	Attribute_type	Default_value	Cardinality	Description
STUDENT	SET_OF_STUDENT_REGISTERED	SET_OF_STUDENT_REGISTERED			M	Set of student who registered the course

Method Class

Class_name	Method_name	Parameters	Sequence_no	Method_type	Condition	Action	Next_sequence_no
STUDENT	SET_OF_STUDENT_REGISTERED	1		SQL		SELECT * FROM COURSE WHERE COURSE_NO =:1	

Additional constraints for enhancing the referential integrity that is not provided by relational database, e.g., in the prototype CLASS pt_student, the constraint method not_ft_student() will check if the creation of new pt_student instance is an full-time student, if not the creation of part-time tudent is allowed.

The declaration of methods is stored in the Method Class of the Frame

Fame model metadata

Method Class

Class_name	Method_name	Parameters	Sequence_no	Method_type	Condition	Action	Next_sequence_no
FULL_TIME_STUDENT	NOT_PT_STUDENT	0		PLSQL	NOT_PT_STUDENT		

Constraint Class

Class_name	Constraint_name	Method_name	Parameter	Ownership	Event	Sequence	Timing
FULL_TIME_STUDENT	NOT_PT_STUDENT	NOT_PT_STUDENT		SELF	CREATE	BEFORE	1

Model schema, and the actual executable code for methods are required to create and compile using the RDBMS store procedures. For example, PLSQL stores procedures for the Oracle database, the store procedure for NOT_PT_STUDENT is defined as follows:

```
CREATE PROCEDURE NOT_PT_STUDENT (V_STUDENT_ID_NO IN
NUMBER)
IS
V_COUNT NUMBER;
BEGIN
  SELECT COUNT(*)
  INTO    V_COUNT
  FROM    PT_STUDENT
  WHERE  STUDENT_ID_NO = V_STUDENT_ID_NO
  ;
  IF V_COUNT > 0 THEN
     RAISE APPLICATION_ERROR(-20010,'Student is a Part-time
student');
  END IF;
END;
```

6.5 SUMMARY

This chapter is a summary of the application of the methodologies described in Chapter 3, 4, and 5. Database conversion consists of schema translation, data conversion and program translation. Chapter 3 shows methodology for schema translation, Chapter 4 for data conversion, and Chapter 5 for program translation. As a result of integrating them, we can perform a methodology of converting a hierarchical or network database into a relational database. Our approach is to translate schema from hierarchical or network to relational in the first phase. We can then provide a relational interface in the second phase by imposing secondary indices in the hierarchical database schema and data. A software layer is developed for emulating SQL statements to hierarchical or network database DML statements. As a result, the users can run an embedded-SQL program using a hierarchical or network DBMS. The objective is to let users write new programs using SQL and phasing out the hierarchical or network database programs as a temporary solution. As all the obsolete hierarchical or network database are rewritten or deleted, we can then perform the third phase of data conversion from hierarchical or network database to relational database as a permanent solution of database conversion (migration). In converting a relational database into an object-oriented database, we suggest using a frame model metadata to implement an object-oriented interface to a relational database to allow user using OSQL to access a relational database. The frame model metadata allows users to specify data operation into its method class for encapsulation.

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QUESTIONS

Question 6-1

What is Inheritance and what is Encapsulation in an object-oriented database? How can these two features be implemented in a relational database? What are the major differences in the level of hidden operations (automation) of using these two features in an object-oriented database and in a relational database?

Question 6-2

What is a frame model metadata and how it can be used in converting a relational database into an object-oriented database?

CHAPTER 7

HETEROGENEOUS DATABASES INTEGRATION

Over the last two decades, a number of database systems have come into the market by using predominant data models: hierarchical, network, relational, object-oriented and XML. As the performance of the Relational Database (RDB) is improved, it has been accepted by the industry and created the need of converting companies' hierarchical or network database to RDB and XML.. To meet users' requirements, there is a need to support various data models in a single platform. However, due to the implied constraints of the various data models, it is difficult for organizations to support heterogeneous database systems.

Survey results show that coexistence and integration of database systems is an option to solve the problem. These databases are created and managed by the various units of the organization for their own localized applications. Thus the global view of all the data that is being stored and managed by the organization is missing. Schema integration is a technique to present such a global view of an organization's databases. There has been a lot of work done on schema integration. Batini et al. (1992) and Özsu amd Valduriez (1991) present surveys of work in this area. But all these techniques concentrate on integrating database schemas without taking into consideration new database applications. This chapter presents a practical approach to schema integration to support new database applications by comparing the existing databases against data requirements of the new applications. If the existing databases are inadequate to support new applications, then they are evolved to support them.

Relational database system (RDB) has been dominant in the industry for the last two decades. Object-oriented database application (OODB) is recognized as a post-relational technology that can improve productivity. Hence, most companies need to enhance their existing relational database systems to support new object-oriented applications as and when needed. The current trend is to implement an object-relational database system (ORDB) using a relational engine with OO features. This chapter proposes a methodology to integrate existing ORDB systems based on user requirements. We can recover and verify schema semantics by data mining and store it in metadata. A frame model metadata is used to enforce constraints for solving semantic conflicts arising from schema integration. The frame model metadata is an object-relational like metadata that can specify static data semantic as well as dynamic data operation based on four relational tables.

7.1 SCHEMAS INTEGRATION FOR RELATIONAL DATABASES

In any schema integration methodology, all the database schemas have to be specified using the same data model. The proposed approach uses an extended entity relationship (EER) data model. Therefore, the first step in the schema integration methodology is to translate a non-EER database schema to an EER database schema.

In our approach, a successful schema integration process should require information capacity of the original schemas to be equivalent or dominated by the transformed schemas. To achieve this, we must prove that each proposed integrated process can preserve data semantics constraints to ensure information completeness. The following three major steps must be followed in its sequence. However, the sequence of sub-steps in each major step is immaterial.

Step 1. Resolve conflicts among conceptual schema in EER models.

Sub-step 1.1. Resolve conflicts on synonyms and homonyms.

This step is subject to user input during the transformation process. Role, by definition, is the functional usage of an entity. However, to define role, in the case of synonyms, either A.x or B.x dominates one another in its data type and size. The only trigger here is the user identification of its semantics equivalence. Similarly, once a user has identified that the attributes are of homonyms, the data types and its size can be redefined into a different data structure (Kwan and Fong, 1999).

```
Rule 1:
IF A.x and B.x have different data types or sizes
THEN x in A and B may be homonyms, let users clarify x in A and B
ELSE IF x $\neq$ y, and A.x and B.y have the same data type and size
        THEN ((x,y) may be synonyms, let users clarify (x, y));
```

(Note: Classa and Classb are synonyms, Attributex are homonym)

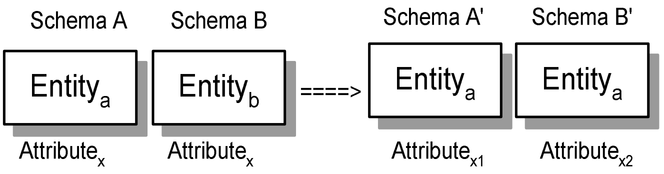

Figure 7-1 EER model with synonyms and homonyms

Sub-step 1.2. Resolve conflicts on data types.

Case 1 conflict occurs when an attribute appears as an entity in another schema. Case 2 conflict occurs where a key appears as an entity in another schema and case 3 conflict occurs when a component key appears as an entity in another schema. To verify case 1, since the translation process has preserved the information capacity in both the original schema A and schema B into the transformed schema A = (A, R(A,A'), A'), the transformed schema A has proved to dominate original schemas. The transformation process is information preserved. This transformation mapping between schema A and schema B resolves conflicts on data types since schema B remains its original structure. The verification of case 2 and case 3 is similar for all cases that are transforming entity with attributes as an entity in another schema. The only difference is the cardinality between the created entity A' and the original entity.

```
Rule 2:
IF x $\in$ (attribute(A) $\cap$ entity(B))
THEN entity A' $\leftarrow$ entity B such that cardinality (A, A') $\leftarrow$ n:1
ELSE IF x $\in$ (keys(A) $\cap$ entity(B))
        THEN entity A' $\leftarrow$ entity B such that cardinality (A, A') $\leftarrow$ 1:1
         ELSE IF (x $\subset$ keys(A)) $\cap$ (entity(B))
      THEN entity A' $\leftarrow$ entity B such that cardinality(A, A') $\leftarrow$ m:n
```

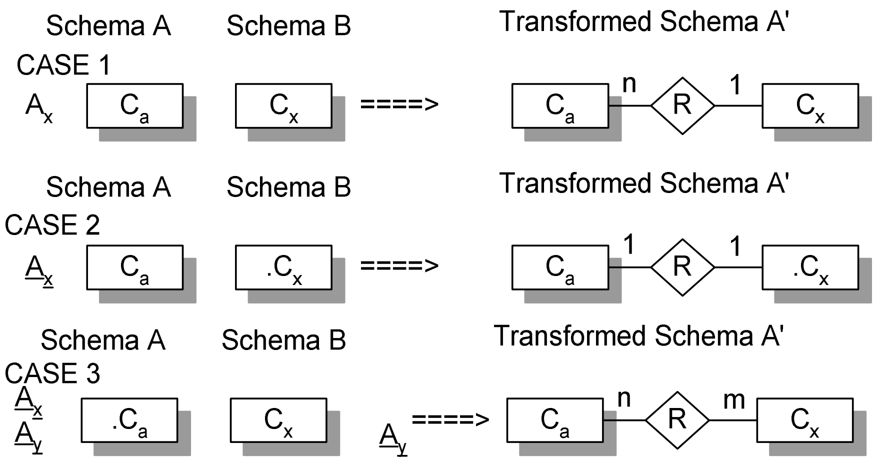

Figure 7-2 EER model with data types conflicts in three cases

Sub-step 1.3. Resolve conflicts on key.

The conflict exists where a key appears as a candidate key in another schema. The verification of this rule is subject to the users' input. Users will have to decide on whether schema B dominates schema A. If so, schema A will take the key of schema B as its own key, or vice versa. Hence, this translation process is information capacity preserved and bi-directional.

Rule 3:
IF x $\in$(key(A) $\cap$ candidate_keys(B))
THEN let users clarify x in A and B

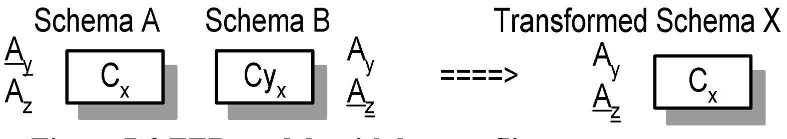

Figure 7-3 EER models with key conflicts

Sub-step 1.4. Resolve conflicts on cardinality.

Conflict exists where identical entities are of different cardinality in two schemas. The verification of this step is subject to which schema has higher cardinality. Schema with higher cardinality naturally dominates the other schema with identical entities. Hence, higher cardinality will override the lower cardinality conflicts. This translation process is therefore information capacity equivalent and is bi-directional with feasible recovery of original schema from transformed schema.

Rule 4:

IF (entity(A_1) = entity (B_1)) $\wedge$ (entity(A_2) = entity (B_2)) $\wedge$ (cardinality(A_1, A_2) = 1:1) $\wedge$ (cardinality(B_1, B_2) = 1:n)

THEN cardinality(A_1, A_2) $\leftarrow$ 1:n;

ELSE IF (entity(A_1) = entity(B_1)) $\wedge$ (entity(A_2) = entity(B_2)) $\wedge$ (cardinality(A_1, A_2) = 1:1 or 1:n) $\wedge$ (cardinality(B_1, B_2) = m:n)

THEN cardinality(A_1, A_2) $\leftarrow$ m:n;

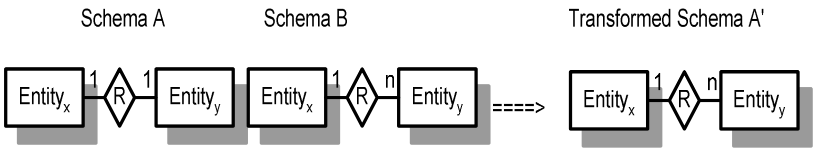

Figure 7-4 EER model with cardinality conflicts

Sub-step 1.5. Resolve conflicts on weak entities.

Conflict occurs when a strong entity appears as a weak entity in another schema. The verification of this resolution step is subject to the interdependence between entities. The schema has a weak entity that is similar to another strong entity in another schema, but with an additional key component from its strong entity. The former dominates the latter. Hence, weak entity overrides the strong entity by transforming the strong entity to weak entity for consistency. This translation process is bi-directional and information capacity equivalent.

Rule 5:

If ((entity(A_1) = entity (B_1)) $\wedge$ (entity(A) = entity(B) $\wedge$ ((key(A_2) = key(B_2))=0) $\wedge$ ((key(B_1)) $\cap$ key(B_2)) $\neq$ 0)

then Key(A_2) $\leftarrow$ (Key(A_1)+ Key (A_2))

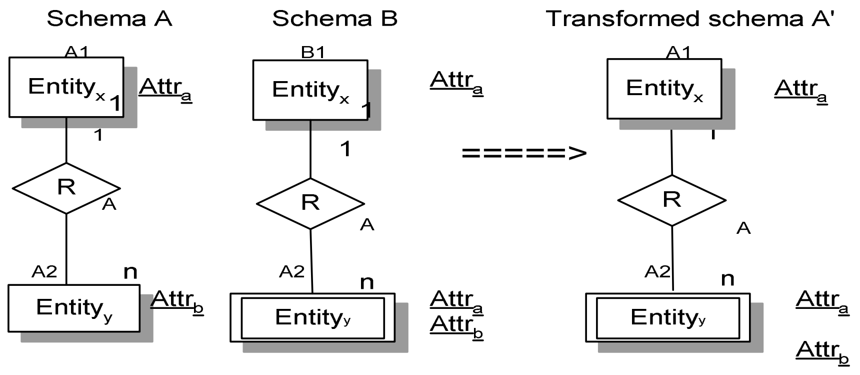

Figure 7-5 EER model with weak entity conflict

Sub-step 1.6. Resolve conflicts on subtype entities.

Conflict exists where a subtype entity appears as a super type entity in another schema. The verification of this step is to identify the overlapping of two identical entities in bi-directional in two different schemas. A1 isa A2 in one schema and A2 isa A1 in another schema. This translation process is transformed into schema with 1:1 cardinality.

Rule 6:

IF ((entity(A_2) $\subseteq$ entity(A_1)) $\wedge$ (entity(B_1) $\subseteq$ entity(B_2)) $\wedge$ (entity (A_1) = entity (B_1)) $\wedge$ (entity (A_2)= entity (B_2)))

THEN begin entity $X_1 \leftarrow$ entity A_1

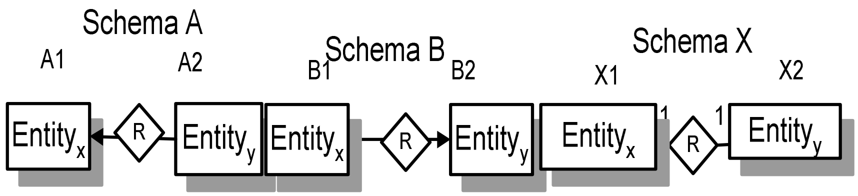

Figure 7-6 EER model with subtype conflict

In step 2 and step 3, the transformation processes are totally based on its precondition without users' interference during the integration process.

Step 2. Merge entities.

Sub-step 2.1. Merge entities by union.

In this step, there is a one-to-one mapping between every instance of domain A∪B and every instance of domain X, and vice versa.

Rule **7:**

```
IF ((domain(A) $\cap$ domain(B)) $\neq$ 0)
THEN domain(X) $\leftarrow$ (domain(A) $\cup$ domain(B))
```

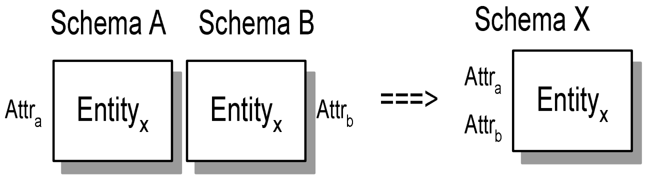

Figure 7-7 Merge EER models by union

Sub-step 2.2. Merge entities by generalization.

