Edited by

Dac-Nhuong Le
Chung Van Le
Jolanda G. Tromp
Gia Nhu Nguyen

Emerging Technologies for Health and Medicine

Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0

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Emerging Technologies for Health and Medicine

Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Publishers at Scrivener
Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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Dac-Nhuong Le
Deputy-Head, Faculty of Information Technology, Haiphong University, Haiphong, Vietnam

Chung Van Le
CVS Center, Duy Tan University, Danang, Vietnam

Jolanda G. Tromp
University of New York in Oswego, NY, USA

Gia Nhu Nguyen
Dean, Graduate School, Duy Tan University, Danang, Vietnam

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WILEY

This edition first published 2018 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA

For more information about Scrivener publications please visit www.scrivenerpublishing.com.

Wiley Global Headquarters
111 River Street, Hoboken, NJ 07030, USA

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Library of Congress Cataloging-in-Publication Data
ISBN 978-1-119-50981-3

Cover images: Provided by the author
Cover design by: Russell Richardson

Set in size of 11pt and Minion Pro by Exeter Premedia Services Private Ltd., Chennai, India

Printed in the USA

10 9 8 7 6 5 4 3 2 1

Contents

List of Figures

List of Tables

Foreword

There are some key factors driving the increasing adoption of augmented reality (AR) and virtual reality (VR) technologies, which depend mainly on the growing integration of technology and digitization in the field of healthcare, as well as increasing healthcare expenditures which focus on delivery of efficient health services and its significance in training healthcare professionals. The advanced technologies related to AR and VR have a great effect on the healthcare industry with their adoption in virtual training of surgeons in 3D operating room simulations for difficult surgeries and as phobia buster in mental health treatment as well as for chronic pain management. Also, VR plays a major role in eye movement desensitization and reprocessing (EMDR) therapy to enable reframing of traumatic memories through certain eye movements. Furthermore, this technology offers benefits in various areas of care management such as autism and depression therapy, cancer therapy, and assisted living. VR-based organ models have played a crucial part in preparing surgeons for delicate and complicated operations that demand greater precision, less complications, and reduced trauma. On the other hand, AR is considered a useful active and powerful tool for training and education. AR-based applications are effectively used to provide the improved care of many patients. For example, the vein visualization technology, developed by AccuVein Inc. was developed to handle scanning, which helps doctors and nurses successfully locate veins and valves at the first go, reducing pain and the required time. These applications are also used in the aftercare of patients and assist elderly people in managing their medications. This book focuses on adopting robots in conjunction with VR and AR to help in healthcare and medicine applications; for instance, we discuss a training system developed for a lower limb rehabilitation robot based on virtual reality (VR), mainly including trajectory planning and VR control strategy. It can simulate bike riding and encourages patients to join in their recovery and rehabilitation through a built-in competitive game. The robot could achieve linear trajectory, circle trajectory and arbitrary trajectory based on speed control, in which the training velocity and acceleration in the trajectory planning have been simulated. A human-machine dynamics equation was built which is used to judge the intent of a patient's movement. The VR training mode is a variable speed active training under the constraint trajectory, and it has an adapting training posture function which can provide an individual riding training track according to the leg length of patients. The movement synchronization between the robot and virtual model was achieved by interaction control strategy, and the robot can change the training velocity based on the signal from feedback terrains in the game. A serious game about a bike match in a forest was designed in which the user can select the training level as well as change perspective through the user interface.

The main purpose of this book is to publish the best papers submitted to the special session on VR/AR Healthcare and Medicine Applications at the International Conference on Communication, Management and Information Technology (ICCMIT 2018) in Madrid, Spain.[1] ICCMIT 2018 is an annual meeting for scientists, engineers and academicians to discuss the latest discoveries and realizations in the foundations, theory, models and applications of nature-inspired systems, and emerging areas related to the three tracks of the conference covering all aspects of communication, engineering, management, and information technology given by panels made up of world-class speakers and at workshops.

Prof. Ibrahiem El Emary
Prof. Musbah J. Aqel
International Cyprus University

[1] http://www.iccmit.net/

Preface

With the current advances in technology innovation, the field of medicine and healthcare is rapidly expanding and, as a result, many different areas of human health diagnostics, treatment and care are emerging. Wireless technology is getting faster and 5G mobile technology allows the Internet of Medical Things (IoMT) to greatly improve patient care and more effectively prevent illness from developing. This book provides an overview and review of the current and anticipated changes in medicine and healthcare due to new technologies and faster communication between users and devices. In Chapter 1, Abdullah *et al.* review the implications of VR and AR healthcare applications, and Chapter 5 provides a review of current augmenting dental care, by Nayyar and Nguyen. Chapter 6 provides an overview of typical human-computer interaction (HCI) informed empirical experiments and psychophysiological measurement tools that can help inform the development of user interface designs and novel ways to evaluate human behavior to responses in virtual reality (VR) and with VR and other new technologies by Munoz *et al.* In Chapter 12, Puri and Tromp provide provide a review of telemedicine technologies.

Patient Empowerment

Patient empowerment is facilitated by the wide availability of medical information via the internet and the ability to share reliable medical information, personal experiences with medicines and medical assessments via social media, in social groups established based on shared interests and a desire to support each other. This enables patients to have a voice in their healthcare procedures and exert more control and influence on healthcare worldwide, making it a very powerful technology-enabled medicine and healthcare improvement. This internationally accessible crowd sourced medicine and healthcare resource has the potential to change the role of patients from being passive witnesses in their own treatment to informed citizens proactively involved in monitoring and choosing treatments.

The e-NABLING Future project is a great example of patient empowerment. It is a global network of volunteers that share 3D printing designs and instructions to create prosthetic hands for free, thus enabling people in underdeveloped countries who have no access to prosthetics make their own at low cost. Medical 3D printing is still in its infancy; however, 3D bio-printers are already commercially available, making the printing of human body parts from bio-ink containing real human cells a commonplace occurrence in the near future.

Chapter 3 describes various technologies that enable patient empowerment and build empathy in young children using AR, as shown in a case study in Malaysia by Zamin *et al.* In Chapter 4, Garcia *et al.* report on the empirical experiments used to test the effectiveness of VR for mock interview training. In Chapter 7, AI technologies for mobile stroke monitoring and rehabilitation robotics control are discussed by Elbagoury *et al.* In Chapter 9, Elbagoury *et al.* discuss an AI-powered "doctor brain" app, along with artificial intelligence (AI) for healthcare based on the Internet of Things (IoT). In Chapter 10, an artificial intelligence mobile cloud computing tool is discussed by Shalhoub *et al.*, and the previously mentioned Chapters 1 and 3 also include discussions on patient empowerment through new technologies for medicine and healthcare.

Smart Wearable Sensors

Smart wearable home sensor technologies contribute to the empowerment of patients. These technologies, such as the popular Fitbit, give users more insight and control over their health and can help prevent illness by giving real-time feedback on health status by monitoring vital signs, allowing the user to adjust and target their activities to reach optimal fitness or health results. In Chapter 14, Kolhe *et al.* discuss smart wearable sensors, along with automation of appliances using electroencephalography. In Chapter 18, Kolhe *et al.* discuss smart home personal assistants and baby monitoring systems, previously mentioned in Chapters 1, 3, 6, 8 and 15.

Real-time health feedback is extremely suitable for gamification, as behavioral change and motivation regarding exercise can be influenced by adding points and badges and leader-boards to the data stored in the cloud and on the device. These wearable sensors are becoming smaller, less obtrusive and more integrated with the human body. For instance, Google's digital contact lens will allow diabetes patients to monitor and manage their glucose levels from tears in real time.

Additional integration can be expected from digestible sensors, sensors placed in teeth and organs of the body and thin e-skin sensors or biometric tattoos and radio frequency identification chips (RFID) implanted under the skin, which store vital health information and act as control devices for purposes such as automatically calling for assistance if vital signs signify that health problems are imminent. Early adopters of these new technologies are already using implants to give themselves superpowers; for instance, the use of recreational cyborgs to improve their eyesight or hearing.

Medicine and Healthcare Education

Another area that will benefit greatly from technological advances is medicine and healthcare education. Medical students can now learn anatomy and practice operations in virtual reality, allowing them to interact with the human models in real time and zoom in and out to focus on the details, in a way that has not been possible before. In Chapter 2, Le *et al.* discuss the use of 3D simulation in medical education, in which VR is used in extensive user (*students and teachers*) acceptance comparative testing for teaching anatomy. Additionally, augmented reality can help to provide real time instructions and visualizations, as discussed in the previously mentioned Chapter 5, such as the Microsoft Hololens app for use in the OR, showing where the blood veins are located in a body part. With the use of 360 degree video cameras, anyone can observe operations in progress in real time.

Artificial Intelligence

Artificial intelligence (AI) will be able to assist doctors in medical decision making. The IBM Watson computer system has already shown great potential in helping to analyze symptoms and prescribe the best treatment (for more details see https://www.ibm.com/watson/). Watson can read 40 million documents in 15 seconds and suggests treatments based on the analysis. Watson will not replace human doctors because it does not answer medical questions, instead it analyzes medical information and comes up with the most relevant potential outcomes that can help them make the most informed decisions in the shortest amount of time. In Chapter 8, Shalhoub *et al.* address the topic of artificial intelligence for smart cancer diagnosis. and in Chapter 10 Shalhoub *et al.* discuss an artificial intelligence mobile-cloud computing tool. Ionel-Alexandru *et al.* discuss advanced intelligent robot control interfaces for VR simulation in Chapter 11, and along with the previously mentioned Chapter 8 AI topics relevant for innovation of medicine and healthcare technologies.

Google's DeepMind Health mines data from medical records with the aim of improving health services by making them faster, more accurate and more efficient. It has the potential to be bigger than the Human Genome Project. Google is also working on the ultimate artificial intelligence-controlled brain under the supervision of Ray Kurzweil, director of engineering at Google. He predicts that the singularity (*the moment when artificial intelligence exceeds man's intellectual capacity*) will only take about 10 years of further development. It will allow us to connect our neocortex to the internet and develop our creativity.

Artificial intelligence also drives medical robot assistants that will be of great use in care homes and hospitals and even for home care. Robots can be made to lift more weight than humans and have already been developed to assist in carrying medical equipment and patients, helping patients get out of bed into their wheelchairs, etc. More complex robots equipped with image analysis techniques are under development to help with more complex tasks. In Chapter 13, Migdalovici *et al.* discuss an environment model applied on the critical position of the walking robots. and in Chapter 14, Pop *et al.* discuss walking robot equilibrium recovery applied on the NAO robot. In Chapter 15, Zamin *et al.* discuss the development of a robotic teaching aid for disabled children in Malaysia; and the previously mentioned Chapters 1, 3, 6 and 10 discuss various applications of robotics in medicine and healthcare innovation.

Real-Time Diagnostics

Real-time diagnostics tools will provide technological advances and new application areas, and help reduce the complexity of medical procedures and analysis, such as, for instance, the iKnife, an intelligent surgical knife that can identify malignant tissue to remove as the operation is in progress.

Other New Technologies in the Technology Innovation fields for Medicine and Healthcare

In order to complete the overview of current predictions, we discuss a few more new technologies that are expected to revolutionize the medicine and healthcare industries and services. The technology advancements discussed here are in-silico organs-on-chips technology, optogenetics and multifunctional radiology. Finally, we discuss some of the perceived risks and dangers that need to be considered before adopting some of these new technologies into our medicine and healthcare treatments.

A huge advance in clinical trials is predicted from the in-silico organs-on-chips technology. Microchips simulate cells and whole human organs and systems, so that drugs can be tested without risk to human or animal subjects, making clinical trials more efficient and accurate. The Human Genome Project which mapped all the human genes, generating the field of genomics, makes it possible to use DNA analysis to customize health procedures and medicines. The Personalized Medicine Coalition aims to help bring about the paradigm shift to personalized healthcare (see their latest report[1]).

Optogenetics is a promising new technique used in neuroscience. It uses genes of proteins that are sensitive to light. These are then used to precisely monitor and control their activity by using light signals after introducing them in specific brain cells. This allows researchers to control how nerve cells communicate in real time, with completely wireless techniques so that complex behaviors can be observed while the experimental subjects can freely move around. This technology will be very helpful in understanding the neural codes for psychiatric and neurological disorders.

Multifunctional radiology is developing very fast and within the next 10 years great progress can be expected from this technology advancement. Radiology uses medical imaging to diagnose and sometimes also treat diseases within the body. Multifunctional radiology consists of one machine that can detect many different medical problems at once. This will make practitioners more productive and one machine will take up less space than multiple devices, making the workspace more efficient.

The most profound risks regarding the adoption of the Internet of Medical Things (IoMT) are the finances and ability to adapt to the changing healthcare and medicine industry itself, in addition to all the other institutions that need to adopt

[1] http://www.personalizedmedicinecoalition.org /Userfiles/PMC-Corporate/file/The PM Report.pdf

these new technologies. This also includes the finances for the implementation of new regulations. As new technologies are used for medicine and healthcare, governments will have to keep up with the change, by providing the best regulations for these new services to the public. This requires significant resources from multiple regulatory bodies and governments.

Another problem is caused by the diversity in medical record keeping technologies, and the lack of compatibility and interoperability between the different systems used by institutions. If data cannot be shared efficiently, it cannot be merged and aggregated for improvement of information exchange and patient record sharing between the different medical experts the patient may have to deal with. This can significantly slow down the progress of big data analysis and communications between institutions with different or incompatible database designs.

Major demographic shifts are taking place in the populations around the world. Populations are growing and aging and the number of patient cases are rising as a result, which drives the costs of healthcare up. If current trends persist there will be nearly 1.5 billion people ages 65 or older by 2050 and they will significantly outnumber children younger than 5. It is projected that more than 60% of the Baby Boomer generation will be managing more than one chronic condition by 2030. Our medicine and healthcare systems need to help these patients by managing the increased cost of healthcare, as they are expected to make twice as many visits to physicians and hospitals by 2030. With improved healthcare, life expectancy is increasing, and while the prevalence of severe disabilities can be expected to decrease along with this improvement, milder chronic diseases and the need for solutions, such as remote disease management, engagement and patient responsibility for monitoring their own symptoms and treatments, will increase.

Dr. Jolanda G. Tromp
University of New York in Oswego
New York, USA

Acknowledgments

First of all, I would like to thank the authors for contributing their excellent chapters to this book. Without their contributions, this book would not have been possible. Thanks to all my friends for sharing my happiness at the start of this project and following up with their encouragement when it seemed too difficult to completed.

I would like to acknowledge and thank the most important people in my life, my grandfather, grandmother, and finally thanks to my wife. This book has been a long-cherished dream of mine which would not have been turned into reality without the support and love of these amazing people, who encouraged me despite my not giving them the proper time and attention. I am also grateful to my best friends for their blessings and unconditional love, patience and encouragement.

Dr. Dac-Nhuong Le
Deputy-Head, Faculty of Information Technology
Haiphong University, Haiphong, Vietnam

Acronyms

AAL	Ambient Assistive Learning
ADR	Adverse Drug Reaction
AI	Artificial Intelligence
ANN	Artificial Neural Network
ANS	Autonomic Nervous System
API	Application Program Interface
AR	Augmented Reality
ASQ	After Scenario Questionnaire
ASD	Autism Spectrum Disorder
ATA	American Telemedicine Association
BAN	Body Area Network
BCI	Brain Computer Interface
BoS	Boundary of Support
BP	Blood Pressure
CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
CAVE	Cave Automatic VEs
CHI	Child Health Information
CTA	Computed Tomographic Angiography
CV	Consumer Version
CBR	Case-based Reasoning
CLR	Common Language Runtime
CW	Cognitive Walkthrough
DC	Direct Current
DSS	Decision Support System
DWT	Discrete Wavelet Transform
ECG	Electrocardiogram
ECoG	ElectroCorticoGram
ECP	Embedded Context Prediction
EDA	Electrodermal Activity
EDD	Empathy Deficit Disorder
EEG	Electroencephalography
EER	Energy Efficiency Ratio
EGC	Embedded Gateway Configuration
EKG	Electrocardiography
EMG	Electromyography
EMDR	Eye Movement Desensitization and Reprocessing
EMR	Electronics Medical Records

EZW	Embedded Zero Tree Wavelet
FCM	Fuzzy C-means
fMRI	Functional Magnetic Resonance Imaging
HMD	Head Mounted Display
HHU	Hospital in Home Unit
HCV	Hepatitis C Virus
HR	Heart Rate
HRV	Heart Rate Variability
HE	Heuristic Evaluation
ICT	Information and Communication Technologies
IC	Integrated Circuit
ICU	Intensive Care Unit
IR	Industrial Revolution
IC	Integrated Circuit
IIT-D	Indian Institute of Technology-Delhi
IEH	Indirect Emergency Service
IoT	Internet of Things
JIST	Job Interview Simulation Training
GPS	Global Positioning System
GND	Ground
GSR	Galvanic Skin Response
HR	Heart Rate
HRV	Heart Rate Variability
KIT	Keep-in-Touch
LQR	Linear Quadratic Gaussian
LED	Light Emitting Diode
LDR	Light Detector
MLP	Multilayer Perceptron
MIME	Multipurpose Internet Mail Extensions
MEG	Magnetoencephalography
MEMS	Micro Electro Mechanical System
ManMos	Mandibular Motion Tracking System
NodeMCU	Node Microcontroller Unit
NN	Neural Network
PTSD	Post-Traumatic Stress Disorder
PCA	Principal Component Analysis
PSO	Particle Swarm Optimization
PID	Proportional Integral Derivative
PIR	Passive Infra-Red
PSSUQ	Post-Study System Usability Questionnaire
RBF	Radial Basis Kernel function
RF	Radio Frequency
RPA	Robot Process Automation
RST	Reset
ROI	Region of Interest
RMS	Root Mean Square
SCR	Skin Conductance Response