Case 1 : Disjoint generalisation - Entities with the same attributes appear in two schemas, but an instance of the first entity in one schema cannot appear as an instance of the second entity in another schema. There is a one-to-one mapping between every unique instance of domain A or B and every unique instance of domain X. This results to a one-to-one relationship between every instance of domain A or domain B and every instance of domain X, and vice versa. It is able to recover the instance of x, which is derived from either X1 or X2.

Case 2 : Overlap generalisation - Entities with the same attributes appear in two schemas, but an instance of the first entity in one schema can appear as an instance of the second entity in another schema. There is a one-to-one mapping between every unique instance of domain A and B and every unique instance of domain X. This results in a one-to-one relationship between every instance of domain A and B and every instance of domain X. It is able to recover the instance of x, which is derived from either domain A or B.

Rule 8:

```
IF ((domain(A) $\cap$ domain(B)) $\neq$ 0) $\wedge$ ((I(A) $\cap$I (B))=0)
THEN begin entity $X_1$ $\leftarrow$ entity A
        entity $X_2$ $\leftarrow$ entity B
                domain(X) $\leftarrow$ domain(A) $\cap$ domain(B)
                (I ($X_1$) $\cap$ I($X_2$))=0
     end
ELSE IF ((domain(A) $\cap$ domain(B)) $\neq$ 0) $\wedge$ ((I(A) $\cap$I (B)) $\neq$ 0)
```

```
THEN begin  entity $X_1 \leftarrow$ entity A
        entity $X_2 \leftarrow$ entity B
        domain(X) $\leftarrow$ domain(A) $\cap$ domain(B)
        $(I(X_1) \cap I(X_2)) \neq 0$
     end;
```

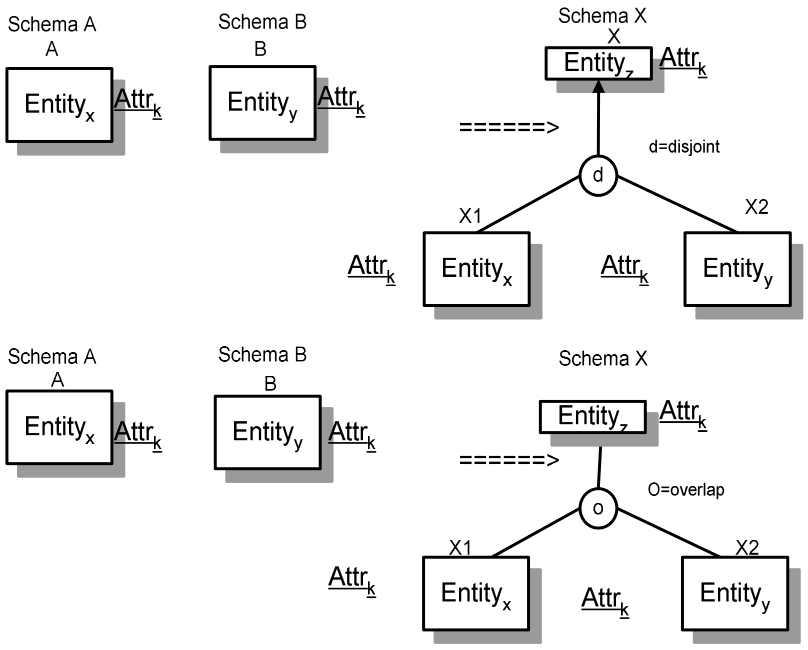

Figure 7-8 Merge EER models by generalizations

Sub-step 2.3. Merge entities by subtype relationship.

There is a one to one relationship between every instance of domain A and every instance of domain X1 and between every instance of domain B and every instance of domain X2. It is able to recover the instance of x, which is derived from either A or B. The practical recovery search logic is that any element that does not exist in domain B will be in domain A only and any element that exists in domain B will be also in domain A.

```
Rule 9:
IF domain(A) $\subset$ domain(B)
THEN begin entity $X_1 \leftarrow$ entity A
        entity $X_2 \leftarrow$ entity B
        entity $X_1$ isa entity $X_2$
```

```
end;
```

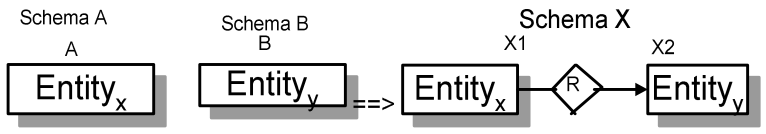

Figure 7-9 Merge EER models by subtype

Sub-step 2.4. Merge entities by aggregation.

X is an aggregation of B1, B2, and R(B). Entity A and entity B and their relationships are preserved in the transformed schema X. There is a bi-directional one-to-one mapping between elements of A, (B1,B2 R(B)) and (X1, X2, R(X)) by introducing a common key field. It is able to recover the instance of x, which is derived from either B1 or B2. X1 dominates the (B1and B2) to ensure that information is preserved after schema is transformed and X is proved to be equivalent to (A,B).

```
Rule 10:
IF relationship B →→ entity A   /*MVD  →→  means  multi-value dependency/
THEN begin aggregation $X_1$ ← (entity $B_1$ , relationship B, entity $B_2$ )
          entity $X_2$ ← entity A
          cardinality ($X_1$, $X_2$) ← 1:n
    end;
```

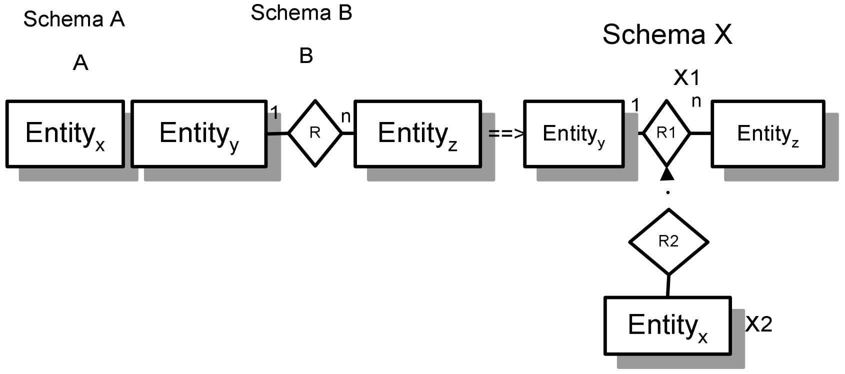

Figure 7-10 Merge EER models by aggregation

Sub-step 2.5. Merge entities by categorization.

X provides a view to schema A and schema B. X1 is a union of A1 and A2. There is a one to one mapping between every unique instance of domain A1 or A2 and every instance of domain X1. Entity X1 dominates entity (A1, A2) $\Rightarrow$ entity (A1, A2) $\leq$ entity X1, entity X2 dominates entity B $\Rightarrow$ entity B $\leq$ entity X2 to ensure that there is no information loss during transformation. It is able to recover the instance of x1, which can be derived from either A1 or A2.

```
Rule 11:
IF $(I(B) \subset I(A_1)) \vee (I(B) \subset I(A_2))$
THEN begin    entity $X_2 \leftarrow$ entity B
              entity $X_{c1} \leftarrow$ entity $A_1$
              entity $X_{c2} \leftarrow$ entity $A_2$
              categorisation $X_1 \leftarrow$ (entity $X_{c1}$ , entity $X_{c2}$)
                        $(I(X_2)$ isa $I(Xc_1)) \vee (I(X_2)$ isa $I(Xc_2))$
                        /* $X_2$ is subtype to $X_{c1}$ or $X_{c2}$ */
    end;
```

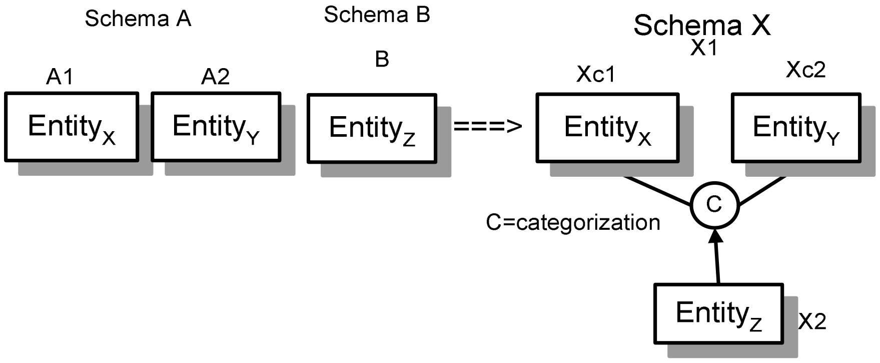

Figure 7-11 Merge schemas into categorisation

Sub-step 2.6. Merge entities by implied binary relationship.
X provides a view to A and B. There is a mapping between every unique instance of entity A and B and every instance of entity X. There is a common field of entity key to enable relationships built at each pair of instance in entity (A,B) and instance in entity X . It is able to recover the instance of entity X, which is derived from entity(A, B).

```
Rule 12:
IF x $\in$ (attribute(A) $\cap$ key(B))
THEN begin entity $X_1 \leftarrow$ entity A
           entity $X_2 \leftarrow$ entity B
           cardinality $(X_1, X_2) \leftarrow$ n:1
     end
ELSE IF ((attribute(A) $\cap$ key(B)) $\neq 0$ ) $\wedge$ ((attribute(B) $\cap$ key(A)) $\neq 0$ )
```

```
        THEN begin entity $X_1 \leftarrow$ entity A
                   entity $X_2 \leftarrow$ entity B
            cardinality $(X_1, X_2) \leftarrow$ 1:1
end;
```

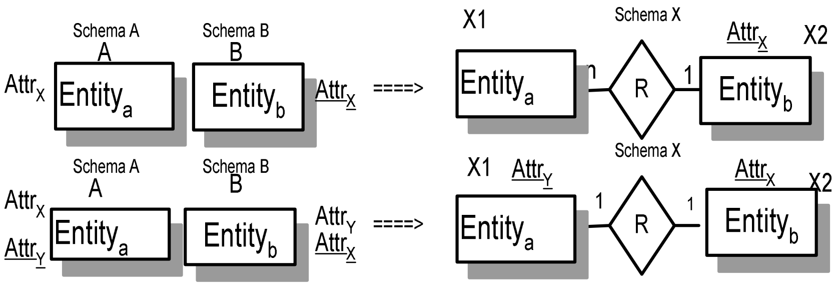

Figure 7-12 Merge EER model by implied relationship in two cases

Step 3. Merge relationships.

Sub-step 3.1. Merge relationships by subtype relationship.

Case 1: Two relationships A, B are in the same role with different levels of participation. The verification of this step is to identify the participation of two identical schemas A and B with different levels of participation but with the same role. The schema with total participation will naturally dominate the schema with partial participation to ensure no information loss after transformation. As the higher level of participation has absorbed the lower level of participation in the transformed schema with a new entity and relationship created, no alteration of data semantics is necessary.

Case 2: Two relationships have different semantics but with an intersecting relationship. The verification of this step is to identify two relationships that have different semantics but with an intersecting relationship. The schema which has overlapping relationships of different kinds of semantics would naturally dominate these schemas by assigning an overlap generalization relationship to its intersecting schemas. Hence, information about its original semantics and relationships should both be preserved.

```
Rule 13:
/*      Case 1                                    */
IF (entity($A_1$) = entity($B_1$)) $\wedge$ (entity($A_2$) = entity($B_2$)) $\wedge$
(participation($A_1$ , A) = total) $\wedge$(participation($B_1$ ,B) = partial)
THEN begin entity $X_1 \leftarrow$ entity $A_1$
```

```
        entity $X_2 \leftarrow$ entity $A_2$
        entity $X_3$ isa entity $X_1$
        relationship X $\leftarrow$ entity($X_3$, $X_2$ )
        participation($X_3$, X) $\leftarrow$ total
    end
ELSE
/*               Case 2                                  */
IF (entity ($A_1$)=entity($B_1$ )) $\wedge$ (entity($A_2$) = entity($B_2$)) $\wedge$((relation(A) $\cap$
relation(B)) $\neq$ 0)
        THEN begin      entity $X_1 \leftarrow$ entity $A_1$
                        entity $X_2 \leftarrow$ entity $A_2$
                        entity $X_3$ isa entity $X_2$
                        entity $X_4$ isa entity $X_2$;
                        relationship Xa $\leftarrow$ Relationship A
                        relationship Xb $\leftarrow$Relationship B
                  end
```

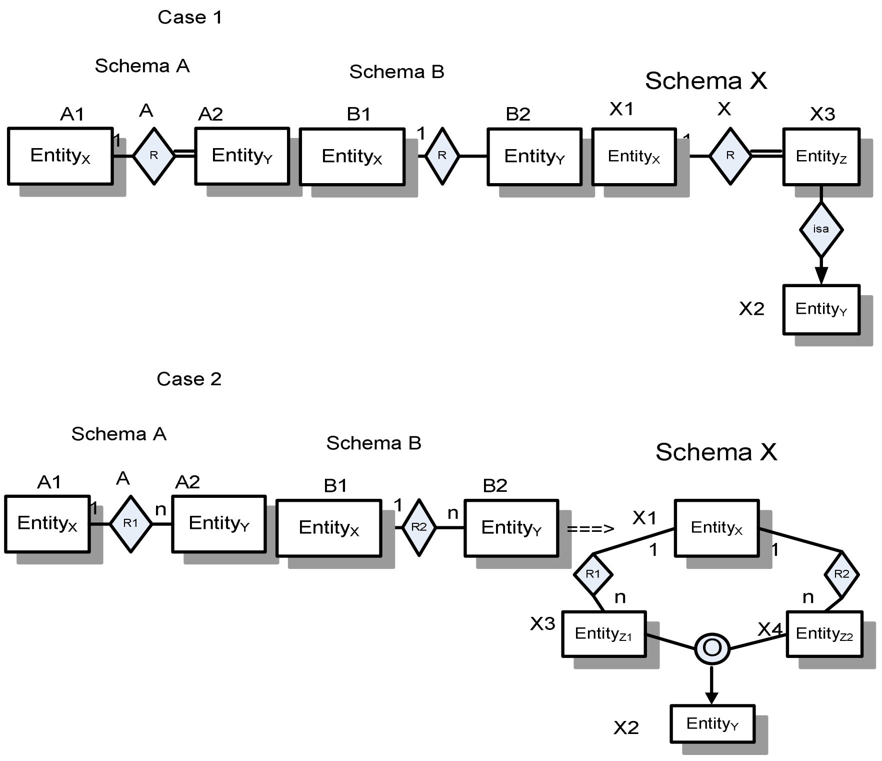

Figure 7-13 Merge EER models by subtype relationship

Sub-step 3.2. Absorbing lower degree relationship into a higher degree relationship

This step is to identify the inconsistent degree level of two identical entities in different schema A and B. The schema with the higher degree naturally dominates the schema with the lower degree to ensure that there is no information loss after transformation. This translation process is to absorb the schema with the lower degree relationship by the schema with the higher degree relationship.