SCL	Skin Conductance Level
SMS	Short Message Services
SMA	Semantic Medical Access
STT	Speech To Text
SVM	Support Vector Machine
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SUS	System Usability Scale
TTS	Text to Speech
UAT	User Acceptance Test
URL	Uniform Resource Locator
VCC	Voltage Common Collector
VHA	Veteran Health Administration
VR-JIT	Virtual Reality Job Interviews Training
VR	Virtual Reality
VE	Virtual Environment
WBA	Web Browser Automation
WDA	Wearable Devices Access
WLAN	Wireless LAN
WCF	Windows Communication Foundation
XLM	Extensible Markup Language
ZMP	Zero Momentum Point

Part I

VIRTUAL REALITY, AUGMENTED REALITY TECHNOLOGIES AND APPLICATIONS FOR HEALTH AND MEDICINE

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (1–284)

CHAPTER 1

REVIEWS OF THE IMPLICATIONS OF VR/AR HEALTH CARE APPLICATIONS IN TERMS OF ORGANIZATIONAL AND SOCIETAL CHANGE

MUHAMMAD SHARIF[1], GHULAM JILLANI ANSARI,[1], MUSSARAT YASMIN[1], STEVEN LAWRENCE FERNANDES[2]

[1] Department of Computer Science, COMSATS University Islamabad, Wah Campus
[2] Department of Electronics and Communication Engineering, Sahyadri College of Engineering & Management, Mangaluru, India
Emails: muhammadsharifmalik@yahoo.com, steven.ec@sahyadri.edu.in

Abstract

Recently it has been observed that computer related applications are vigorously available to support training and learning of health care professionals being involved in diversified organizations to put into practice an impactful change in society. Virtual Reality (VR) and Augmented Reality (AR) are swiftly becoming progressively more available, accessible and most importantly within an individual reach. Thus, services and applications related to health care certainly improve the use of medical data. This will result in exploring new health care opportunities not only in the organizations but cover the whole society for auxiliary transformation and enhancement. Furthermore, combination of VR/AR technologies with Artificial Intelligence (AI) and Internet of Things (IoT) will present powerful and mainly unexplored application areas that will revolutionize health care and medicine practice. Hence, the aim of this systematic review is to implicate to which extent VR/AR health care services and applications are presently used to genuinely support for organizational and societal change.

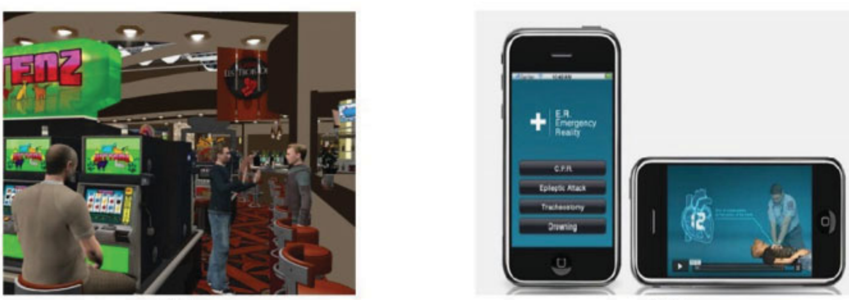
Keywords: Health Care, Virtual Reality, Augmented Reality, Immersion, AI, IoT

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (3–284)

1.1 Introduction

Advances in technology directly affect our lives and behaviors. On one hand, it enhances our learning abilities effectively when integrated with our curriculum to alleviate submissive experiences of lectures for large number of students in the class. On the other hand, it acts as a tool for students to gain knowledge in a meaningful environment [52]. Therefore, the goal is to create a powerful interactive learning environment for students where they can use their inborn capabilities of learning to clutch intricate notions and acquire knowledge through participation, observation and simulation [28]. The term student is taken generally in this chapter for medical students, doctors, and various types of medical professionals, medical trainers and all those who are directly or indirectly using health care services and applications in society or in any organization for learning and training purposes.

Simulation technology is now being increasingly used to improve the student's learning abilities in a variety of domains like marketing, engineering, education and most importantly in health care which is one of the biggest adopters of VR/AR like simulated surgery, treatment of phobia, robotic based surgery, skill based training, dentistry and disabled treatment are some of the examples. It is generally recognized that VR and AR are in the forefront having strong potential to lead health care for impactful change in society [10]. Nowadays, this can be possible with the development and provision of multimedia information delivery tools such as apps, pod-casts, medical and educational software and screen casts which can be easily used on personal computers and mobile devices specifically on smart phones [30, 51]. In addition, numerous visualization technologies have been released such as Oculus Rift, Gear VR and Head Mounted Displays (HMD) to incorporate VR in giving intuitive feeling of actually being engrossed in the simulated world [21]. AR is also known as mixed reality that has lined a possibility to understand the concepts in a novel way which was not ever possible in the past.



(a) (b)

Figure 1.1 (a) Example of Virtual Reality [10], (b) Example of Augmented Reality Training in Health care [4]

VR and AR can be viewed in Figure 1.1. Although there is a very slight difference between both concepts which will be discussed later in the chapter, but today, AR (*mixed reality*) shown in Figure 1.2, supersedes VR because of the collaboration of real world and virtual objects rather than the whole computer generated virtual world. Therefore, VR is now being transformed into AR in the near future gradually. Taking the advantage, we schematically unfold rest of the chapter by briefly discussing VR/AR, their formats and design elements, relationship among presence, reality and realism in context with VR/AR, features of VR/AR technologies and in detail the implications of VR/AR applications related to enhance health care issues using AI and IoT for impactful change in the society and organization. To end this chapter, challenges and limitations of the technology along with conclusion are finally discussed.

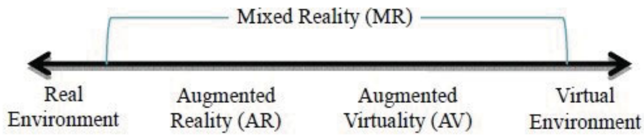


Figure 1.2 Relationship of Real and Virtual Environment (*Augmented Reality or Mixed Reality*) [15]

1.2 Virtual Reality and Augmented Reality

The following section will explain VR/AR and how both differ from each other. Further, Table 1.1 will summarize standard terms and definitions related to the simulating environment.

Table 1.1 Standard terms in Virtual Reality and Augmented Reality

STANDARD TERMS IN VR/AR	
Terms	**Definitions**
Virtual Systems or Simulation	Collectively graphics, navigation and sounds present screen based simulation to accentuate three dimensional nature of environment.
Screen Based Simulation	A simulation presented on computer screen using text and graphical images.
Serious Games	Interactive computer applications mimicking or simulating real world events designed specifically for educational and training purposes to bring impactful change in society. It is challenging to deliver the user knowledge, attitudes or skills which are useful in reality.
Virtual Standardized Patient	Avatar based representation of human patients which can communicate with his/her physician in a natural language for training purposes in organizations keeping health care perspective.

1.2.1 Virtual Realty

Virtual revolution has emerged to impart VR simulation technology for clinical and medical purposes since 1995. Although VR has been emerged since 1950s when Morton Heiling invented Sensorama which enabled users to watch television in three dimensional ways. Today, technology advances in the areas of power, image processing and acquisition, computer vision, graphics, speed, interface technology, HMD devices, a variety of software, body tracking, AI and IoT have given rise to build cost effective and functional VR applications capable of operating on mobile devices and/or on personal computers [61].

In context, VR states: It typically refers to use interactive simulations created by computer software and hardware to engage users with an opportunity in an environment that generates feelings similar to real world events and objects [71]. In another definition, VR is interpreted as: VR systems are deployed in the form of concert to perform sensory fantasy or illusion that construct more or less believable simulation of reality [12]. Comprehensively, VR can be defined as a way to replicate real life situations using immersive learning environment, high visualization and three dimensional characteristics by involving physical or other interfaces like motion sensors, haptic devices and head mounted display in addition to computer mouse, keyboard, voice and speech recognition. In general, the user interacts and feels that it is real world but the focus of interaction is digital environment [52].

Hence, VR systems have been widely applied in phobia, neuroscience, rehabilitation, disorders and different forms of therapeutic issues for students learning and health care to uplift the society in productive manners incorporating serious games and other techniques [14].

1.2.2 Augmented Reality or Mixed Reality

AR is a subset of VR (*not a complete virtual reality*) that overlays digitized computer generated information on objects, places and entities from real world for the purpose of enhancing the learning experience of user. Therefore, its ability to combine physical elements and virtual objects makes it popular in studying and implementing health care, medicine, fashion and several other fields since 2008 [11]. According to Moro, et al., 2017, AR is a form of VR in which a synthetic stimuli is super imposed on real world objects to enhance user learning experience with the help of head mounted display, wearable computers (*displays projection onto humans and mannequins*) and overlays of computer screen. The result of AR is to focus interaction in performing tasks within the real world instead of digital world.

In short, AR is a set of technologies which help to integrate digital and real. Although there are many flavors and versions of implementing AR but common among all are computers, displays, input devices (*especially pointing device of any sort*) and tracking mechanism. Merely, displays are required for the user to distinguish between realities and digitally supplied information. Pointing device (*input device that must have GPS or some location based services for locating device and of course the user as well*) like smart phones, wireless wrist bands etc. are needed to make sure that the digital information is appropriately placed or aligned with what the user is seeing (*tracking*). Finally computer software must exist to manage and run the application.

1.2.3 Line of Difference between VR/AR

The definitions above clarify that everything is virtual and digital or simulation of reality in VR whereas AR exhibits virtual learning experiences embedded in a physical context. It means AR is a process of overlaying computer generated information on any geographical place or object in reality for the sake of enhancing the understanding and experience of user [78].

1.2.4 Formats and Design Elements of VR/AR Technology

This section reflects general understanding about the available formats of VR/AR and which one is best accepted for health care. In addition, Table 1.2 summarizes the design elements for implementing VR/AR. The contents of Table 1.2 are taken from Lemheney et al., 2016.

Table 1.2 Design Elements in Virtual Reality and Augmented Reality

Elements	Description
Situated Learning	Familiar circumstances that can be recognized by a user or participant.
Debriefing	Opportunity to interact and focus by a participant on health care analysis and reflections.
Navigation	Components which can guide and sequence the directions.
Identical Elements	Visual representation of health care artifacts accurately.
Stimulus Variability	Range of relevance indicating objects found in health care settings.
Feedback	Prompts to facilitate progression through an activity.
Social Context	Collaborative environment to synchronize contribution of participants.

Formats of VR: VR systems have three formats namely non immersive, semi-immersive and fully immersive. The main concept which is frequently used is ”*immersion*” with VR. ”*Immersion*” refers to the sense of being involved in task environment without considering the time and real world and up to which extent high fidelity important inputs (*e.g. sound waves, light samples*) are supplied to diverse sensory modalities (*touch, audition, vision*) for the purpose of building powerful illusion of realism [36, 39]. The three formats also refer to the level of immersion:

- A non immersive VR system utilizes usual graphics terminal with a monitor typically desktop system to view VR environment using some portal or window. This format imitates a three dimensional graphics environment on television or flat panel within which the user can interact and navigate. Hence, this format is less popular [49, 60];
- A semi immersive VR system is relatively a new implementation which comprises of comparatively high performance graphics computing system together with an outsized projection plane to display scenes [49];
- A fully immersive system gives a sense of presence but the level of immersion depends on various factors like the field of view of resolution, contrast, update rate and illumination of display. Generally, an immersive VR system clubs computer, body tracking sensors, specialized interactive interface such as head mounted display or an outsized projection screen encasing the user (e.g. *CAVE–Cave Automatic VEs where VE is projected on a concave surface*) and real time graphics to immerse the participant in a computer generated world of simulation to perform alterations in a natural way with body and head motion [56, 60]. Thus, this format leads us to adopt immersive learning environment for health care services and applications presently and also for future. Figure 1.3 presents some snap shots of various immersion levels.

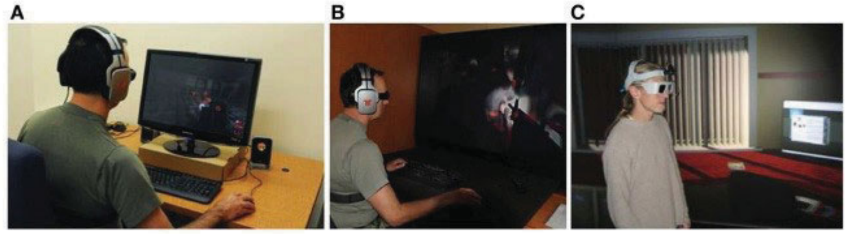


Figure 1.3 Levels of VR Immersion (a) A Non Immersive VR System (b) A Semi Immersive VR System (c) A Fully Immersive VR System [10]

Formats of AR: Since the advent and extreme usage of smart phones in recent times, most of AR applications are based on this new invention. Hence focusing the smart phones, there are two major AR formats. According to Pence, 2010:

(a) Marked or mark based AR system utilizes two dimensional barcode normally QR code (*quick response code*) to connect a mobile phone and/or personal computer for overlaying information digitally on real world object or usually on a website;

(b) Mark less AR system employs location based services like GPS (*Global Positioning System*) used by cell phone to serve as a platform of adding native information on a camera vision [11].

Figure 1.4 shows snap shots related to formats of AR.

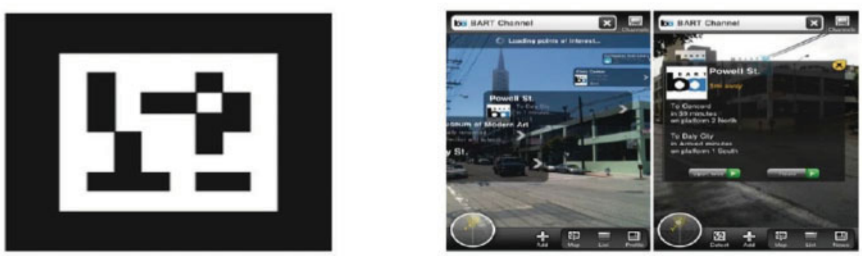


Figure 1.4 AR Systems Formats (a) Marked AR System. (b) Mark less AR System [38]

1.2.5 Presence, Reality and Realism

Following section briefly explains the cognitive aspects of user perception related to virtual environment and to some extent augmented environment as well.

Presence: According to Heeter, 1992, presence is a complex feeling with three dimensions:

- Personal or physical presence which gives sense of actually being in VR environment, a room where immersion takes place;
- Environmental existence means that VR environment seems to be responsive on user's action;

- Social presence refers that user is not alone in VR environment. Put simply, it is an ability to describe interaction among the user and virtual objects, locations and animated entities.

Reality: Reality refers through which the user experiences the immersion as genuine in reply of stimulus. Thus, higher level of reality is related to higher level of realism [7, 8].

Realism: Realism is a fact which relates to level of convergence among the user's expectation and actual experience in VR environment. The key factor here is to consider that how much the virtual stimulus converges expectations of the user [7].

1.3 Features of VR/AR Technology in Health Care

The most emerging feature of VR/AR technology in health care is E-Health with many enlightening features to support health care like patients can explain their symptoms in a better way; nurses can easily find veins, pharmaceutical companies can supply innovative drug information, surgeons can get assistance, invoking empathy, treatment for post therapeutic stress disorder, support for physical therapy, pain management, doctor or hospital visits, surgical trainings with the help of visualization and maintenance of labs etc.

1.3.1 Implications of VR/AR Technology in Health Care Services and Applications

VR and AR are being predicted to become more and more a part of reality and for the betterment of humanity presently and over the next coming years. Here a question is raised that how well health care services and applications capitalize on VR/AR since most of health care issues employ both technologies to counter clinical practices, medical trainings, surgery, phobia, rehabilitation and emergency medicine since 2008. Nevertheless, there is still ample room to develop suitable applications with the involvement of AI and IoT because health care demands precise, accurate, flexible, robust and efficient agents, expert systems, gadgets, apps, software and hardware not only to meet the requirements of society but also helpful for flourishing the working environment of an organization for radical change. It is further mandatory that people must have computer science expertise and understanding about the potential implications of these technologies which may lead them to envision practice in their area of interest.

Following section discusses in detail the implications of health care services and applications keeping in context with AI implicitly and IoT explicitly.

1.3.2 Health Care Services

AI and IoT are two main factors in recent days to make possible the range of health care services, where each service makes available a set of health care solution. This section endorses that services are generic in nature and have the possibilities to become building block for a set of way outs and applications. Therefore, these services might include feedback or notification services, internet services; agents based services, connectivity and protocol services etc [37]. The subsequent discussion highlights various kinds of health care services.

Exergaming (Digital gaming technology) is new where health care issues are tackled with the help of serious games. These methodologies when applied to a user encountering with any kind of medical disease, not only makes himher energetic but also resolves his/her health issue in an entertaining way. Such services are gaining popularity and drawn scientific attention to the emergent health dilemma of childhood diabetes, obesity and in nursing domain. The central notion of exergaming is to involve energetic body activities as an input to integrate with digital game with an expectation to succeed the sedentary activity rather than conventional gaming style [45, 61]. This health care problem can also be tackled using off-the-shelf game console systems like Sony Eyetoy, Nintendo Wii games and Konami DDR [18, 21, 29, 43, 44].