Rule 14:

```
IF ((relationship(A) ⊃ relationship (B) ∧ (degree(A) > degree(B))
∧(entity(A1)=entity(B1)) ∧ (entity (A2)=entity (B2))
THEN begin    relationship(X) ← relationship(A)
              entity X1 ← entity A1
              entity X2 ← entity A2
              entity X3 ← entity A3
     end;
```

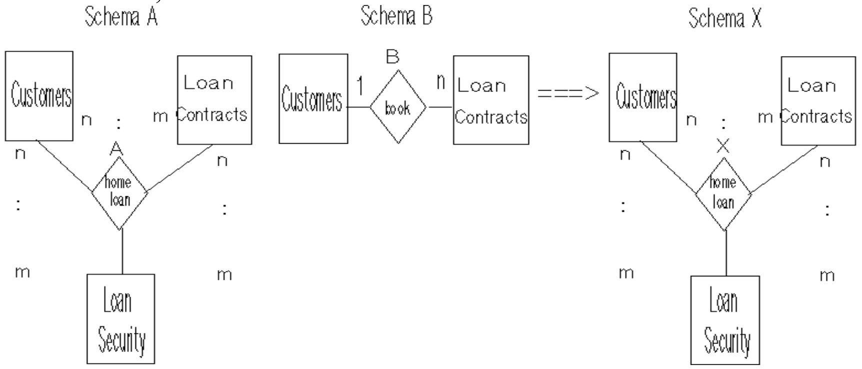

Figure 7-14 Merge EER models by absorbing relationships

7.2 CASE STUDY OF SCHEMA INTEGERATION FOR RELATIONAL DATABASES

A bank has existing databases with different schemas: one for a Mortgage Loan Customer, one for an Auto Loan Customer, one for Loan Contract and one for an Index Interest Rate. They are used by various applications in the bank. However, there is a need to integrate them together for an international banking loan system. The following are the four source schemas shown in Figure 7-15. In applying the algorithm of our methodology, the relevant steps are used in this case study as follows:

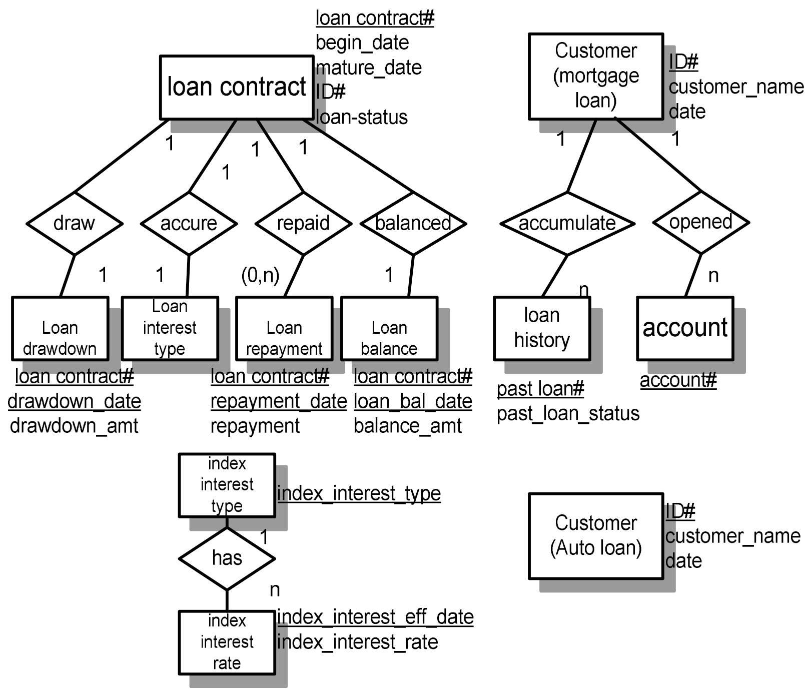

Figure 7-15 EER models of the loan system

In the first iteration, in step 1.1, there are two synonyms: Loan_status and Balance_amt such that the Loan_status can be derived from the Balance_amt. As a result, we can replace Loan_status by Balance_amt with a stored procedure to derive Loan_status value from Balance_amt. In step 2.2, the intermediate integrated schema will be merged with the index rate schema. There is an overlapping generalization between the two schemas such that a loan must be on fixed or indexed interest rate. Thus, by joining the integrated schema and the index rate schema with overlap generalization, the two schemas can be integrated.

In the second iteration, in step 2.6, there is an implied relationship between the Loan Contract schema and (Mortgage loan) Customer segment such that ID# is used as an attribute in loan schema but as an entity key in customer schema. Thus, we can derive cardinality from the implied relationship between these entities, and integrate the two schemas into one EER model.

In the third iteration, in step 2.6, there is an implied relationship between the Loan Contract schema and (Auto loan) Customer segment and integrate the two schemas into one EER model. In step 3.1, the relationships between the loan contract and the two customer entities can be merged into an overlap generalization as shown in Figure 7-16.

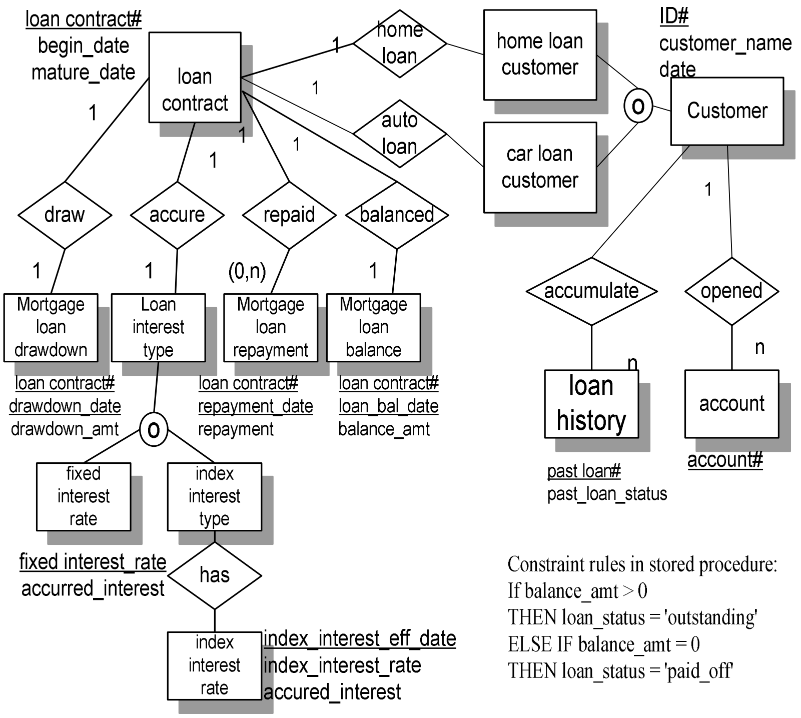

Figure 7-16 Integrated loan system schema

7.3 SCHEMA INTEGRATION FOR OBJECT-RELATIONAL DATABASES

The relational database system (RDB) has been dominant in the industry for the last two decades. Object-oriented database application (OODB) is recognized as a post-relational technology that can improve productivity. Hence, most companies need to enhance their existing relational database systems to support new Object-oriented applications as and when needed. The trend of the current industrial is to implement an object-relational database system (ORDB) using a relational engine with OO features. This section proposes a methodology to integrate existing ORDB based on user requirements. A frame metadata is used to enforce constraints for solving semantic conflicts arising from schema integration. The metadata is an object-relational metadata that can specify static data semantics as well as dynamic data operation based on four relational tables.

In order to have coherence between new OO database applications and the existing database systems, leading database manufacturers gradually modify their relational database system to support OO features. It results in the so called object relational database management System (ORDBMS) in the current market. Most of these ORDBMS are powered by a relational database engine with extensions to OO interface and features. When designing database using these systems, user employ either relational view with some OO features, or use OO view under a relational core. We propose a practitioner approach to integrate this kind of ORDBMS. A simplified schema integration technique is applied to the source database schemas, either in relational or object oriented structure, based on user requirements. The frame model metadata is used to capture these semantic constraints and other abstractions result from the integration. The resultant system is an integrated schema of the object relational database system (Fong, 2000).

Frame Model Metadata

The frame model metadata follows an object-oriented paradigm, based on frame. All conceptual entities are modeled as objects and group in object types called classes. The frame model metadata is implemented with a knowledge representation schema that represents the taxonomy inheritance structure (i.e., abstract relationship), properties of objects (i.e. classes and attributes), and the relationship between those objects in a standardized form. The details can be referred to Figure 8.2 in Chapter 8.

Schema integration provides a global view of multiple schemas. Our approach uses a bottom-up approach to integrate an existing database into a global database by pairs. The main objective is to provide an integrated schema based on user requirements with no loss of information. The general algorithm is as follows:

```
Begin
  For each existing database do
    Begin
      If its conceptual schema does not exist
      then reconstruct its conceptual schema by reverse engineering;
      For each pair of existing database schema A and schema B do
      begin
       resolve semantic conflicts between schema A and schema B;
       /*step1*/
      Merge classes/entities and relationship relations between schema
       A and B;
```

```
        /*step2a*/
        Capture and resolve the semantic constraints arising from
         integration using Frame Model metadata
        /*step2b*/
        end
        end
end
```

The input schemas must analyze in pairs and resolve semantic conflicts in different areas. Conflicts are resolved using well-defined semantic rules with user supervisions. Classes are merged by union or abstractions like subtype, generalization, aggregation, and others. To demonstrate this step, UML diagrams are used to represent the conceptual schema of relational and object-oriented, respectively. The constraints arising from the integration are then captured and enforced in the frame model metadata. The details of each of the above steps are demonstrated as follows.

Step 1. Identify and resolve the semantics integrity conflicts among input schemas.

Input: Schema A and B with classes and attributes in conflicts to each other on semantics.
Output: Integrated Schema Y after data transformation.

In dealing with definition-related conflicts like inconsistency in keys or synonyms/homonyms in names, user supervision is essential. For instance, two entities may have some candidate keys overlapping with each other but using different keys as the primary key. The user has to clarify in this kind of situation.

On the other hand, for conflicts arising from structural differences, the goal is to capture as much information from the input schemas as possible. The most conservative approach is to capture the superset from the schemas. For example, in dealing with cardinality, the cardinality of the same relationship relation in schema A is 1:1 while the other one in schema B is 1:n. Since a 1:n relationship is the superset of a 1:1 relationship, the 1:n cardinality is used for the integrated relation. Another example is the participation constraint. If the same relationship relation in different schemas have different levels of participation constraints, partial participation always overrides total participation in the integrated schema. It is because total participation is a subset of partial participation.

When dealing with data type and subtype conflicts, the association/relationship relation is used for resolution. To illustrate this, assume we have an attribute *Department* of the entity *School* in one schema and an entity *Department* in another schema. To resolve the data type conflict, a 1:n relationship is formed in the integrated schema to link up these two entities.

Step 2. Merge classes and relationship into frame model metadata

Input: Existing schema A and B
Output: Merged (integrated) schema X with semantic constraints captured by frame model metadata

Classes are merged using the union operator if their domain is the same. Otherwise, abstractions are used under careful user supervision. By examining the same keys with the same class name in different database schemas, we can merge the entities by union. The integrated class takes all the attributes from both entities. Abstractions like generalization and aggregation are used in merging classes in different input schemas when they fulfill the semantic condition. The details are as follows.

Sub-step 2.1. Merge associations by capturing cardinality.
The integration can be based on the richer data semantics of 1:n association and which can be specified in the cardinality attribute of the Attribute class in the frame model metadata.

Rule 1:
```
IF (class($A_1$) = class ($B_1$)) $\wedge$ (class($A_2$) = class ($B_2$)) $\wedge$
    (cardinality($A_1$, $A_2$) = 1:1) $\wedge$ (cardinality($B_1$, $B_2$) = 1:n)
THEN cardinality($A_1$, $A_2$) $\leftarrow$ 1:n;
ELSE IF (class($A_1$) = class($B_1$)) $\wedge$ (class($A_2$) = class($B_2$)) $\wedge$
            (cardinality($A_1$, $A_2$) = 1:1 or 1:n) $\wedge$ (cardinality($B_1$, $B_2$) = m:n)
        THEN cardinality($A_1$, $A_2$) $\leftarrow$ m:n;
```

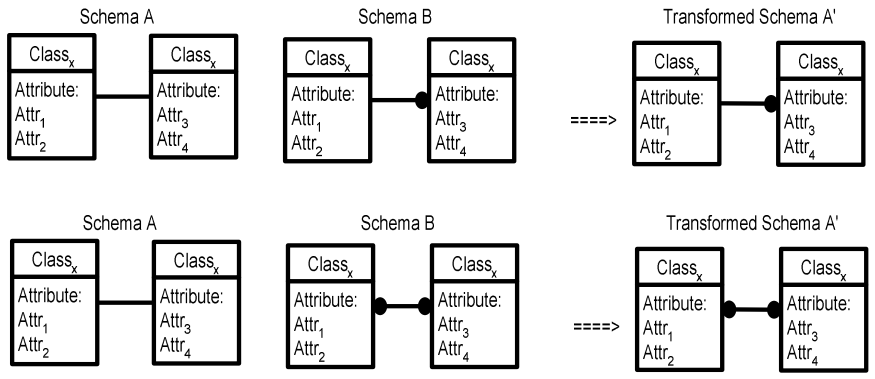

Figure 7-17 Merge classes by associations

Frame Model Metadata Implementation

Header class

Class Name	Parents	Primary key	Operation	Class Type
X	0	A_1		Static
Y	0	A_3		Static

Attribute class

Attribute Name	Class Name	Method Name	Attribute Type	Default Value	Cardinality	Description
A_1	X		String			Attribute
A_2	X		String, Y		1	Pointer to Y
A_3	Y		String, X		N	Attribute, Pointer to X
A_4	Y		String			Attribute

Sub-step 2.2. Merge classes by subtype.

The integration can be based on the subtype relationship between two classes and which can be specified in the Parent attribute of the Header class in the frame model metadata.

```
Rule 2:
IF domain(A) $\subset$ domain(B)
THEN begin Class($X_1$) $\leftarrow$ Class(A)
           Class($X_2$) $\leftarrow$ Class(B)
           Class($X_1$) isa Class($X_2$)
   End;
```

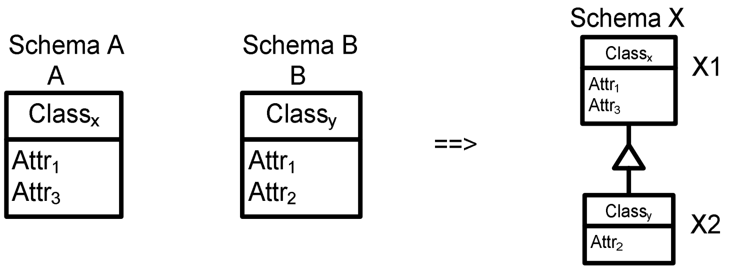

Figure 7-18 Merge classes by subtype class

Frame Model Metadata

Header class

Class Name	Parents	Primary key	Operation	Class Type
Y	X	A_1		Static
X	0	A_1		Static

Attribute class

Attribute Name	Class Name	Method Name	Attribute Type	Default Value	Cardinality	Description
Y	A_1		Integer			Superclass primary key
Y	A_2		Date			Subclass non-key attribute
X	A_3		Date			Superclass non-key attribute

Sub-step 2.3. Merge classes by generalization.

The integration can be based on the subtype relationship between two subclasses and one superclass and which can be specified in the Parent attribute of the Header class and the method class in the frame model metadata.

```
Rule 3:
IF ((domain(A) $\cap$ domain(B)) $\neq$ 0) $\wedge$ ((I(A) $\cap$ I(B))=0)
THEN begin  Class($X_1$) $\leftarrow$ Class(A)
            Class($X_{2)}$ $\leftarrow$ Class(B)
            Domain(X) $\leftarrow$ domain(A) $\cap$ domain(B)
            (I ($X_1$) $\cap$ I($X_2$))=0        /* disjoint generalization
```

```
        end
ELSE IF ((domain(A) $\cap$ domain(B)) $\neq$ 0) $\wedge$ ((I(A) $\cap$ I(B)) $\neq$ 0)
        THEN begin Class($X_1$) $\leftarrow$ Class(A)
                   Class($X_2$) $\leftarrow$ Class(B)
                   domain(X) $\leftarrow$ domain(A) $\cap$ domain(B)
                   (I ($X_1$) $\cap$ I($X_2$)) $\neq$ 0        /* overlap generalization
             end;
```

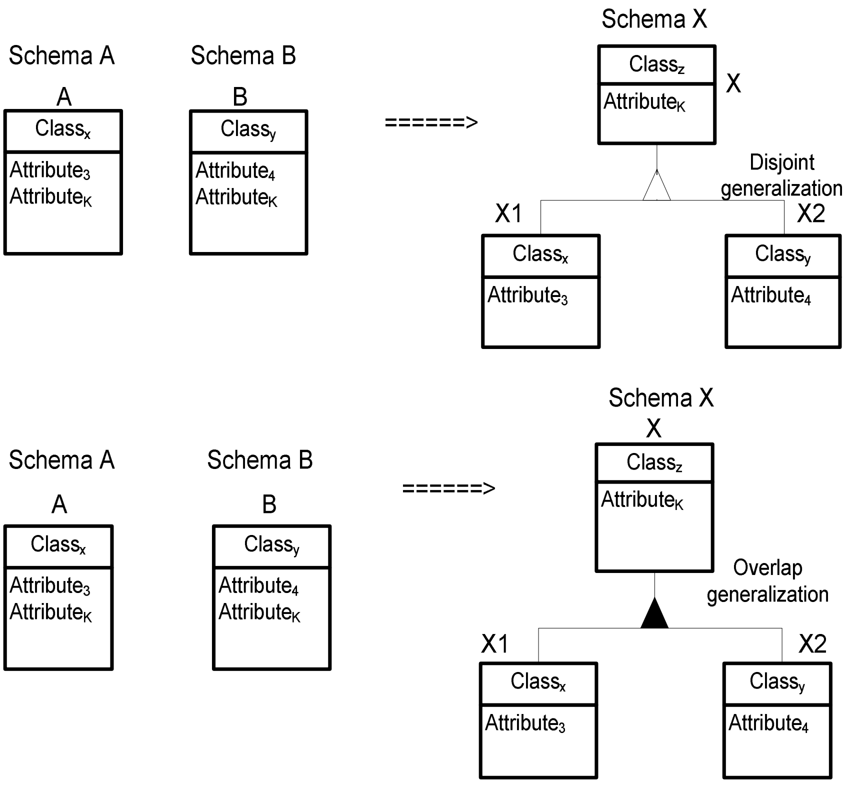

Figure 7-19 Merge classes by generalization

Frame Model Metadata Implementation

Header class

Class Name	Parents	Primary key	Operation	Class Type
Z	A_k	0		Static
X	A_k	Z	Call Ins_X	Active
Y	A_k	Z	Call Ins_Y	Active

Attribute class

Attribute Name	Class Name	Method Name	Attribute Type	Default Value	Cardinality	Description
Z	A_k		integer			Superclass primary key
X	A_3		date			Subclass non-key attribute
Y	A_4		date			Subclass non-key attribute

Constraint class

onstraint_ Name	Method_ Name	Class_ Name	Param eters	Owners hip	Even t	Seque nce	Timing
Ins_X	Insert_X	X	A_k	Self	Insert	before	Repeat
Ins_Y	Insert_Y	Y	A_k	Self	Insert	before	Repeat

Method class

Method_ Name	Class_ name	Parame ter	Seq_ no	Condition	Action	Descrip tion
Insert_X	X	@A_k		If (Select * from Y where A_k = @A_k) = null	Insert X (@A_k, A_3)	
Insert_Y	Y	@A_k		If (Select * from X where A_k = @A_k) = null	Insert Y (@A_k, A_4)	

Sub-step 2.4. Merge classes by aggregation.
In the object-oriented view, aggregation provides a convenient mechanism for modeling the relationship *IS_PART_OF* between objects. By extending the semantics of slot values, an attribute stores either the reference of another object or a copy of that object to make it a composite value. An object becomes dependent upon another if the dependent object is referred by an attribute in the 'parent' object. When an object is deleted, all dependent objects it related to are also deleted. Since the implementations of this abstraction are different in relational and OO models, the merging procedures are different as well.