Phobia: means that an individual is experiencing extreme anxiety to a certain stimulus; the stimulus might be any animal or any situation like addressing the people, height, blackout, driving and swimming etc. In this situation, an individual feels anxiety and stress which may result increase heart beat, high blood pressure, dry mouth and sweating [1]. To address this health care service, the researchers point out that exposure based therapy is suitable for a variety of anxiety and disorders. It means that the exposure works by allowing the patient to interact fully with activation and subsequent reduction of fear in a natural way in the presence of phobia stimulus such as the use of ”*crutches*” (*e.g. entertaining exercises*) or absolute avoidance behavior (*psychologically, cognitively or behaviorally overlooking the phobia stimulus*) [2, 17, 26, 59].

Child health information (CHI) is an IoT based health service which is gaining popularity in a sense that it helps to raise child understanding and educating society as well as the children themselves about how mental, health and emotional issues and problems among family members are important [37, 68]. An IoT based interactive setup is placed in pediatric ward of any hospital for CHI services such as totem with an aim to empower, amuse and educate hospitalized children [21, 63, 69].

Adverse drug reaction: An injury occurrence from taking medication refers to adverse drug reaction (ADR). This injury can happen due to some factors:

- Taking a single dose of drug;
- Combination of two or more drugs;
- Taking drugs for long period of time.

Hence ADR is inherently generic. So there is a need to have some ADR services based on common technical issues and their solutions to design them. The implication regarding ADR is to have such systems where the patient’s terminal accesses the information of a particular drug with the help of pharmaceutical AI based information system and then synchronizes to whether the drug is well matched with his/her energy profile and e-health record. An example of such implication is iMedPack developed as a part of iMedBox to overcome ADR by using control delamination technologies [48. 74].

Indirect emergency health care: Health care services have been vigorously involved in lot of emergencies like accidents, transportation (*e.g. ship, bus, car, airplanes and trains etc.*), adverse weather conditions, fire and earthen sites collapse. Therefore, in this context the health care services are known as indirect emergency services (IEH). Such services can offer lot of techniques and solutions to counter the situation on the basis of available information of site, record keeping, post accident measures and notifications [34, 62].

Ambient assistive living: Health care services are readily available for elderly individuals in the society. One popular and important health care service is Ambient Assistive Learning (AAL) which is available with IoT powered by AI to address aging and injured individuals. The main objective of AAL services is to make elderly individuals powerful and confident by giving them independence and human servant like assistance to resolve their issues. It has been further noticed that keep-in-touch (KIT) smart objects and blocked loop health care services can make AAL possible. Both KIT smart objects and closed loop services function through IoT and AI, therefore an open source cloud based application is available to implicate AAL which is proposed by researches with minor changes to this service [41, 58, 77].

Community health care: This idea has been emerged to design and develop a network on local level around a small area for monitoring community health care. This can be accomplished with the use of AI based IoT infrastructure. The structure of community network health care can be seen as "*virtual hospital*". A tenant health information service platform based on functional requirements can be established for the distribution and sharing of data between medical facilities and service platform in order to acquire medical advice and health record remotely. Therefore, a specialized community health care (CH) is unavoidable for providing the technical requirements under one umbrella for impactful change in the society [48, 70].

Semantic medical access: Sharing huge amount of medical information and knowledge by a significant application to somewhere else can be possible with the use of semantics and ontologies and the service is called semantic medical access (SMA). This service helps the researchers and designers to prepare such health care applications in which semantics and ontologies can be obtained simultaneously. Implementation of SMA application requires sensors, medical statue based engines to analyze huge amounts of sensor data stored on a cloud and all time available data access methods to collect, merge and interoperate for medical emergency services [73].

Medical Training: VR/AR has immense implications for medical training and considered very beneficial in health care training programs and/or student's learning. Numerous software (*apps*) are available for the society to run them on smart phone for immediate training, learning and treatment in an emergency. The medical training program provides a list of medical measures for health care personal to select from it. Once any measure is selected by health care personal, the screen will display and search the tracking pattern situated in the patient body. Further, the training program will show an animated solution in three dimensional views representing when, where and in what conditions different exercises should be carried out. Also the user can amend point of view of the mock-up (*simulation*) by moving mobile device back and forth [4, 29].

1.3.3 Health Care Applications

In addition to health care services, there are numerous health care applications which can help to revolutionize not only the society but organizations as well. It has been noticed that health care services (*see above section*) are the basis for health care applications whereas these applications are directly used by patients and users. Hence, services are developer centric and applications are user centric. Moreover, there exist lot of gadgets, wearable devices and other health care devices to work with some health care application. Figure 1.5 shows some of the gadgets used in health care applications.

Electrocardiogram monitoring: Electrocardiogram (ECG) is the measure of electrical activity of heart recorded using electrocardiography on the basis of heart rate, focusing of basic rhythm and diagnosis of myocardial ischemia, extended QT intervals and versatile arrhythmias [3, 16, 75]. The ECG monitoring system can be formed using portable wireless acquisition transmitter and wireless receiving processor. Both together search out automation methods to notice abnormal data in order to identify cardiac function on real time basis [35].

Figure 1.5 Gadgets and Wearable Devices used in Health Care Applications [37]

Rehabilitation systems: Rehabilitation represents vital branch of medicine. It means that physical medicine can improve and overcome the working ability and quality of life of people having some sort of physical injury or disability. The intelligent and IoT based smart rehabilitation systems and upper limb rehabilitation systems are given by many profound researchers [20, 47, 67]. This design successfully demonstrates all essential resources to offer real-time information connections. Other rehabilitation systems such as prison rehabilitation system, smart city medical rehabilitation system, language training system for childhood autism and rehabilitation training for hemiplegic patients have been addressed in the past but require advancements to meet today's requirements.

Blood pressure monitoring: Monitoring blood pressure (BP) is a fundamental aspect in our daily life. Now it is possible to monitor BP remotely with the involvement of AI and IoT. To accomplish this notion, there exists a remote communication between health post and health center which is responsible to monitor the BP of patients. A device is used for collecting and transmitting BP data to BP apparatus having communication module along with location intelligent terminal for monitoring BP gradually on real time basis [19, 31, 72]. However, advances are necessary to overcome upcoming flaws to incorporate with recent research.

Glucose level sensing: Diabetes (*blood glucose or sugar*) is a common metabolic disease and prime health care application. It is necessary to make it our habit to monitor blood glucose on daily basis. Diabetes monitoring for an individual discloses changes in blood glucose patterns and helps to adjust activities, medication and meal timings [50]. A utility model reveals the transmission of somatic blood glucose data on a device comprised of a mobile phone, a computer, a blood glucose collector and a background processor [32]. The whole setup is a combination of AI and IoT features.

Medication management: One of the serious threats to society is non compliance of medication as a result of which the patient has to bear enormous financial loss. To overcome this issue, an AI based packaging method is introduced in medicine boxes for medication management, for example IoT based iMedBox is proposed by [55]. The packaging method has controlled sealing based on delaminating control by wireless communications.

Body temperature monitoring: Monitoring body temperature is a vital habit in health care service because body temperature is a critical indicator for monitoring and maintenance of homeostasis. Therefore, m-IoT has the successful solution which uses body temperature sensor embedded in TelosB mote to attain body temperature variations in an effective manner [37].

Smart phones and health care solutions: Recently, smart phone has become the driver and rise of health care applications because this device has smart phone controlled sensor. Smart phone is now considered a popular health care device because of the invention of multiple types of hardware and software (*apps*) which can be easily and freely available for download and can be used by any user for his/her personal health care and satisfaction. Table 1.3 summarizes some of general smart phone health care apps in detail.

Table 1.3 Smart phones health care apps

Apps	Description
Finger Print Thermometer	It is used to determine body temperature with the help of finger print.
iOximeter	Calculates oxygen intake that is SpO_2 and pulse rate.
Calorie Counter	Keeps track of user food intake and his/her weight and relationship among them.
Eye Care plus	Monitors and tests eye vision.
Period Tracker	Helps to track periods and forecasts fertility.
Blood Pressure Watch	Tracks, analyzes, shares and collects blood pressure data.
Cardiomobile	Remotely monitors cardiac rehabilitation on real time basis.
On Track Diabetes	Helps to monitor and track blood glucose for medication to manage diabetes.
Noom Walk	It acts as pedometer to count user's steps in daily routine work.
Monitoring Heart Rate	Used for real time heart rate monitoring and tracking.
Google Fit	It is used to track cycling, walking and running for the user.
Asthma Tracker and Log	Used to track asthma for patient.

The current section discussed in detail some of health care services and applications. However, few other health care services such as wearable devices access (WDA), the internet of m-Health things (m-IoT), embedded context prediction (ECP) and embedded gateway configuration (EGC) require more implications and advances to overcome future health care issues. In the same manner, certain health care applications need to be addressed vigorously like wheel chair management, imminent health care solution and oxygen saturation monitoring for potential resolution and integration of new ideas [37].

1.4 Future Assessments in VR/AR Technology

This section introduces some of the prominent implications and applicable researches made by researchers for the sake to transform their ideas into VR/AR applications which not only offer an immense change in an organization but will become useful for the society as well. Mostly, these researches are based on medical imaging and its related areas under the domain of image processing and computer vision. This will help the novice VR/AR professional to build new VR/AR applications that can specifically run on mobile devices for the betterment of health care issues. Following are some of the research ideas available for transformation.

Glaucoma detection is a vital task in eye care especially when fundus imaging is available for glaucoma. This could be handled using implications and ideas proposed by [13] while detection of lung nodule [53], lung cancer [24], brain tumor [5], diabetic retinopathy [6], skin cancer [22] and extraction of cotton wool from retinal images [64] can also become smart applications in future to improve health.

An important property is the colorization of medical images in order to retrieve required medical image from a database. This idea and technique has been proposed and available for developing VR/AR applications [54, 76]. VR/AR environment has an ability to absorb diversified domains hence we can have applications to classify facial expressions [66], simulation based facial recognition [22] and biometric based person re-identification [65] on our mobile devices for enhancing ourselves not only as an individual but also as a society. Despite all that, potential research has been proposed to build numerous intelligent systems in future for improving health care services and applications [22, 25].

1.5 Key Challenges for Adopting VR/AR Technology

In recent times, no doubt there is no comparison of any kind of technology with VR/AR technology. Nevertheless, there still exist certain challenges and gaps in adopting such diversified technology in this modern era. In this section, some challenges are mentioned for the reader interest to provide baseline in overcoming these in future:

- Funding and monetary issue, which means the organization must have enough funds for product development, research and coping marketing cost;
- Technical limitations is a broad spectrum which reflects that VR/AR systems limit their use in certain clinical settings and mobile VR/AR systems limit to the pocket size computer which can be enhanced to take out from constraints. Moreover resolution, memory and processing are challenging in this aspect;
- Organizational issues concerns about having an infrastructure to adopt technology like blue tooth connectivity, platform compatibility, provision and usage of health care software and hardware, networking, privacy issues, provision of digital medical data, vendor relationship and above all the prime factor is acceptability of technology within the organization;
- Lack of knowledge is a primary challenge because most of the people are unaware with the use of VR/AR technology in health care domain rather than using it as an entertaining medium. Disseminating knowledge will be an important goal to make the people aware in using these technologies in health care domain;

- Lack of research studies around VR/AR. It has been observed that there may only be a handful of useful research studies. So, this needs to be enhanced in future.

Some other additional challenges also need to be focused and emphasized like market issues and cultural obstacles; regulation and insurance policies, resistance from end user, lack of interest about concerned side effects etc. which are significant in adopting these technologies.

1.6 Conclusion

The foremost purpose and objective of this review is to discuss the implications of VR/AR technologies in health care services and applications for improving societal and organizational change. This chapter highlights diversified priorities in health care services and applications and efforts made by researchers in this respect taking AI and IoT as baseline. Further, it also emphasizes on definitions, formats, differences, features, design elements, cognitive aspects and challenges to VR/AR as a part of discussion.

Unlike VR which is accomplished through a complete virtual environment, AR limits itself to involve certain virtual elements to merge them with physical world. Although both technologies are being considered competent for the last two decades in view of some professionals and researchers but another thought exists that these are still in their initial phases. Therefore, research is needed to identify finest practices, determine optimal solutions to implement these technologies and facilitate for rapid adoption in society.

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CHAPTER 2

USING 3D SIMULATION IN MEDICAL EDUCATION: A COMPARATIVE TEST OF TEACHING ANATOMY USING VIRTUAL REALITY

Chung Van Le, J.G. Tromp, Vikram Puri

Duy Tan University, Da Nang, Vietnam
Emails: levanchung@duytan.edu.vn, jolanda.tromp@duytan.edu.vn, purivikram@duytan.edu.vn

Abstract

Our project created a 3D model in Virtual Reality (VR) of the human body for anatomy training. We modeled the skeletal, muscle, nervous, digestive, and cardiovascular systems to teach anatomy. A study was conducted to assess the effectiveness of the application for teaching anatomy at three major medical training universities. The research was conducted with a total of 135 students participating in the research from these three universities. 45 students from each school were divided into three conditions based on the teaching method: a plastic manikin, a real cadaver, or the 3D VR model. The scores of the groups using the 3D VR simulation at the three universities were consistently higher than the other conditions. The remarkable difference in the groups scores suggests that 3D VR simulation technology can be effective and efficient for teaching anatomy.

Keywords: 3D Virtual Reality Simulation, Anatomy, 3D Human Body Simulation, Medical Training

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (21–284)

2.1 Introduction

Teaching anatomy relies on observational practice [1, 2]. At most universities, students learn through the plastic mannequins and pictures while progressively more universities stopped using cadavers to teach anatomy [4, 7]. Using cadavers is still the best visual teaching method for anatomy training. It helps learners identify every detail of the body accurately and adequately. Only when learners understand a normal body structure, can they identify abnormal changes caused by illness or injury. Knowledge of anatomy, therefore, is essential for all clinicians. Cadavers are less easily available than in past centuries, so it has become an expensive anatomy models. However, when teaching with plastic mannequins, the number of mannequins [18, 19] in class, is generally not proportional to the number of medical students in class.

A medical education system based on virtual patients has gradually become a reality, thanks to the rapidly improving computer hardware, and computer graphics techniques for Virtual Reality (VR) [12-15].

Figure 2.1 3D virtual reality simulation of human anatomy

Our medical training system (see Figure 2.1 for an impression of some of the 3D VR models), consists of two basic components: The 3D interactive component is a fully interactive virtual biopsy model that allows users to perform surgical operations through virtual anatomical [17] instruments; the two-dimensional user interface component provides interactive access to the 2D anatomical models as well as instructional information in training sessions. Highly interactive training methods are promising advantages over other more traditional teaching methods [22-24]. Firstly, unlike plastic models, during anatomy training in VR, the system is able to provide natural feedback similar to a living organism, such as during operations trainees can see changes in heart rate, blood pressure. This gives trainees the feeling of going through an operation in a real situation. Secondly, unlike practice on real patients, it is clear that the trainee's mistakes during their training do not cause risks to real patients. Practicing in VR also reduces the pressure on the trainees when performing a operation, which can help them feel more confident and pro-active during their practice studies.

Figure 2.2 Practicing in Virtual Reality

2.2 Literature Review of Training with Medical VR

Many researchers are working on the implementation [20, 21] of 3D technology in the general field of anatomy education and investigating the different areas like teaching, training and many more where the 3D is helpful for the learning anatomy. Several researchers have evaluated the effectiveness of VR as a teaching method and compared it with student scores with the traditional teaching methods [3, 4, 8-11, 16]. Marsh, Giffin, Lowrie Jr.'s research found that [3] web-based learning can improve traditional teaching when they used it for training about embryonic development of 2D and 3D model. Students learned more from web based learning modules, they performed better than the students in the other condition and test score of retention of the new knowledge over time is also higher for those students who learned via the web based learning module. Researchers Abid, Hentati, Chevallier, Ghorbel, Delmas, and Douard compared 3D anatomy models with board & chalk teaching [9] for student learning retention, from a class on embryogenesis. It was found that for short term memorization, 3D teaching technique is more beneficial than he traditional board & chalk technique, and that in future, further research is needed to assess the mid-term, and long-term effects and the long term impact. Keedy, Durack, Sandhu, Chen, Sullivan, Breiman assessed a interactive 3D teaching technique [11] for teaching liver and biliary anatomy and found it a more effective technique than traditional textbooks. Seo, Kim, Choe assessed how effective clay modeling [6] is for learning gross anatomy and neuroanatomy and compare this clay models with the CT and MRIs. Bareither, Arbel, Growe, Muszczynski, Rudd, Marone assessed the degree of knowledge improvement [16] comparing clay modeling as teaching technique with written module and found that Clay modeling is beneficial for the anatomy education but more research is needed.

Hu, Yu, Shao, Li, Wang assessed a new Dental 3D Multimedia system [5] for a junior student's education system for clinical practice and found that Dental 3D Multimedia system works faster and no worse than traditional group. Lundberg, Low, Patman, Turner, Sinha found that medical students studying gross anatomy, prefered using the self-directed study learning methods [25]. Hu, Wilson, Ladak, Haase, Fung assessed [8] the 3D educational model of the larynx and students found it easier to learn the larynx with 3D Model as compared to traditional class lectures. Cui, Wilson, Rockhold, Lehman, Lynch have proposed the efficacy of 3D Vascular Stereoscopic Model in Anatomy Computed Tomographic Angiography (CTA) [26] and found that 97% of the students agreed with the statement "*the 3D Model is interesting and occupied [the student] to learn the materials*", showing that a 2D screen orientation is not as effective as 3D screen, i.e. a stereoscopic 3D vascular model gives better opportunities to learn about head and neck vascular anatomy and 3D learning sessions improve spatial abilities in students which have low spatial ability.