Rule 4:

```
If Domain (Key(B1)) $\subset$ Domain (Attr(A)) AND
   Domain (Key(B2)) $\subset$ Domain (Attr(A))
THEN  begin aggregation($X_1$) $\leftarrow$ Class(A)
                Class($X_2$) $\leftarrow$ Class(B1, association, B2)
```

End;

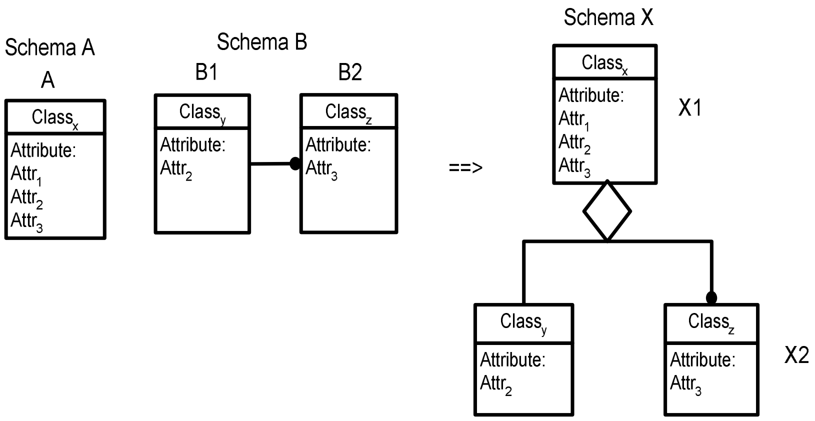

Figure 7-20 Merge classes by aggregation

Frame Model Metadata Implementation

Header class

Class Name	Parents	Primary key	Operation	Class Type
X	A_1	0	Call Del_X, Ins_X	Active
Y	A_2	X		Static
Z	A_3	Y		Static

Attribute class

Attribute Name	Class Name	Method Name	Attribute Type	Default Value	Cardinality	Description
X	A_1		Integer		1	Superclass primary key
X	A_2		Y		1	Attribute pointer to Y
X	A_3		Z		N	Attribute pointer to Z
Y	A_2		Date		1	Superclass non-key attribute
Z	A_3		Date		N	Subclass non-key attribute

Constraint class

Constraint_ Name	Method_ Name	Class_ Name	Paramet ers	Owne rship	Event	Sequ ence	Timing
Del_X	X	Delete _X	A_1, A_2, A_3	Self	Delet e	Befo re	Repeat
Ins_X	X	Insert_ X	A_1, A_2, A_3	Self	Insert	Befo re	Repeat

Method class

Method_ Name	Class_ name	Paramet er	Seq _no	Condition	Action	Descrip tion
Delete_ X	X	@A_1, @A_2, @A_3			Delete from Z where A_3 = @A_3 Delete from Y where A_2 = @A_2 Delete from X where A_1 = @A_1	
Insert_ X	X	@A_1, @A_2, @A_3		If ((Select * from Y where A_2=@A_2) <> Null) AND ((Select * from Z where A_3=@A_3) <> Null)	Insert X (@A_1, @A_2, @A_3)	

7.4 CASE STUDY OF OBJECT-RELATIONAL SCHEMAS INTEGRATION

In a bank, there are existing databases with different schemas: one for the local mortgage customers, another for overseas banking customers and one for local car loan customers. They are used by various applications in the bank. However, there is a need to integrate them for an international banking loan system. Assume the schema integration has to be done in both the relational representation as well as the OO representation. The following are the input schemas and final integrated schema for both models followed by the one frame model metadata representing the integrated schema of both models.

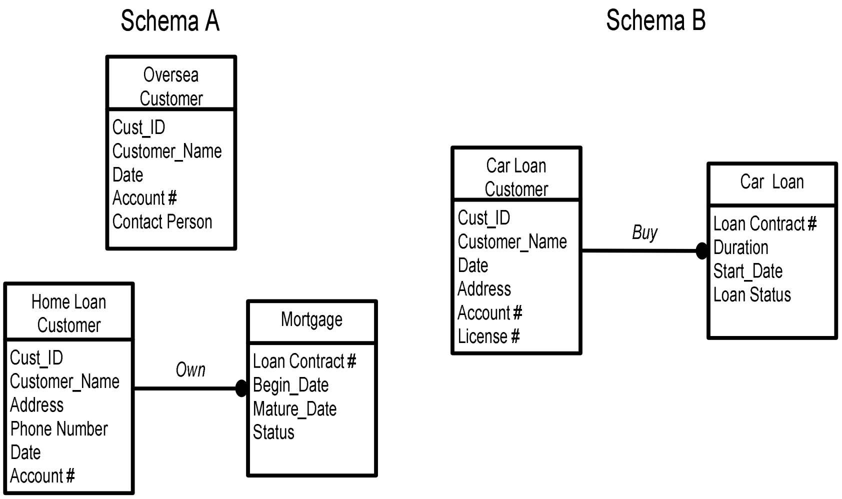

Figure 7-22 Object-relational schemas to be integrated

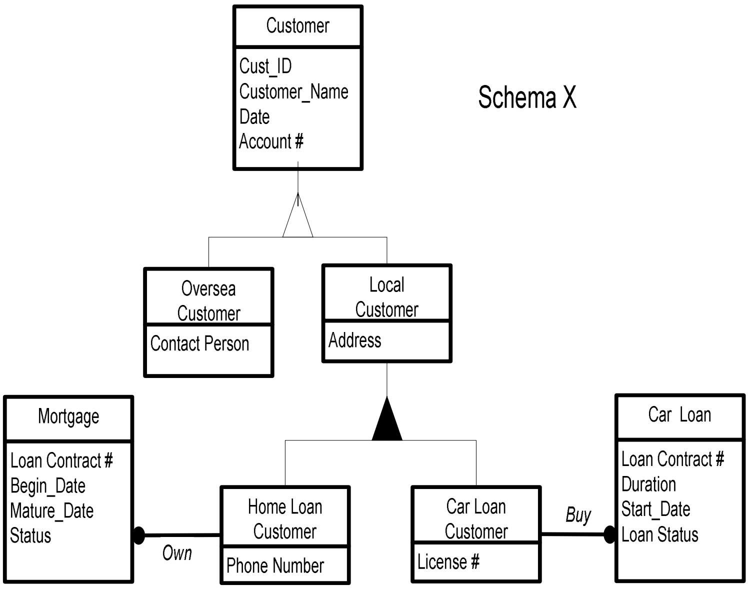

Figure 7-22 Integrated object-relational schemas for loan system

Frame Model Metadata:

Header class

Class Name	Parents	Primary key	Operation	Class Type
Customer	0	Cust_ID	Call Del_Cust	Static
Local Customer	Customer	Cust_ID	Call Ins_Local, Del_Local	Active
Oversea Customer	Customer	Cust_ID	Call Ins_Overseas	Static
Car Loan Customer	Local Customer	Cust_ID		Active
Home Loan Customer	Local Customer	Cust_ID		Active
Car Loan	Loan_Contract #	0		Static
Mortgage	Loan_Contract #	0		Static

Attribute class

Attribute Name	Class Name	Method Name	Attribute Type	Default Value	Cardinality	Description
Customer	Cust_ID		String			Superclass Key Attribute
Customer	Customer_ Name		String			Attribute
Customer	Date		Date			Attribute
Customer	Account #		String			Attribute
Local Customer	Address		String			Attribute
Oversea Customer	Contact_Pe rson		String			Attribute
Car Loan Customer	License #		String			Attribute
Home Loan Customer	Phone_ Number		Numeric			Attribute
Car Loan	Loan_ Contract #		String			Key Attribute
Car Loan	Duration		Integer	1		Attribute
Car Loan	Start_Date		Date			Attribute
Car Loan	Loan_ Status		String			Attribute
Mortgage	Loan_ Contract #		String			Key Attribute
Mortgage	Begin_		Date			Attribute

	Date					
Mortgage	Mature_ Date		Date			Attribute
Mortgage	Status		String			Attribute

Constraint class

Constraint_ Name	Method_ Name	Class_ Name	Param eters	Owner ship	Even t	Sequ ence	Timing
Del_Cust	Customer	Delete_ Custom er	Cust_ ID	Self	Dele te	Befo re	Repeat
Ins_Local	Local Customer	Insert_ Local	Cust_ ID	Self	Inser t	Befo re	Repeat
Del_Local	Local Customer	Delete_ Local	Cust_ ID	Self	Dele te	Befo re	Repeat
Ins_Overse as	Overseas Customer	Insert_ Overse as	Cust_ ID	Self	Inser t	Befo re	Repeat

Method class

Method_ Name	Class_ name	Parame ter	Seq _no	Condition	Action	Descr iption
Delete_ Customer	Custo mer	@Cust _ID		If (Select * from Local_Customer where Cust_ID = @Cust_ID) then call Del_Local If (Select * from Oversea where Cust_ID = @Cust_ID) then Delete Oversea_Customer(Cust_ID)	Delete Customer (@Cust_ID)	
Insert_ Local	Local Custo mer	@Cust _ID		If (Select * from Oversea_Customer where Cust_ID = @Cust_ID) = null	Insert Local_Custo mer (@Cust_ID)	
Delete_ Local	Local Custo mer	@Cust _ID		If (Select * from Car_Loan_Customer where Cust_ID = @Cust_ID) then Delete Car_Loan_Customer (Cust_ID) If (Select * from Home_Loan_Custom er where Cust_ID =	Delete Local_ Customer (@Cust_ID)	

				@Cust_ID) then Delete Home_Loan_Customer(Cust_ID)		
Insert_ Oversea	Overseas Customer	@Cust _ID		If (Select * from Local_Customer where Cust_ID = @Cust_ID) = null	Insert Overseas_ Customer (@Cust_ID)	

7.5 SUMMARY

We have presented a three step schema integration methodology with proof of its schema integration rules in terms of information dominance and equivalence in the transformation processes. We have justified the correctness of our proposed schemas integration rules by (1) preserving data semantics between original schema and translated schema to ensure that there is no information loss in our transformation processes and (2) most of these steps are capable of being reversed to recover the original schema via the translated schema.

This chapter proposes a methodology to integrate existing object-relational database schemas in both relational and object oriented view to facilitate different application requirements. The main objective of this methodology is to integrate existing source schemas to fulfill user requirements with no loss of information. A bottom-up schema integration technique is used to integrate existing object-relational schemas. Frame model metadata, an object-relational data model, is used to capture the semantic conflicts and other high level abstract relationships arising from the integration process.

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QUESTIONS

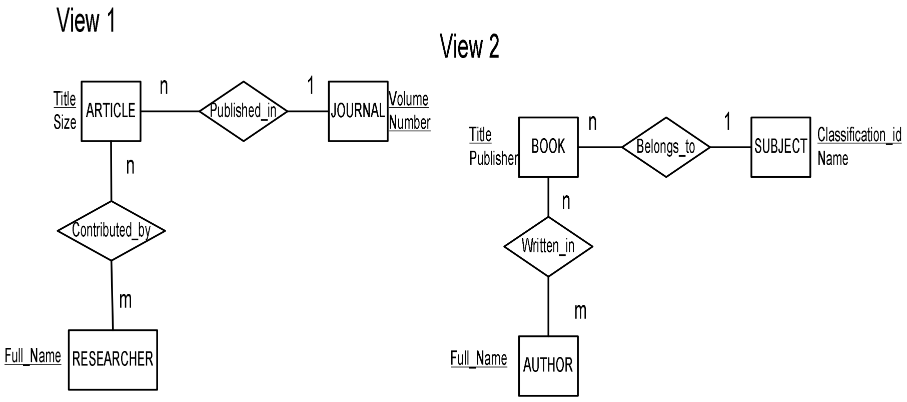
Questions 7-1

Can multiple relational schemas be integrated into one relational schema? Give the rational of your answer. How can the integration of relational schemas be compared with the integration of extended entity relationship models with respect to meeting users' requirements?

Question 7-2

Provide an integrated schema for the following two views, which are merged to create a bibliographic database. During identification of correspondences between the two views, the users discover the followings:

1. RESEARCHER and AUTHOR are synonyms.
2. CONTRIBUTED_BY and WRITTEN_IN are synonyms,
3. ARTICLES belongs to a SUBJECT.
4. ARTICLES and BOOK can be generalized as PUBLICATION.



CHAPTER **8**

DATABASE AND EXPERT SYSTEMS INTEGRATION

System reengineering is broadly defined as the use of engineering knowledge or artifacts from existing systems to build new ones and is a technology for improving system quality and productivity. Traditionally this work has focused on reusing existing software systems, (i.e., software programs, files, and databases). However, knowledge based systems have also been developed within these organizations and are growing in popularity. It will soon be necessary for us not only to reuse existing databases, but also to reuse the existing expert systems to create new expert systems and expert database systems.

Reusing or developing an integrated system for existing expert systems and database systems is a complex process. There are three possible scenarios that a system developer may encounter:

1. Reusing expert systems - The system developer reuses an existing expert system and builds new databases to create an integrated expert database system. This happens when:

- The existing expert system has difficulty handling a growing volume of factual data.

- A new database is required in the organization and this database can support the existing expert systems.

- A new database system is required to work underneath an existing intelligent interface, such as a natural language interface.

2. Reusing databases - The system developer reuses existing databases and builds a new expert system to create an expert database system. This happens when:

- There is a requirement to build intelligent components into existing database, (for example, integrity constraints, natural language interfaces or intelligent interfaces, deductive rules, intelligent retrieval, or query optimization).

- A new expert system is required and the existing databases can support this system.

3. Reusing both database and expert systems - The system developer reuses both existing database and expert systems to create an expert database system. For example, the company links expert systems and databases, or the company has bought a new expert system and links it with their existing databases.

8.1 USING A KNOWLEDGE-BASED MODEL TO CREATE AN EXPERT DATABASE SYSTEM

To provide a solution for the reengineering and/or the integration of DBSs and ESs, a knowledge based model with the following properties is required (Huang, 1994):

- A higher level synthesis model. The best approach to integrate DBSs and ESs was to embrace the facilities of both DBSs and ESs technologies under one umbrella; that is, a higher order synthesis was needed. The new model will combine high-level information modeling features, deductive capability, active capabilities (i.e., integrity constraints), and the flexibility of AI-based systems with the efficiency, security, and distributed and concurrent access provided by DBSs. Computer scientists have investigated the use of abstract data type concepts to define this richer data model that includes semantic data modeling concepts and object-oriented concepts and makes no real distinction between data and knowledge (in the form of rules).

- Reengineering capability. The most feasible approach to integrate DBSs and ESs was to enhance existing systems to couple both technologies. This is due to the concept of reengineering to save on the cost of implementation. The peer-to-peer architecture for the DBSs and ESs integration has been seen as the easiest way to achieve the reengineering of existing DBSs and ESs.

The above criteria can be used to create a four-tier framework as depicted in Figure 8-1. In this figure, the existing systems form the lower tier. The required data from these systems is extracted using coupling classes. The coupling classes extract, and possibly transform, the data of the lower tier into knowledge usable by the integrated system. The upper tier combines and enhances the knowledge of the existing system with additional knowledge to create an integrated expert database system

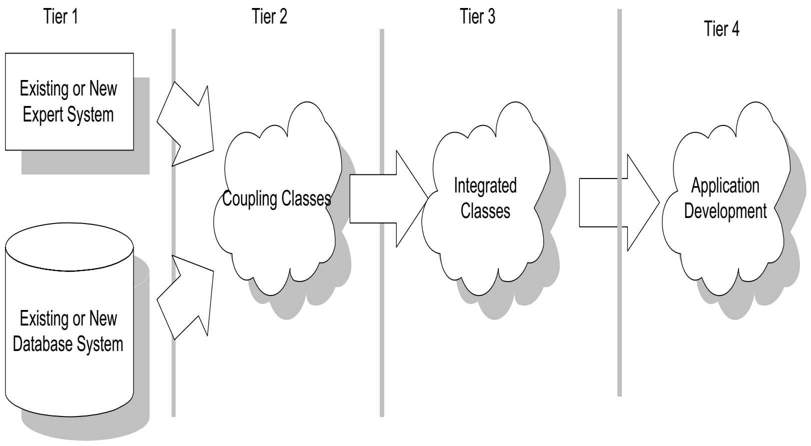


Figure 8-1 The four tier integrate expert database system model

Tier 1: Existing Systems

The existing systems contain data to be reused in the new/integrated EDS. Only the data required for the operation of the integrated system is extracted. This data is brought into a consistent state through the coupling classes of tier 2.

Tier 2: Coupling Classes

Coupling classes describe the information in existing systems. A coupling class provides the interface between the extension (or reengineered upper) layer and the existing systems. The uniformity of this interface layer insulates the upper layers from changes in the lower layers and can be used to bring information together so that data representing the same entities or attributes are consistent.

An attribute in a coupling class is derived from the values of the entities stored in the underlying systems. The derivation is a simple one-to-one mapping.

The coupling classes provide information from existing knowledge repositories, and additional information can also be stored by the integrated system. The information from the existing systems is only extracted on demand, as it would be unwise to copy information out of these repositories to store in the integrated systems without endangering the consistency of information across the organization.

Tier 3: Integrated Classes

The third layer combines the components of the coupling classes with additional classes (and objects) to create an integrated system. To form an integrated system, name conflict and semantic conflict problems need to be solved. Since the system has a unified structure, (i.e., a higher level synthesis model), the name conflict problem can be easily solved by using the synonym index. The synonym index creates a relationship between two different attributes with the same values.

To solve the semantic conflict problem between different attributes, additional classes must be appended into the integrated system. For instance, the value "vacancy" in the employment attribute of the Employee relation in an existing relational database indicates that the employee is available for assignment to a new project. In an existing ES, the same information is represented using an attribute availability with values "yes" or "no". To resolve this conflict, an additional class must be created to enable the availability attribute of the existing ES to derive its value from the Employee database coupling class. The new additional class must involve the following method:

```
IF employment = "vacancy"
THEN availability = "yes"
ELSE availability = "no"
```

Tier 4: Application Development

After the integrated system has been developed, the system developer can use it as a knowledge base to develop its own application. The application system defines the components necessary to answer and give explanations for all problems that it is to solve.

8.2 A Knowledge-Based Model For The Integration Of Expert Systems And Database Systems

An expert system frame model metadata (Huang, 1994) is a good example of a knowledge based model that fulfills the requirements for constructing an integrated EDS. The frame model metadata is an EER model framework used to construct an effective knowledge based management system. It is a higher-order synthesis that includes frame concepts, semantic data modeling concepts and object-oriented concepts to ensure no real distinction between “data” and “knowledge.”

The frame model metadata is an object-oriented-like database that structures an application domain into classes. Classes are organized via generalization, aggregation, and user-defined relationships. Knowledge-based system designers can describe each class as a specialization (i.e., subclass) of its more generic superclass(es). Thus, attributes and methods of objects of one class are inherited by attributes and methods of another class lower in the ordering.

The ability to attach procedures to objects enables behaviour models of objects and expertise in an application domain to be encapsulated in a single construct. The attached procedures follows an IF-THEN structure that enables representation of production rules as well as normal procedures.

The constraints of database systems include integrity constraint enforcement, derived data maintenance, triggers, protection, version control and so on. These are referred to as active database and deductive database systems. The frame model metadata unifies data and rules allowing these advanced features to be implemented. The knowledge processing mechanism (i.e., inference engine) and data retrieval mechanisms, have also been built into the frame model metadata. It also supports very strong integrity constraint enforcement.

The frame model metadata follows the object-oriented paradigm. All conceptual entities are modeled as objects. The same attribute and behaviour objects are classified into an object type, called a class. An object belongs to one, and only one, class. Both facts and rules are objects in the frame model metadata.

The frame model metadata is implemented with a knowledge representation schema that includes object structure descriptions (i.e., classes), user-defined relationships between entities, and structure inheritance descriptions defined by taxonomies of structure that support data and behaviour inheritance (i.e., abstract relationship) as shown in Figure 8-2.

```
Description: Class
 Class  { Class_Name   /* a unique name in all system */
          Primary_Key /*an attribute name or by default a
                                  class_name */
          Parents   /* a list of class names */
          Description  /* the description of the class */
          Attributes /*a list of attributes */
          Methods  /* a list of methods; */
          Constraints  /* constraint methods for the class */
          }
Description: Attribute
Attribute {
         Attribute_Name  /* a unique name in this class */
         Attribute_Type  /* the data type for the attribute */
         Default_Value  /* predefined value for the attribute */
         Cardinality  /* is the attribute single or multi-valued */
         Description /* a description of the attribute */
         Constraints /* constraint methods for the attribute */
         }
Description: Method
Method {   Method_Name /* a unique name in this class */
           Parameters   /* a list of arguments for the method */
           Type /* the final result data type */
           Description  /* the description of the method */
           Method_Body  /* processing function of the method */
           {     If /* the rule conditions */
                 Then /* the rule actions or normal methods */   }
           Constraints /* a list of constraints for this method */
           }
Description: Constraint
Constraints  /* a list of constraint methods for this class */
      {    Method_Name  /* constraint method name */
           Parameters     /* a list of arguments for the method */
           Ownership   /* the class name of the owner of the
                 method*/
           Event /* triggered event */
           Sequence  /* method action time */
           Timing /* the method action timer */ }
```

Figure 8-2 The structure of the frame model metadata

The components of the frame model metadata can be described as follows:

- Classes

The Frame model metadata consists of three classes: static classes, active classes and coupling classes. Static classes represent factual data entities, active classes represent rule entities, and coupling classes represent the temporal entities imported from tier 1 and used by tier 3 to form an EDS. In other words, an active class is event driven, obtaining data from database when invoked by certain events. Static classes store data in its own database. The three classes all use the same structure. Combining these three types of objects within the inheritance hierarchy structure enables the frame model metadata to represent and combine heterogeneous knowledge.

The structure of a class includes three main parts: attributes, methods, and constraints. An attribute may be an ordinary attribute as in the EER model, a complex attribute in the sense that it is structured or it may represent a set, or a virtual attribute defined in the method part. A method can represent the behavior of the class, or give definitions of a virtual attribute, a deductive rule, or an active rule. Constraints represent additional knowledge concerning the attributes, the methods, and the class. Every class includes basic frame information to represent the class entity, called the header. The header of the class structure includes class name, primary key, parents, and a description. The Class_Name is a class identifier; that is, a unique name defined by the application developer. The Primary_Key assists the system to define the semantics of an object identifier. The frame model metadata supports a mechanism to deal with the Primary_Key and object name to ensure the object name is a unique name in the application. Parents represent the generalization/specialization relationship between the current class and its super class. Each class also has a Description document, which contains a textual description of the class.

Figure 8-3 shows an example of a relational table and its correspondent coupling class structure in the frame model metadata for illustration.

Relation Person in database

Field name	Type	Field
Name	Character	15
Sex	Character	1
Father	Character	15
Mother	Character	15

Mapped correspondent class in the frame model metadata
Class Name: Persons

```
Attributes:
    Name: Method(name)
    Sex: Method(sex)
    Father: Method(father)
    Mother: Method(mother)
Methods:
    name (): Text; {............}
    sex (): Text;{............}
    father (): Text;{............}
    mother (): Text;{............}
```

Figure 8-3 An example of a relation in the frame model metadata

The database coupling class mirrors the database structure (i.e. schema), but does not include all of the data in the database. The reason is that it is difficult to hold a large amount of data in the integration system. The expert system coupling class represents the communication that must be performed when data passes between the frame model metadata and an expert system. The expert system coupling class includes:

- Output Part Attributes: All the data that are required by the expert system.

- Input Part Attributes: All the results that are generated by the expert system.

The conversion procedure will translate all input data variables that exist in the expert system into the output part attributes of the class. The program developer will decide the variable name in which to save the resultant information from the expert system. All the attributes of an expert system coupling class are represented as virtual variables. The communication functions between the frame model metadata and the external system are built into the method of each attribute. For example: Consider a credit assessment system called Credit that was built in the Crystal system. The expert system and its coupling class are shown below in Crystal format in Figure 8-4.

```
*  Credit Assessment Expert System in Crystal
*  RULE LIST                        Thu Oct 21 22:13:33 1993  Page:    1
[  1]  bank references are good
         IF          DO: Test Expression    customer_overdraft<50
           AND    DO: Test Expression    customer_history$="good"
[  2]  credit rating
       + IF    [   4] customer status is house_owner
       +   AND [   3] customer salary is sufficient
       +   AND [   1] bank references are good
           AND   DO: Assign credit_rating$ = "good"
[  3]  customer salary is sufficient
        IF    DO: Test Expression  monthly_salary>monthly_repayment
[  4]  customer status is house_owner
         IF        DO: Test Expression  customer_status$="house-owner"
[  5]              CRYSTAL  MASTER  RULE
       +IF    [   2] credit rating is good
```

[<Number>] means rule number
$ means the variable is text

```
Class Name: Credit
Attributes:
     Customer_Status: Method(customer_status)         /*output part*/
     Monthly_Salary: Method(monthly_salary)           /*output part*/
     Monthly_Payment:Method(monthly_payment)          /*output part*/
     Customer_Overdraft:Method(customer_overdraft)/*output part*/
     Customer_History: Method(customer_history)       /*output part*/
     Customer_Credit: Method(customer_credit)          /*input part*/
Methods:
     customer_status (): Text; {.........................}
     monthly_salary (): Number; {.........................}
     monthly_payment (): Number; {.........................}
     customer_overdraft (): Number; {.........................}
     customer_history (): Text;{.........................}
     customer_credit (): Text;{.........................}
```

Figure 8-4 An expert system and its coupling class in the frame model metadata

● Attributes

These represent the properties of a class. A particular object will have a value for each of its attributes. The attribute values that describe each object become a major part of the data stored in the database. An attribute that is composed of several more basic attributes is called a composite attribute. Attributes that are not divisible are called simple or atomic attributes. An attribute value can also be derived or calculated from the related attributes or objects; for example, the Age and Date_of_Birth attributes of a person. For a particular person object, the value of Age can be determined from the current date and the value of the person's date of birth. This type of attribute is called a virtual attribute in the frame model metadata, and is the result of a deductive rule or an active rule. For example, an attribute Generation of a person class can be deduced from the following rule:

```
If age > 40 then old person;
    if age < 16 then child;
          if 16 < age < 40, then young;
               on the event dead then dead person.
```

Most attributes have a single value for a particular object; such attributes are called single-valued. In some cases an attribute can have a set of values for the same object; for example, a College_Degrees attribute for a person. A person can have two or more degrees. A multivalued attribute may have lower and upper bounds on the number of values it can store. For example, the Colors attribute of a car may have between one and five values. Figure 8-5 shows an example of attributes of an object Hector_Person:

Object Identifier: Hector_Person

```
Attributes:
     Name="Hector"
     Date_of_Birth="06/02/65"
     Sex="M"
     Address="63 Chester Road, Sunderland, SR2 7PR"
     Age= Method(age)+
     Father= Object(Andrew)++
     Mother= Object(Anne)
```

+The syntax to represent a virtual value in an object is Method(<method>)

++ The syntax to represent an object value in an object is Object(<object>)

Figure 8-5 An example of an attribute in the frame model metadata

- Methods

Rules extend the semantics of the data. The specification of rules is an important part of semantic data modeling, since many of the facts in the real world are derived rather than consisting of pure data (Gray et al, 1992). It is increasingly important to integrate rules into data models in new information systems. A crucial characteristic of an object-oriented system is that the paradigm provides mechanisms for structuring and sharing not only data, but also the programs (i.e., methods) that act on the data. The frame model metadata uses this characteristic to integrate rules into its model. The methods of the frame model metadata represent the behavior, the active rules, and the deductive rules of a particular object. Since the behavior representation of the object-oriented model is reflected by the different needs of different user communities, there is not an established way of representing behaviour in object-oriented systems. The method body takes a production rule structure in the frame model metadata. Figure 8-6 shows an example of a method of the object Hector_Credit_Rating.

```
Object Identifier: Hector_Credit_Rating
Attributes:
        Customer= "Hector"
        Customer-Status= "House-Owner"
        Credit-Rating= Method(credit-rating)
Methods:
credit-rating (): Text;
        { IF Customer-Status = "House-Owner"
          Then Credit-Rating = "Good"}
```

Figure 8-6 An example of a method in the frame model metadata

- Constraints

There are many properties of data that cannot be captured in the form of structures. These properties essentially serve as additional restrictions on the values of the data and/or how the data may be related (structured). For example, there may be a restriction that if a person is head of a department, the person must also belong to the department. Such restrictions cannot be expressed in terms of structures, but must be captured by some additional mechanism. It is a primary consideration of database technology to ensure data (or knowledge) correctness and consistency. This requires the system to support integrity constraint functions. These functions are also required to allow proper handling of updates of knowledge for interrelated actions and active database rules. There are many semantics present in constraints that can be very useful when answering queries. Constraints can be used to prevent a possibly expensive database search operation or to answer otherwise unsolvable queries (Houstsma and Apers, 1990). The constraint technology used in current database systems requires different levels of integrity constraint. There are two types of constraints used in database technology:

1) Static constraints that limits the allowable database states so as to accurately reflect the real world situation.

2) Dynamic constraints that restrict the possible database state transitions.

For example, we can define an attribute constraint in the attribute salary. The constraint will be:

```
(salary_refuse ( ) Self Insert Before ( ) )
```

The method of salary_refuse is that no raise more than 500 is allowed. (note: salary@new is the data for new salary.)

```
If salary@new  -   salary > 500
Then (fail)
```

The Hierarchical Structure

The frame model metadata uses the generalization relationship to build its hierarchical structure. There are three different types in the frame model metadata, i.e., static generalization, active generalization, and coupling generalization. These are discussed below.

1) Static Generalization

Static objects use the generalization relationship to represent abstract knowledge in their hierarchical structure. For example, we can use a static hierarchical structure to represent Male person knowledge by creating a new class called Male as shown in Figure 8-7. The new class Male inherits all the features of the Persons class and appends with it a constraint rule to ensure that the sex of the person is male. This type of generalization can be found in most semantic data models.