Hoyek, Collet, Di Rienzo, Da Almeida, and Guillot evaluated the effectiveness of 3D teaching methods by comparing it to teaching with 2D drawings on PowerPoint slides and the result showed that 3D digital animation was considered to be a very important tool to teach the human anatomy, especially for knowledge retention.

2.3 Methodology of this Study

A total of 135 students were randomly selected from three largest medical training universities of Vietnam in three different regions.

We had to run the experiment at three universities in three different regions in order to rule out effects on the experimental results cause by teaching style, or quality by only testing in one university, in one region.

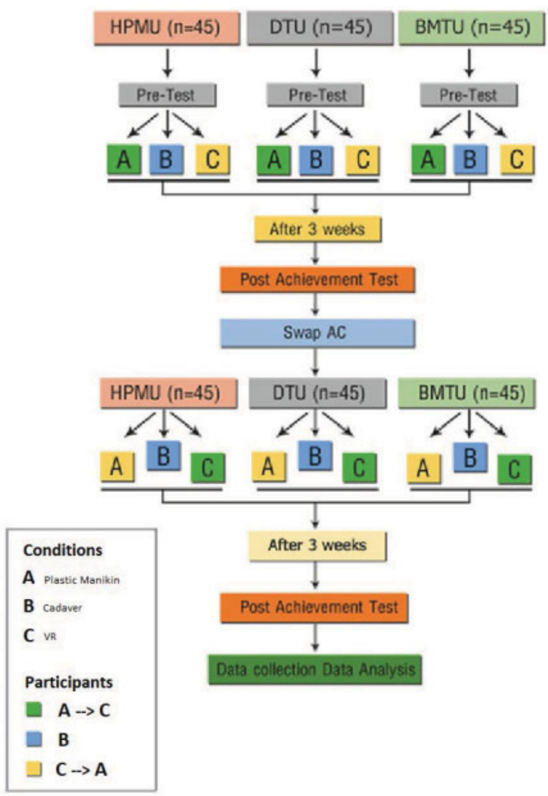

Figure 2.3 Design of the Study

The participants in all research conditions (*the three different teaching methods*) are tested at the beginning and at the end of the course by a group of independent professors. The first test is to assess the student's level of knowledge, any differences in ability to learn and acquire technical and scientific knowledge. The next test comes after 3 weeks of learning about the human skeleton and skeletal muscle. The test is an official exam. Then students in condition A: plastic manikin, swap condition and go to condition C: VR. And they receive 3 more weeks of training about Neurology and Digestive System. This is followed by an official exam (Post Achievement Test or Post Test 1 or Post Test 2 for short). See Figure 2.3 for a diagram of the design of the experiment. The design is described in further detail below.

A total of 135 students, sophomores of a Major to be General Practitioner, participated in the research, which is 45 students from each these three universities:

- Hai Phong University of Medicine and Pharmacy (HPMU),
- Duy Tan University (DTU), and
- Buon Ma Thuot Medical University (BMTU).

The lecturers who teach the anatomy classes during our experiment are from the universities that are participating in this experiment. These lecturers were assessed with regards to their professional competence and teaching ability by an independent team of experts. The results of these tests verified that the professional skills of the university lecturers are relatively equal and that they have the required expertise in anatomy.

All students of at each of the universities first learn about anatomy theory in the normal classroom. The lecturers introduce students to the basics of anatomy such as the concepts of human skeleton and skeletal muscle, as well as their functions.

After the first week of theoretical lessons, students are tested of their knowledge and ability to learn and acquire new theoretical knowledge.

This test was conducted by an independent review team of anatomical specialists. Based on student score results of this first test, the students were allocated to the different teaching method conditions (*A*, *B*, or *C*) in such a way that their level of knowledge and learning abilities were equally distributed across all of the groups in each university.

Age, gender, and ability to study Anatomy were also taken into account to distribute student ability evenly across groups or experimental conditions, see Table 2.1 for an overview of the resulting age and gender distributions, for each group.

At each school the 45 students were assigned to one of three conditions, the *A*, *B* or *C* group. Each group consists of 15 students. The difference between groups is based on the teaching method used:

- Teaching Method A "*Manikin*": Using pictures, specimens, plastic models, which is labeled by.
- Teaching Method B "*Cadaver*": Learned directly on dead human bodies called
- Teaching Method C "*VR*": Taught through a 3D virtual reality simulation.

After completing the pre-test, groups of students from the universities participated in the experimental conditions, which consisted of practical anatomy training activities depending on the learning methods they were assigned to. Students practiced in A: laboratories, or B: clinical practice rooms or C: simulation rooms. The duration of the anatomy lessons was three weeks including the modular skeletal system.

Table 2.1 Age and gender variation among groups and conditions (Group A plastic manikin, group B real cadaver, group C Virtual Reality)

University Name		Mean	Minimum	Maximum	Median	Std. Deviation	p	Male	Female
HPMU	Group A	20.53	19	23	20.00	1.187	0.637	9	6
	Group B	21.67	19	24	22.00	1.676		8	7
	Group C	20.00	19	23	20.00	1.195		6	9
	Total	20.73	19	24	20.00	1.514		23	22
DTU	Group A	20.20	19	22	20.00	1.014	0.461	6	9
	Group B	21.60	19	24	21.00	1.549		7	8
	Group C	20.53	19	23	20.00	1.407		6	9
	Total	20.78	19	24	20.00	1.444		19	26
BMTU	Group A	21.27	19	24	22.00	1.438	0.551	6	9
	Group B	20.60	19	23	20.00	1.242		7	8
	Group C	19.67	19	21	20.00	.617		8	7
	Total	20.51	19	24	20.00	1.308		21	24

After three weeks of learning and practicing surgery, each group of students had an examination of what they had learned about the human skeleton and skeletal muscle in the previous 3 weeks. This exam is an official test, administered by independent, official examiners. The exam consists of multiple choice and free response questions testing their knowledge and understanding of anatomy, composed of 100 questions to be answered in 60 minutes by each student. The independent supervisory board determines the topic and questions for the examination. This third party is traditionally responsible for ensuring the security and marking the exam papers in the country.

A. B. C.

Figure 2.4 Three teaching methods: A. Plastic models, B. Real cadaver, C. Virtual Reality

2.4 Results

The exam results show the scores of each group as follows:

- Group A (*Learning by observing plastic models, specimens*) got the lowest score 5.81 (HPMU, $M = 5.67$; DTU, $M = 5.97$; BMTU, $M = 5.80$);
- Group B (*Cadaver*) $M = 6.69$ (HPMU $M = 6.70$; DTU $M = 6.60$; BMTU $M = 6.77$) and

- Group C (VR) the highest score $M = 7.74$ (HPMU $M = 7.93$; DTU $M = 7.68$; BMTU, $M = 7.63$), (see Table 2.2, for the details on the scores of Post Test 1).

A statistical comparison between the scores on the pre-test and post-test 1 is not valid here, because the pre-test measured current knowledge and ability to learn efficiently, the post-test 1 measures the newly acquired knowledge that the students at each institution (HPMU, DTU, BMHU) learned as expressed by their scores on the official end-exam for this course. The exams were audited and scored by an independent official organization that is responsible for the quality and security of the exam-procedures nationwide.

However, it is interesting to look at the scores of the students on post test 1 (*Human Skeleton and Skeletal Muscle exam*) and post test 2 (*Neurology and Digestive System exam*) and compare the scores between the three different conditions. The scores of the different university students (HPMU, DTU and BMTU) after the first post-training exam can be seen in Figure 2.5.

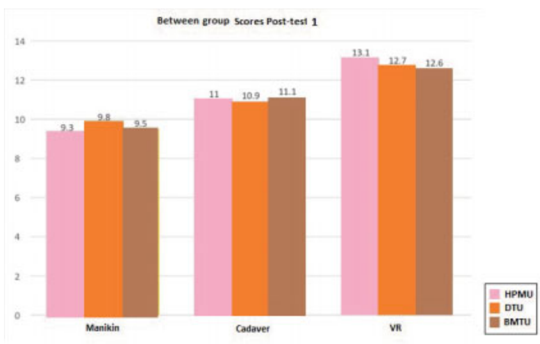

Figure 2.5 The scores of the different university students (HPMU, DTU and BMTU) after the first post-training exam

The scores of the different university students (HPMU, DTU and BMTU) after the second post-training exam can be seen in Figure 2.6.