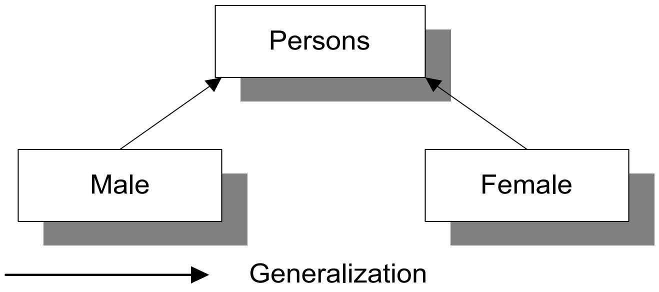


Figure 8-7 The static hierarchy structure

2) Active Generalization

Active classes use the generalization relationship to represent the hierarchical rule structure that is found in most production rule systems. This enables the system to represent complex knowledge. This also enables the system to easily trigger rules, since all related rules are clustered together, i.e., stored in the same object because of inheritance. For example, consider the family rule base system shown in Figure 8-8. This rule base is presented in a format devised by the author.

```
Rule Name: Male (X:Person)  /* (X:Person) means the paramenter X
                                              is a Person object */
        IF  (X::sex="Male")  /* X::sex means the sex attribute value of
                                             the object X */
        Then true;  /* The result of this rule is a boolean */
Rule Name: Child(X:Person, Y:Person)  /* The parameters X and Y
                                             are Person objects */
        IF  (X::father=Y) .OR. (X::mother=Y)
        THEN true;
Rule Name: Son(X:Person, Y:Person)
        IF Child(X,Y) .AND. Male(X)
        THEN true;
```

Figure 8-8 A family knowledge base

Each rule is represented as an active class as shown in Figure 8-9. The Son class inherits all the attributes and methods from the Male class and the Child class. The system will easily trigger the child rule (i.e., method child) and the male rule (i.e., method male) in the Son class by using the inheritance hierarchy.

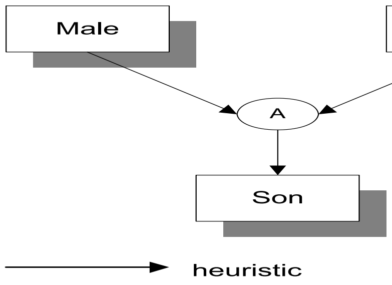


Figure 8-9 The active generalization structure of the family knowledge base

Active generalization is similar to Heuristics. Heuristics can combine logical operators (such as AND, OR, and NOT) to represent complex rules easily and clearly. The AND and OR logical operators combine multiple active entities together in active generalization. For example, the AND operator can combine the Child and Male entities via the active generalization relationship to produce the Son entity. Each active object is represented by a boolean value, i.e., true or false, in the frame model metadata. If the rule in an active class fails to be triggered, the active object will be false; otherwise, the active object will be true. The NOT entity allows negation, i.e., 'not false' is 'true'.

3) Coupling Generalization

The form of generalization between the coupling classes is the same as active generalization. Different coupling classes can use the generalization relationship to combine to form a new coupling object. This hierarchical structure can represent distributed knowledge (or distributed DB) semantics. For example: Consider two databases, Person (in MS SQL Server) and Staff (in Oracle). The attributes for these two databases are:

Person (MS SQL Server)	Staff (Oracle)
Name	Name
Sex	Department
Father	Position
Mother	Age

The frame model metadata can be used to create two coupling classes to represent these two databases. We can then create a new class called Employee that inherits its properties from these two coupling classes. One problem that may occur during the process is when the same attribute name exists in two different parent classes; for example, Name exists in both the Person class and the Staff class. In such cases, the user needs to define which attribute has a higher priority.

Reengineering is an important feature in the frame model metadata. The system enables reengineering through the coupling classes and coupling generalization. For example, consider an existing paediatric ES. The frame model metadata can be used to reuse parts of this system when building a new ES for child cardiology medical diagnosis. This is similar to what happens in the real world. A child cardiology case is diagnosed by a cardiology doctor who consults with a pediatrician.

Implementation of the Frame Model Metadata

To implement the frame model metadata, we must include as inputs, the database system and the expert system and as output, the Frame model metadata classes as shown in Figure 8-10.

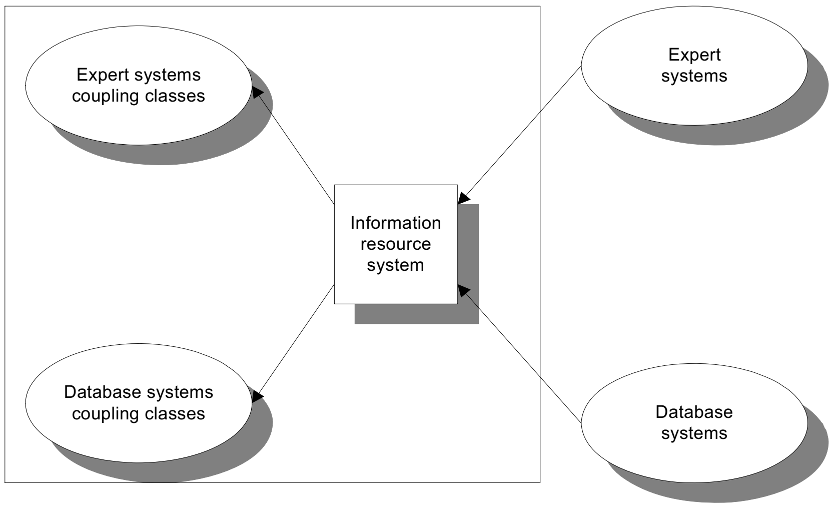

Expert systems coupling classes
Expert systems
Information resource system
Database systems coupling classes
Database systems

Figure 8-10 The overview of the frame model metadata architecture

8.3 STEPS FOR USING THE FRAME MODEL METADATA IN DATABASE AND EXPERT SYSTEM INTEGRATION

We can apply the frame model metadata as an object-oriented-like database in reengineering existing database systems and expert systems in the following:

Reusing Expert Systems

A company may have an expert system. The ES does not, however, store any data in a database. The system developer is required to create a database used by the expert system. This database could be built into a DBMS that has an interface with the existing expert system. This would require many changes to the source code of the existing expert systems. The steps for this implementation are:

Step 1. New application systems requirement analysis.

The system developer must analyze the existing expert system in order to understand what information is required. Database analysis is also required to implement the expert database system.

Step 2. Database creation within the Frame model metadata.

The system developer must develop a database for the expert system. The system developer then converts this database description within the frame model metadata as a static class. Again, the system developer can also add rules to the existing expert system. He/she then converts the rules into the Frame model metadata. Each rule is represented as an active class. Each condition of a multi-condition rule is also represented as an active class. If the condition is not a rule, it will be recognized as a fact. Atomic attributes will be attached to this class. The existing expert system can be coupled into the frame model metadata as coupling classes. Each attribute is a virtual attribute in this coupling class.

Step 3. Integration of databases and expert systems within the Frame model metadata.

Create the integrated classes within the frame model metadata by synchronizing the attributes among the coupling classes. With the integrated class in static or active class format, we can form an EDS. The EDS can extract information from the source ES and DBS into coupling classes, synchronize the coupling classes by the integrated classes, and transform information into knowledge (i.e., knowledge engineering) to meet the application requirements.

Step 4. Develop an application using the EDS.

The EDS from the previous steps is a knowledge-based system. System developers can use it to develop new applications. The input to the EDS is the source ES and source DBS; the coupling classes and the integrated classes are temporal in the sense that their existence depends on the users requirements, at run time only.

Reusing Database

In this case, a database exists in the company. The system developer is required to build a new expert system to interface an existing DBMS to access the database. The procedure is:

Step 1. Knowledge acquisition.

The system developer must perform the necessary knowledge acquisition. The result will be the rules of the expert system. The system developers must know the existing database structure, in order to understand what data exists to support the expert system.

Step 2. Create expert systems within the frame model metadata.

The system developer implements the expert system within the frame model metadata. The existing database will be used as "coupling classes."

Step 3. Integrate database systems and expert systems within the Frame model metadata.

The system developer will then integrate the existing database and the existing expert system within the Frame model metadata.

Step 4. Develop new applications using the EDS.

With the EDS, system developer can apply the rules from the source ES, using the data from the source DBS, and develop a knowledge-based system.

Integrate Database System and Expert System

In this case, a database system and an expert system already exist in the company. The system developer is required to build a communication channel between these two systems. The usual method to build this integrated system requires changes to some parts of the existing systems. The data can be passed into the existing system by the system I/O stream. The procedure is as follows:

Step 1. Knowledge acquisition.

The system developer must perform the necessary knowledge acquisition. The acquisition processing will focus on what is needed for the integration of the two existing systems. The knowledge acquisition will define what data will be integrated between the two systems.

Step 2. Create coupling classes.
The database system and the expert system will be coupled within the frame model metadata as two separate coupling classes.

Step 3. Integrate database systems and expert systems.
The system developer will then integrate these two subsystems into a system within the frame model metadata.

Step 4. Application development using the EDS.
The source ES and the source DBS can be integrated into an EDS, which transform the input information into knowledge by developing a knowledge-based system; i.e., applying ES rules and extract data from a DBS.

8.4 A CASE STUDY: BUILDING AN INTELLIGENT HUMAN RESOURCE SYSTEM

This section is concerned with an application of EDS in information processing—the Integrated Human Resource Management System (IHRMS) within a UK government agency. The IHRMS in this agency has been conceived as an information system. The benefits sought from EDS technology are greater flexibility and the ability to handle problems in terms of knowledge and symbolic reasoning.

The government agency employs approximately 4,000 staff, and is subdivided into a number of Directorates, each being responsible for specific services. Each Directorate has a resource manager who is responsible for a number of projects. The duty of the resource manager is to fit suitably qualified people to specific jobs within each of the projects for their Directorate. Project requirements and progress are monitored by Staff Management Units (SMUs) assigned to each project. It is the SMU who reports back to the resource manager within the directorate. Any vacancy that cannot be filled within the directorate is then considered across the other directorates. This involves staff being transferred between directorates, which is coordinated by the resource manager after consultation with the other directorate SMU and resource managers.

The main task of this project was to match staff with suitable placements and the ability to hold data relating to staff skills, location, availability, personal factors, and other human resource management knowledge. An EDS will be developed for this purpose. In order to keep this example simple, Table 8-1 is a subset of the knowledge base (only three rules) held in the Human Resource Management System (HRMS) ES and Table 8-2 only shows a part of the personnel database sub-schema used by the EDS.

Table 8-1 The sample rules for the HRMS ES

```
Rule Find-Employee:
        IF First-Priority-Group
           AND Skill-Sufficient
           AND  Location = Preferred-Working-Area
        THEN  Display Person-id AND Name

Rule First-Priority-Group:
        IF Project-Directorate = Person-Directorate
           AND  Staff-Type = ”Internal”
           AND  Age < Job-Required-Age
           AND Availability =”Yes”
           AND Average-Grade = “High”
        THEN True

Rule Skill-Sufficient:
        IF Job-Required-Skill-1 = Person-Skill-1
           AND Job-Required-Skill-2 = Person-Skill-2
        THEN  True
```

Table 8-2 Personnel Database Sub-Schema

Field Name	Type	Width
ID	Character	8
Name	Character	20
Age	Number	2
Staff-Type	Character	15
Directorate	Character	20
Current-Status	Character	15
Average-Mark	Number	1
Skill-1	Character	20
Skill-2	Character	20

In this case study, the HRMS is to do the job-person matching. Its process includes the consideration of vacancy criteria, skills criteria, and staff's preferred next work areas. As shown in Table 8-1, the execution of a job-person match begins with the matching process in vacancy criteria, which includes staff type (internal or external), location, directorate, availability, and grade. Staff whose details match vacancy details in these aspects will be selected from the database as first priority group staff for further evaluation.

Staff selected as first priority group are then evaluated in their skill criteria. Each vacancy skill is used to match those of staff's skill attainment, and each skill level is checked if it meets the required level. During these processes, a skill qualification point is calculated for each staff and then evaluated to decide whether this staff will be selected as the candidate for this vacancy.

The third condition is to identify if this vacancy is one of the work areas that have been recommended as staff's next moves, and also, if this vacancy is one of staff's preferred next work areas. This information will be displayed together with result explanations for users' reference in decision-making.

The development environment of this EDS example could be any of the three cases as described above. In this case study, we assume that the situation is the case 3, which means the system will reuse an existing ES and an existing database. The frame model metadata forms a communication bridge between the various subsystem.

EDS Development

Step 1. Knowledge acquisition.

In this step, the attributes of existing ES and DB must be analyzed. The EDS developer also must define the characteristics of each attribute. Table 8-3 shows a table structure used to represent the result of the knowledge acquisition from an ES. The schema of the table includes four attributes: name, style, type, and memo. The name attribute represents the object name in the existing system. The object will exist in three different kinds of styles, i.e., atom, rule, and variable, in an ES. Atom means that the object is a fact. Rule means that the object is an inference rule. Variable means that the object value will be generated or supported by another event. The type attribute represents the content type of the object. Memo is to enable the developer to write down comments for the object. This will assist the developer to understand the meaning of the object during the development cycle. Table 8-3 shows the result of the knowledge acquisition for the HRM ES.

Table 8-3 The Result of the Knowledge Acquisition for the HRM ES

Name	Style	Type	Memo
Find-Employee	Rule	Boolean	
First-Priority-Group	Rule	Boolean	
Skill-Sufficient	Rule	Boolean	
Display	Rule	Boolean	
Person-id	Variable	Character	
Name	Variable	Character	
Location	Variable	Character	
Preferred-Working-Area	Variable	Character	
Project-Directorate	Variable	Character	
Person-Directorate	Variable	Character	
Staff-Type	Variable	Character	
Age	Variable	Number	
Job-Required-Age	Variable	Number	
Availability	Variable	Character	“yes”or “no”
Average-Grade	Variable	Character	“high”, “middle”, or “low”
Job-Required-Skill-1	Variable	Character	
Person-Skill-1	Variable	Character	
Job-Required-Skill-2	Variable	Character	
Person-Skill-2	Variable	Character	
”Internal”	Atom	Character	
“High”	Atom	Character	
“Yes”	Atom	Character	
True	Atom	Boolean	

The EDS developer needs to know which existing databases will relate to the new system. The developer also must understand the existing database schema. There are three ways which the developer can discover the existing database schema. One way is to go through the database documents to find out its schema. The second method is to retrieve the database schema from the data dictionary system of the existing database system. The final method is to use the database conversion or migration tools to reverse the database schema into a developer understandable format. In the case study, the existing database is stored in a relational DBMS. We used its data dictionary system to retrieve the database schema. The sub-schema of personnel database can be seen in Table 8-2.

The final phase of this step is to analyze the synonym relationship between these attributes of the existing two systems. Table 8-4 shows the synonym of the attributes for this case.

Table 8-4 The Synonym Table for the IHRMS

Attribute	System-Type	System-Name	Synonym-Degree	Attribute	System-Type	System-Name
Person-id	ES	HRM	Same	ID	DB	Personnel
Name	ES	HRM	Same	Name	DB	Personnel
Person-Directorate	ES	HRM	Same	Directorate	DB	Personnel
Staff-Type	ES	HRM	Same	Staff-Type	DB	Personnel
Age	ES	HRM	Same	Age	DB	Personnel
Availability	ES	HRM	Semantic	Current-Status	DB	Personnel
Average-Grade	ES	HRM	Semantic	Average-Mark	DB	Personnel
Person-Skill-1	ES	HRM	Same	Skill-1	DB	Personnel
Person-Skill-2	ES	HRM	Same	Skill-2	DB	Personnel

There are two kinds of synonym degree: i.e., Same and Semantic. “Same” means that the two attributes represent the same object with the same semantic. “Semantic” means that the two attributes use different semantics to represent the same object. In this case, the developer must solve the semantic conflict problem between these two attributes. For example, Availability of HRM indicates whether an employee is available for the new vacancy job or not. The values for this attribute are “yes” or “no”. Current-Status of personnel database represents the job title for an employee. If the employee does not have any duty, its values will be “Vacancy”. In order to make the synonym relationship between these two attributes, the following rule must be created.

```
IF Current-Status = “Vacancy”
THEN Availability = “yes”
ELSE Availability =”no”
```

The same problem will happen in the attributes of Average-Grade and Average-Mark for this case study. The following shows another semantic rule for this problem.

```
IF Average-Mark >= 80
hTHEN Average-Grade = “high”
ELSE IF average-mark >= 50
THEN Average-Grade = “middle”
ELSE Average-Grade = “low”
```

Step 2. Create coupling classes

The frame model metadata will create two coupling classes for the IHRMS. Figure 8-11 shows the HRM ES coupling class and Figure 8-12 shows the Personnel DB coupling class. The attributes of ES coupling class will come from the attributes of HRM. The Variable style of HRM attributes will become to output part attributes of the ES coupling class (see Table 8-3). The system developer must define an input part attribute that will store the result of the HRM ES. In this case, the system developer defines an attribute, called find-employee. The attached method of this attribute will execute the external ES. The attribute of DB coupling class is a mirror of personnel database schema (see Table 8-4). Each attribute within the coupling class will contain a method.

```
Class Name: HRM
Attributes:
 Person-id : Method(person-id)                    /*output part*/
Name : Method(name)                               /*output part*/
 Location : Method(location)                      /*output part*/
 Preferred-Working-Area : Method(preferred-working-area)
                                                /*output part*/
Project-Directorate : Method(project-directorate)
                                                /*output part*/
Person-Directorate : Method(person-directorate)
                                                /*output part*/
Staff-Type : Method(staff-type)                   /*output part*/
Age: Method(age)                                  /*output part*/
Job-Required-Age : Method(job-required-age)/*output part*/
Availability : Method(availability)               /*output part*/
Average-Grade : Method(average-grade)             /*output part*/
Job-Required-Skill-1 : Method(job-required-skill-1)
                                               /*output part*/
Person-Skill-1 : Method(person-skill-1)           /*output part*/
Job-Required-Skill-2 : Method(job-required-skill-2)
                                                /*output part*/
Person-Skill-2 : Method(person-skill-2)           /*output part*/
Find-Employee: Method(find-employees)             /* input part */
Methods:
   person-id() : text;{...........}
   name() : text; {...........}
   location() : text; {...........}
   preferred-working-area() : text; {...........}
   project-directorate() : text; {...........}
   person-directorate() : text; {...........}
   staff-type() : text; {...........}
   age():number; {...........}
   job-required-age() : number; {...........}
   availability ():text; {...........}
   average-grade ():text; {...........}
   job-required-skill-1() : text; {...........}
   person-skill-1 ():text; {...........}
   job-required-skill-2 ():text; {...........}
   person-skill-2():text; {......}
   find-employee():text; {........}
```

Figure 8-11 HRM ES coupling class

```
Class Name: Personnel
Attributes:
  ID: Method(id)                                /*input part*/
  Name: Method(name)                            /*input part*/
  Age: Method(age)                              /*input part*/
  Staff-Type: Method(staff-type)                /*input part*/
  Directorate: Method(directorate)              /*input part*/
  Current-Status :Method(current-status)        /* input part*/
  Average-Mark: Method(average-mark)            /*input part*/
  Skill-1: Method(skill-1)                      /*input part*/
  Skill-2: Method(skill-2)                      /*input part*/
Methods:
  id():text; {...........}
  name():text; {...........}
  age():number; {...........}
  staff-type():text; {...........}
  directorate():text; {...........}
  current-status():text; {...........}
  average-mark():number; {...........}
  skill-1():text; {...........}
  skill-2():text; {...........}
```

Figure 8-12 Personnel DB coupling class

The standard frame for the method will depend on the attribute that is an output part attribute or input part attribute. Figure 8-13 shows the standard algorithm of these two type methods.

```
Standard-Output-Part-Attribute(); <result-data-type>;
{       Request the data from the system (i.e. Request)
        Send the data to the external existin system (i.e. Write)}

Standard-Input-Part-Of-Attribute();<result-data-type>;
{       Receive the data from the existing external system
                                        (i.e. Receive)
        Save the data to the system     (i.e. Save)}
```

Figure 8-13 The standard algorithm of the method for the coupling class

There are four generic functions for the the frame model metadata to enable process the coupling class.

- **Request**: The function is to get a value from the other class's attribute of the system.

- **Write**: The function will write a value to the standard IO stream of the existing external system or a special defined IO stream.

- **Receive**: The function will read a value from the standard IO stream of the existing external system or a special defined IO stream.

- **Save**: The function will save a value to the other class's attribute of the system.

For example, the method for the "Name" attribute of HRM coupling class will be like:

```
HRM.name(): Text;
{
/* output part attribute variable */
Request (HRM.name);
Write(HRM.name, standard-IO-stream)
}
```

The same process will happen in the DB coupling class. For example, the method for the "Name" attribute of Personnel coupling class will be like:

```
Personnel.name(): Text;
{
/* input part attribute variable */
/* temp = temporary memory. */
Receive (temp, standard-IO-stream);
Save(temp, Personnel.name);
}
```

The real process of the four generic functions will depend on the coupling situation. They will represent different process for the different integrating requirements. For example, the Receive function may involve a SQL statement to request a data from the external relational database or it processes a RPC (Remote Procedure Call) to execute an external existing ES. The process of these four generic functions will be decided in the step 3.

Step 3. Integrate database system and expert system.

To integrate these two coupling classes, the developer must insert the synonym information (see Table 8-4) into the information resource dictionary system (IRDS) as an integrated class. IRDS is a repository for the integrated classes. The integrated class is to integrate and resolve naming conflicts among the coupling classes. The resultant synonym table (Table 8-4) in the form of integrated class is to synchronize and integrate the coupling classes. The solution is to create two active classes for the two semantic rules described in Step 1. Figure 8-14 shows the two active classes.

```
Class Name:          Availability
Attributes:
          Person-id:             text
          Current-Status:        Method(current-status)
          Availability:          Method(availability)
Methods:
          Current-status(): text
          { Request(Personnel.Current-Status)  }

          availability(): text;
          ( IF Current-Status = "Vacancy"
            THEN Availability = "yes"
             ELSE Availability = "no"    }

Class Name:          Average-Grade
Attributes:
          Person-id:             text
          Average-Mark:          Method(average-mark)
          Average-Grade          Method(average-grade)
Methods:
          Average-mark(): number
          { Request(Personnel.average-mark)    }

          Average-grade(): text;
          ( IF Average-Mark >= 80
            THEN Average-Grade = "high"
             ELSE IF Average-mark >= 50
             THEN Average-Grade ="middle"
             ELSE Average-Grade = "low" }
```

Figure 8-14 Availability and average-grade active classes

After this, the developer can insert the synonym data into the IRDS. Table 8-5 shows the synonym part information of the IRDS for the IHRMS.

Table 8-5 Synonym Information for the IHRMS
HRM.Person-id = Personnel.ID
HRM.Name = Personnel.Name
HRM.Person-Directorate = Personnel.Directorate
HRM.Staff-Type = Personnel.Staff-Type
HRM.Age = Personnel.Age
HRM.Person-Skill-1 = Personnel.Skill-1
HRM.Person-Skill-2 = Personnel.Skill-2
HRM.Availability = Availability.Availability
HRM.Average-Grade = Average-Grade.Average-Grade

The processing flow for the coupling class method is:

```
IF the attribute is an output part of attribute
THEN IF the attribute has a synonym
     THEN send message to the synonym object to retrieve
              the data
     ELSE ask users to input the data
ELSE execute the coupling module functions
```

The coupling module functions are a group of low level communication procedures, e.g., RPC. Different systems will have different procedures.

The EDS is created as a result of the previous step and it consists of the integrated classes (static or active), coupling classes, source ES, and source DBS. When the current EDS needs any information from the external existing systems, the frame model metadata will execute a RPC function to trigger an interface program via the network. The interface program will accept the instructions from the output-channel and pass these onto the external system. The frame model metadata then receives the results from the external system and passes these back to the system via the input-channel. Each external system has an identified input-channel and output-channel. This input-channel and output-channel information is stored in the IRDS. Figure 8-15 shows the coupling module data flow diagram.

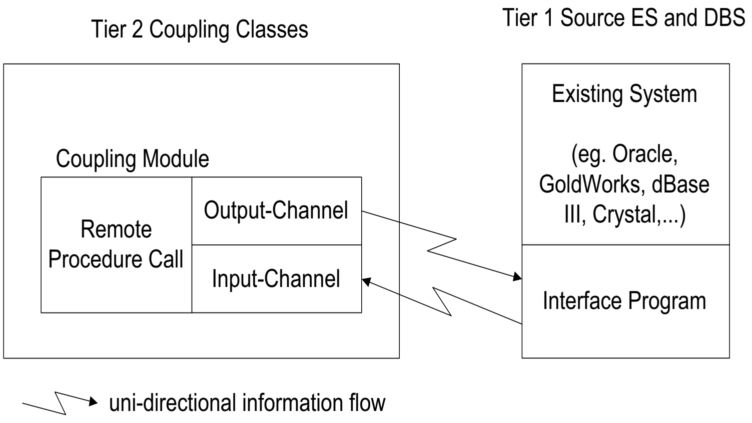


Figure 8-15 The coupling module data flow diagram

Figure 8-16 shows the data flow diagrams of the developed EDS, which acts as a knowledge based system for new application.

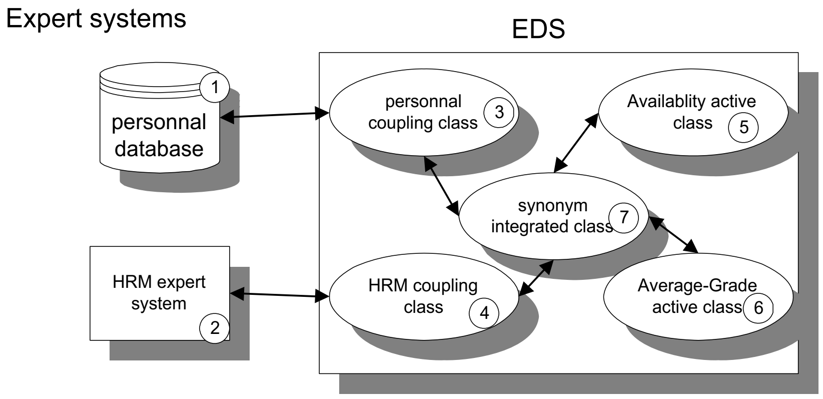


Figure 8-16 Integrated environment of the IHRMS

Note: Each class (module) in the EDS has a number identifier to be used in Figure 8-17.

Step 4. Application development.

After integrating personnel DB and HRM ES, users can ask the IHRMS to give advice for a particular vacancy job. In this case, the EDS will ask users to key-in the vacancy job information. Figure 8-17 shows the flow chart for the personnel information system using the developed EDS.

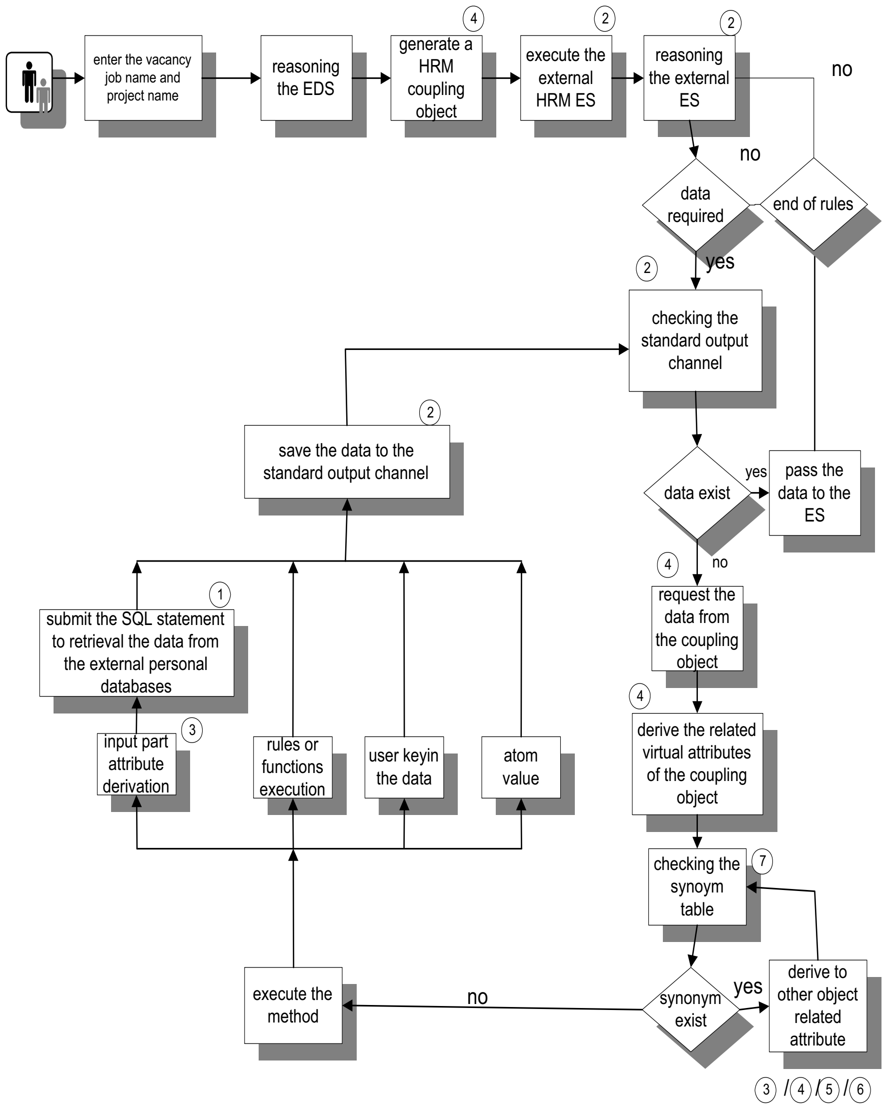

enter the vacancy job name and project name
reasoning the EDS
generate a HRM coupling object
execute the external HRM ES
reasoning the external ES
no
data required
no
end of rules
yes
checking the standard output channel
save the data to the standard output channel
data exist
yes
pass the data to the ES
no
request the data from the coupling object
derive the related virtual attributes of the coupling object
checking the synoym table
submit the SQL statement to retrieval the data from the external personal databases
input part attribute derivation
rules or functions execution
user keyin the data
atom value
execute the method
no
synonym exist
yes
derive to other object related attribute
3 / 4 / 5 / 6

Figure 8-17 The process flow of the IHRMS

In this case of a human resource management (HRM) system, Person-Directorate must be derived. Messages will be passed to the HRM coupling object to execute the virtual attributes of Person-Directorate and Project-Directorate. The HRM Person-Directorate has a synonym Personnel Directorate. The system will generate a Personnel DB coupling object and pass a message to the object to derive the data of the Directorate. The Directorate is an input part attribute. The method will submit a SQL statement to retrieve the data from the external existing database. The data will pass back to the HRM ES. The reasoning continues. The second attribute Project-Directorate does not have a synonym. The system will generate a query to ask the end-users to enter the data (see Figure 8-18).

The same process will happen in the other data required variables, such as HRM.Person-id, HRM.Name, HRM.Staff-Type, and so on. Figure 8-17 shows the process flow mechanism of the IHRMS. There are seven different modules within the IHRMS integrated environment (see Figure 8-16). Modules 1 to 7 represent the personnel database, HRM expert system, personnel coupling class, HRM coupling class, availability active class, average-grade active class, and synonym integrated class. Figure 8-17 identifies how these modules integrate with the process flow.

The basic mechanism to deal with virtual attributes, which applied a method one attribute at a time, will cause a heavy communication traffic problem. To minimize traffic, a cache or “batches up” communication mechanism is needed.

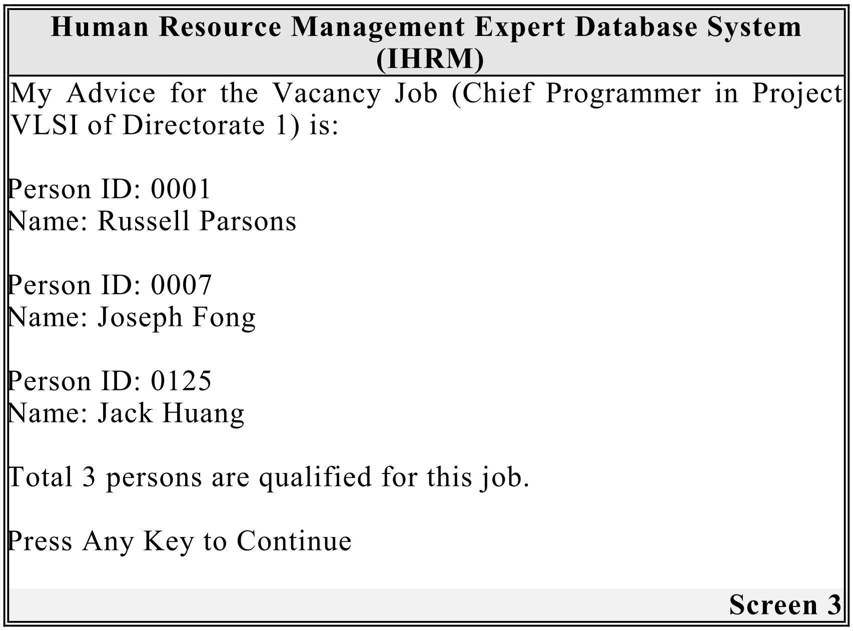
Figure 8-18, Figure 8-19, and Figure 8-20 shows a prototype of the IHRMS. The source DBS provides personnel skill information. The source ES provides selection criteria. The integrated synonym table integrated class, availability class, and average-grade class provide connectivity among coupling classes.

```
Human Resource Management Expert Database System
                     (IHRM)

Please Enter Vacancy Job Name: [Chief Programmer]
Please Enter Project-Name: [VLDB]

Reasoning ……

Please Enter Project-Directorate: [ Directorate 1]

Reasoning ……

Please Enter Job-Required-Age: [ 35 ]

Reasoning ……

Please Enter Job-Required-Skill-1: [Database Design ]

Reasoning …….

Please Enter Job-Required-Skill-2: [Telecommunication ]

Reasoning ……..

Please Enter Job Location: [Newcastle]

Reasoning ……..
Continue ……….
                                         Screen 1
```

Figure 8-18 Sample IHRM interactive session

```
Human Resource Management Expert Database System
(IHRM)

Please Enter 0001 Russell Parsons Preferred-Working-Area:
[Newcastle]

Reasoning .........

Please Enter 0003 Paul Chris Preferred-Working-Area: [London]

Reasoning .........

Please Enter 0007 Joseph Fong Preferred-Working-Area:
[Newcastle]

Reasoning .........

Please Enter 01001 Peter Smith Preferred-Working-Area:
[Edinburgh]

Reasoning .........

Please Enter 0125 Jack Huang Preferred-Working-Area:
[Newcastle]

Reasoning .........

Conclusion .........

                                                      Screen 2
```

Figure 8-19 Sample IHRM interactive session



Human Resource Management Expert Database System (IHRM)

```
My Advice for the Vacancy Job (Chief Programmer in Project
VLSI of Directorate 1) is:

Person ID: 0001
Name: Russell Parsons

Person ID: 0007
Name: Joseph Fong

Person ID: 0125
Name: Jack Huang

Total 3 persons are qualified for this job.

Press Any Key to Continue
```

Screen 3

Figure 8-20 Sample IHRM conclusions

Conclusion for the Case Study

ESs and DBSs have previously been successfully applied to HRM domains (Byun and Suh, 1994). This example is different from earlier systems because it couples both the technologies of ES and DB. It has the capability of embedding job-person match knowledge to allow reasoning on large amounts of employee personnel data.

An interface has been successfully established between the ES and DB components by using the frame model metadata so that the staff attributes stored in the personnel DB can be retrieved for reasoning and thus deducing optimal staff for vacancies.

Within its limitations, the HRM application is fully operational, and has been evaluated both against the original objectives set for its construction and as a basis for full-scale development.

8.5 SUMMARY

This chapter describes the need of reengineering ES (or DBS) for the purpose of updating ES (or DBS) information by integrating it with

DBS (or ES) to form an EDS. The need for reengineering ES (or DBS) can come from the need to update an existing ES (or DBS). The approach is to develop a DBS (or ES) for the purpose of integrating the existing ES (or DBS) to form an EDS. The users can also reengineer an existing ES and DBS by integrating them into an EDS.

The technique to integrate an ES and a DBS is to form a common frame model metadata for both of them. This frame model metadata acts as an object-oriented-like database. It takes each Frame model metadata as a class that consists of class name, static attribute, dynamic methods and constraints. These frame model metadatas form coupling classes that extract data from the source DBS, or rules from the source ES. To resolve the naming conflict between the source ES and the source DBS, an integrated class is formed to link them together by using a set of common names for their attributes (i.e., resolve naming conflict). With the integrated classes, the source ES, source DBS, and coupling class (in static or active class forms) can pass information via messages to each other. The resultant EDS thus becomes a knowledge base because it consists of both ES and DBS information, and the application knowledge from the users after analysis. System developer can then use the EDS to develop new applications.

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QUESTIONS

Question 8-1

The EC countries supply food to Russia in 1991 to aid the Russian people for the forthcoming winter months. The EC countries set several demand centres, one at each Russian state, and some distribution centres and warehouses in different locations within the EC countries to organize the food distribution. The orders are filled either by regional distribution centres, which are set up to ship out orders immediately upon request, or by supply warehouses, which supply the inventory for distribution centres. The centre table and the transportation expert system rule is as follows:

Centre database table:

Field-Name	Type	Width	Dec
<u>Centre-Name</u>	Characte	10	
Food-Type	Character	20	
Distance	Number	12	
Food-Name	Character	30	
Quantity	Number	5	2

Transportation expert system rule:

```
Rule Air-transportation
        IF      Centre-distance > 1500 and Centre-food-type = perishable
        THEN    Transportation-type = air

Rule Train-transportation
        IF      Centre-distance > 1500 and Centre-food-type = bulk
        THEN    Transportation-type = train

Rule Ship-transportation
        IF      Centre-distance ≤ 1500
        THEN    Transportation-type = ship
```

Show the steps of integrating the above expert system rules and the database table into an expert database system using a Frame model metadata approach.

Question 8-2
You are to develop an expert database system by integrating the following database and expert rule for a manufacturing inventory system to derive all subparts of each part.

SUBPART database table:

Field-Name	Type	Width
SUB-PART	Character	10
PART	Character	10

Transportation expert system rule:

Rule Subpart

```
IF      a Subpart's Part  = another part's subpart
THEN    the Subpart  = another part's subpart
```

Show the steps of integrating the above expert system rules and the database table into an expert database system using a frame model metadata approach.

a) Show the steps of integrating the given expert system and the database.

b) Show the result of the integrated expert database systems.

CHAPTER 9

CONCLUSION

As computer technologies evolve, it becomes a necessity for companies to upgrade their information systems. The objective of reengineering is to protect their huge investments and to maintain their competitive edge. However, information systems reengineering is a complicated task that requires much expertise and knowledge. It needs users' input to recover lost semantics inside the existing database system and/or the existing expert system. It also requires technical expertise to replace the obsolete information systems with newer systems. Very often, because of lack of methodologies and expertise, companies choose to redevelop rather than reengineer when upgrading their information systems. The purpose of this book is to convince these companies that reengineering is a more cost effective and feasible solution.

An information system consists of almost all the computer application systems in a company. The major components of such systems are databases for production operation, and expert systems for managerial decision making. The methodologies discussed in this book aim to protect the investment that companies have already put into these systems. The aim is to find methods of reusing these systems with new technologies and/or to meet new applications. The proposed methodology for reengineering information systems is two-fold: database conversion and/or database and expert system integration as follows:

Database Conversion

Our objective is to replace (convert) traditional record-based, hierarchical or network database systems with table-based relational database and then replace the relational database with object-oriented database and XML database. The justification is that relational database is more user friendly than a hierarchical database or network database. Similarly, an object-oriented database is more productive than a relational database. Our technique in converting the database systems is to develop a common data structure for the hierarchical database, network database, relational database, object-oriented database, and XML database. The goal is to eliminate the database navigation steps needed in accessing hierarchical or network databases. This can be accomplished by imposing secondary indices on each record type of network database (besides the system-owned record types) and on the non-root segments of the hierarchical database. The result is that these record types or segment types of the existing nonrelational database can be accessed like a table.

To convert a relational database to an object-oriented database, we must map the static data from the relational database to the object-oriented database in schema translation and data conversion. We then capture the dynamic behavior of each mapped class by translating each database I/O statement into the operations (methods) of each class. We have described the schema translation and data conversion in our methodology. The translation of database programs between the relational databases and the object-oriented databases is difficult to automate. To convert a relational database into an XML database, we extract an XML view of an EER model, and load the relational data into an XML document according to the translated XML schema.

Database System and Expert System Integration

System reengineer, broadly defined as the use of engineering knowledge or artifacts from existing systems to build new ones, is a technology for improving system quality and productivity. Much traditional work is focused on the reuse of existing software systems, (i.e., software programs, files, and databases). Since the use of the knowledge based system is emerging in information systems, many these systems have been built or will be built. In order for knowledge based systems such as expert systems to make further contributions to our society, it will be necessary to reuse their knowledge for other expert systems. The idea of reusing knowledge between expert systems and database systems is an attractive one for much the same reasons as the reuse of software. For example, knowledge from an application for process monitoring may be useful in an application for training the operators. Furthermore, knowledge must be shared among different applications.

A reengineering methodology for these systems must capture the information and the knowledge of the existing systems. Information can be represented by programming. Knowledge can be represented by rules. In our methodologies, we have developed ways to derive and store the knowledge. The rationale behind such a decision is that a class encapsulates both the static data structure, and its feasible operations, (i.e., its dynamic behaviour,) in its methods. Our reengineering technique is to map the data structure of the database system into the static data of each class, and to map the operations of each rule of the expert system into the method of a corresponding class (i.e., class with the same name).

9.1 APPLICATION OF DATABASE CONVERSION METHODOLOGIES

The methodologies described in this book provide an alternative approach for schema translation in which user input contributes to the process. Direct schema translation from hierarchical or network into relational cannot guarantee to capture all of the original conceptual schema semantics. With user input, we can provide a relational schema that is closer to the user expectation and preserves the existing schema constraints such as record key, records relationships, and attributes.

For data conversion, the methodology provides algorithms to unload a hierarchical or network database into sequential files directly and effectively, with minimum user involvement. These files can then be uploaded onto the target system with little additional effort.

In program translation, the methodology provides an "open" data structure by adding secondary indices to the existing hierarchical or network database. This eliminates the navigation access path required to retrieve a target record from a system record. Instead, each target record type can be accessed directly without database navigation. The database access time is thus reduced and the program conversion effort simplified. The methodology also provides algorithms to translate SQL statements into hierarchical or network DML statements. These are sound solutions to the program conversion problem.

Basically, the methodology is similar to the relational interface approach in that both provide a relational interface to make the hierarchical or network DBMS a relational-like DBMS. The methodology can help the users in the following ways:

1. Apply the methodology to convert a hierarchical or network database system into relational database system.

The methodology is an integrated approach to solve the conversion problem,. The user has a solution for the whole task.

2. Apply part of the methodology to reduce conversion problems- The methodology includes schema translation, data conversion, and program translation. Each process can be applied independently as required.

3. Apply schema translation to construct a distributed database system.
In a distributed database system, many local schema act independently for their own local applications. To implement a major application or a global application, we must integrate these schema into a global schema. Our methodology is used to obtain a common EER model for a number of local hierarchical or network schema.

4. Apply the technique of adding secondary indices to provide an "open" structure database gateway.
Currently, many vendors provide database gateways to allow other vendors' database programs to access their databases. The addition of secondary indices is an alternative approach.

5. Apply the methodology for a more user-friendly interface to end-users.
The methodology is used to provide a relational interface to a nonrelational system. It allows a company to continue using a network or hierarchical whilst, at the same time, users can use the friendly interface supported by a relational database.

6. Apply the methodology as a guideline for conversion to next generation database.
As database technology continues to evolve, people will discover the limitations of relational databases, and will look for the next generation databases on the market. To convert from a relational database system to the next generation database system is not an easy task. However, we can make use of the techniques in this book as a guideline.

In conclusion, this book provides an alternative approach for a conversion methodology that is practical enough to be applied. Even though many problems have been resolved in database conversion, the difficulty arises in the translation of semantics. Not only do we not know whether there is a 1:1 or a 1:n relationship between the parent (owner) and the child (member) segments (records) in the hierarchical or network schema, but also we cannot obtain an unique key transformation. The assumption is that they are all either partially internally identified if the record key exists, or internally unidentified if the record key does not exist. This assumption is based on the data structure inherent in the hierarchical or network database where database navigation is needed to retrieve a target record (segment). This implicit constraint is a result of the default assumption of partially internally identified or internally unidentified types that do not apply to relational databases. Therefore, the semantics of the translated relational database may not be correct. There is a possibility that the existing record (segment) key itself is unique and therefore a fully internally identified record (segment).

The complication in semantic analysis appears not only in the DDL of the schema, but also in the database programs. The major weakness of this methodology is that it cannot translate directly a low level hierarchical or network database program DML to a high level relational database program DML by decompilation. The automation of the direct translation from procedural (with database navigation) non-relational DML statement to non-procedural (without database navigation) relational DML statement (e.g., SQL) is still a classical problem in computer science. Application programmers wrote programs based on the conditions and assumptions that they had about the nonrelational database. These conditions and assumptions may not be well documented. If we decompile them to a higher level non-procedural language such as SQL, the outcome will be variable and it will be difficult to prove its correctness.

9.2 APPLICATION OF THE INTEGRATION OF DATABASE AND EXPERT SYSTEMS

The integration of database systems and expert systems forms an expert database system that combines several different technologies and perspectives. Our methodology for developing such systems by reengineering existing database systems and expert systems uses a higher level synthesis model in a frame model metadata. The reengineering capability and the frame model metadata combine together to produce a very powerful and sophisticated expert database system development methodology. The output of the methodology is an expert database system that reuses existing database and expert systems technology.

A traditional problem with expert systems is the difficulty in representing knowledge in an appropriate and effective structure. Our methodology supports a fixed frame structure of rule-based knowledge representation. This addresses the representation problem and provides better storage and retrieval facilities. For example, in our frame model, data and rules are represented in the same way; hence it is easier to manage knowledge.

The applications of the methodology are as follows:

1. Reuse existing database and expert system.
   Produce an (integrated) expert database system as a result of the methodology.

2. Produce a higher level synthesis model.
   Provide an object-oriented conceptual model in a frame model metadata for the integrated expert database system.

3. Knowledge integrity.
   Our methodology supports an integrity constraint mechanism. This allows knowledge to be applied with event-condition-action or demon rules. The implementation of knowledge integrity constraints then becomes very easy.

4. Deductive functionality.
   The data model in our methodology, our frame model metadata, was embedded with a deductive mechanism, allowing the system to deduce many additional facts from the existing data.

9.3 FUTURE TRENDS FOR INFORMATION SYSTEM REENGINEERING

The main idea for information system reengineering is to reuse the existing knowledge as opposed to simply the reuse of data. The techniques for knowledge reuse are extremely important not only because they aid in building an information system, but also because they help to improve the reliability of the information system.

This book has provided a systematic approach to reuse existing information systems. Since the existing system may not be perfect and may be partially nonproductive, it may be necessary to reuse only certain parts of the existing system, but not all.

To reuse knowledge, we must know its structure. Current knowledge representation structure has multiple frames. Data modeling from database research and knowledge representation from artificial intelligence both still have difficulty representing the knowledge completely. A distortion exists between the real world and the information system. It is extremely difficult to recapture the original knowledge from the existing information systems. To solve this problem, a heuristic approach has been taken by computer scientists. This approach is to use an expert system to assist the system developer to recapture the missing knowledge or semantics.

Another approach for knowledge reuse is to define a standard specification for the information systems. In spite of the economical success of reengineering applications, some problems have been detected in using this technology, the largest problem being the lack of agreed standards for information systems. For example, there is no standard for the object-oriented technology. Providing standards for information systems is a way of supporting reengineering, partly because it can provide portability and transparent communications. Some work on high level standards, sometimes referred to as the knowledge level, has been carried out. One example of knowledge level representation is the language developed in the KADS (Tansley and Hayball, 1993) methodology for analyzing domain knowledge. KADS allows developers to build libraries of inference models for specific domains (for example, diagnosis). Computer scientists are now looking at providing a similar approach for sorting the content of knowledge bases in a reusable way; these reusable knowledge bases are called Entologies'.

The object-oriented paradigm has been seen as the most common technique for the conventional software and knowledge base reuse. The object-oriented technology is still growing.

Data is a collection of "fact." Information is the meaning of data. Knowledge is the application of the information. Knowledge is also a necessity of reengineering. Unless a method for the complete representation of knowledge in a computer system is found, the reengineering process will never be finished.

9.4 EPILOGUE

Application knowledge is required for information systems reengineering and integration.

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QUESTIONS

Question 9-1

Compare hierarchical, network, relational and object-oriented, and XML DBMS according to the following criteria:

1. User friendliness and easy to use in terms of data manipulation language
2. Performance
3. Basic logical structure
4. Major advantages and disadvantages

Question 9-2

What are the basic justifications (rationales) for database reengineering and for database integration in terms of data semantics? How can you compare them?

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