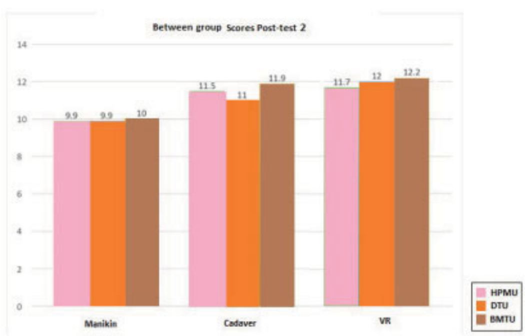

Figure 2.6 The scores of the different university students (HPMU, DTU and BMTU) after the second post-training exam

It has to be noted that, again a statistical comparison of how much more or less the students scores on the second exam compared to the first exam is not valid. Both exams are about different topics and the participants have also a certain amount of learning effect. The participants in the second test have previous experience with the training, through the first condition they were assigned to during the first training and first post test. After the first training and exam, the participants in the condition with the Cadaver, stay in that condition for the second training and exam. However, the group that first learned via the Plastic Manikin condition, now experiences the VR condition for the first time. The participants who experienced the VR condition during the first training and exam, now experience the Plastic Manikin condition.

After the first tests, the teaching / learning methods are swapped between group A (*learning with plastic manikin*) and group C (*learning with VR*), to check the learning effects of the different conditions has the same or similar effects again, and make sure the order in which students are exposed to the different learning conditions does not have an effect, the students who experienced VR, will now learn with the plastic manikin and those of learning with the plastic manikin first, now go to the VR condition. After the students from group A have swapped with the students in group *C*, the students start learning about Neurology and Digestive System during 3 weeks.

The independent supervisory board provides all students with a final exam of 90 minutes, consisting of multiple choice and free response questions. See Table 2.3 for an overview of the scores after the first training, compared to the scores after the second training.

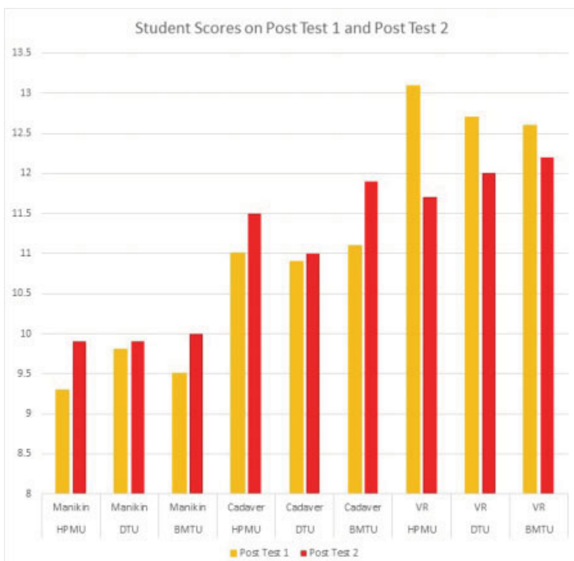

Figure 2.7 The scores of the different university students (HPMU, DTU and BMTU) grouped together per condition (Manikin, Cadaver, VR) after the first post-training exam (*Post test 1, yellow*), and the second post-training exam (*Post test 2, red*)

It was noteworthy that the $(A \rightarrow C)$ participants who firstly learned on plastic models, and secondly used 3D Models and Virtual Reality improved their scores significantly. from the lowest score group on the first test to the high scoring group on the second test.

Participants in group (*B*), learning by observing directly from cadavers, during both sets of lectures, had low scores on the Neurology and Digestive System Lesson. This result could indicate that which of the learning methods is the most effective (*plastic manikin, cadavers or VR*) may also depend on which anatomy topic needs to be learned and how, during different (*types of*) lessons. See Figure 2.7 and Figure 2.8 for the results from each university and each experimental condition respectively. In both independent test the participants in the VR condition scored the best exam scores, the cadaver condition continued to be second best and the plastic manikin condition continued to have the lowest scores.

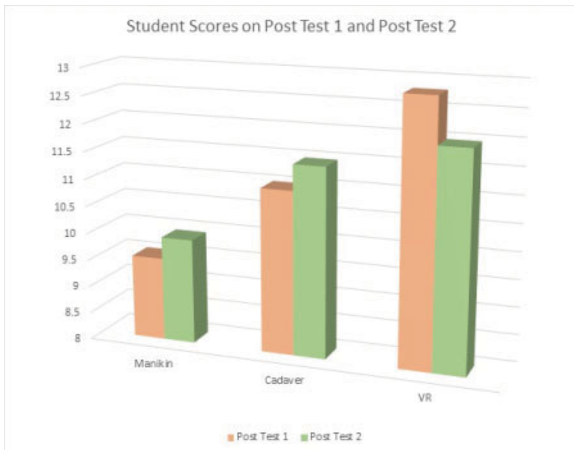

Figure 2.8 The aggregated scores of all university students (HPMU, DTU and BMTU) grouped together per condition (Manikin, Cadaver, VR), with the first post-training exam scores (Post test 1, orange), and the scores on the second post-training exam (Post test 2, green)

2.5 Discussion

The research findings suggest that anatomy teaching at universities can be improved by using 3D computer generated models, and that the application of VR technology in teaching is a more efficient method than the traditional methods using plastic manikins or cadavers. To look further into the problems of using cadavers for teaching and learning, we also collected feedback from 200 students who attended the anatomy training course at universities in Vietnam in previous years, when still learning directly with cadavers. Issues that were brought forward were that the number of donated cadavers is very low for students studying anatomy in universities. It is common practice in medical universities around the world to continue using a cadaver many times, over a long period of time. Normally, a cadaver is used for 6 months and is then replaced. However, in some countries, where access to cadavers in difficult, such as Vietnam, it is used much longer, sometimes more than 2 years. These cadavers are obviously not kept in the original shape, because students practice surgery on them many times. Therefore, during lessons about the nerves or skeletal muscles, it is often no longer possible to recognize the organs in these bodies, which makes using these used cadavers for study more difficult. The cadavers become deflated and black, they are soaked in a formalin used and re-used for a long time and for many different practice tasks; as a result, the medical students' need to practice in a realistic setting, is not fully met. For these additional reasons it is clear that teaching with 3D VR models of the human body is a desirable alternative that promises to be a highly efficient teaching method for universities offering medical and healthcare programs.

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Table 2.2 The statistical summary of pre-test and post-test 1 scores

University Name	Group Name		Pre – Test P = 0.163	Post – Test P = 0.990
HPMU	Manikin	Minimum	5.5	4.0
		Maximum	8.0	7.5
		Mean	6.933	5.667
		Median	7.000	5.500
		Std. Deviation	.7528	.9574
		% of Total Sum	10.8%	9.3%
	Cadaver	Minimum	5.0	5.5
		Maximum	9.0	8.0
		Mean	7.307	6.700
		Median	7.500	6.500
		Std. Deviation	1.1196	.7746
		% of Total Sum	11.4%	11.0%
	VR	Minimum	6.5	6.5
		Maximum	8.0	9.0
		Mean	7.167	7.933
		Median	7.000	8.000
		Std. Deviation	.5876	.7528
		% of Total Sum	11.2%	13.1%
DTU	Manikin	Minimum	6.0	4.5
		Maximum	8.5	7.0
		Mean	7.200	5.967
		Median	7.500	6.000
		Std. Deviation	.9024	.6935
		% of Total Sum	11.3%	9.8%
	Cadaver	Minimum	5.5	5.0
		Maximum	8.5	7.5
		Mean	6.967	6.600
		Median	7.000	6.500
		Std. Deviation	.8756	.7838
		% of Total Sum	10.9%	10.9%
	VR	Minimum	6.5	6.5
		Maximum	9.0	9.0
		Mean	7.633	7.687
		Median	7.500	7.500
		Std. Deviation	.8338	.7754
		% of Total Sum	11.9%	12.7%
BMTU	**Manikin**	Minimum	5.0	4.5
		Maximum	8.0	7.5
		Mean	6.767	5.800
		Median	6.500	6.000
		Std. Deviation	.9037	.7746
		% of Total Sum	10.6%	9.5%
	Cadaver	Minimum	5.0	5.5
		Maximum	8.5	8.0
		Mean	6.967	6.767
		Median	7.000	6.500
		Std. Deviation	.9155	.7761
		% of Total Sum	10.9%	11.1%
	VR	Minimum	5.5	6.5
		Maximum	8.5	8.5
		Mean	7.000	7.633
		Median	7.000	7.500
		Std. Deviation	1.0000	.6673
		% of Total Sum	10.9%	12.6%

Table 2.3 The statistics of scoring average after swapping participants from Manikin condition to VR condition

University Name	Group Name		First Post-Training Exam Post – Test 1 P = 0.990	Second Post-Training Exam Post – Test 2 (Swapped groups: A → C, C → A) P = 0.376
HPMU	Manikin	Minimum	4.0	5.0
		Maximum	7.5	7.0
		Mean	5.667	6.100
		Median	5.500	6.500
		Std. Deviation	.9574	.6325
		% of Total Sum	9.3%	9.9%
	Cadaver	Minimum	5.5	5.5
		Maximum	8.0	8.0
		Mean	6.700	7.067
		Median	6.500	7.000
		Std. Deviation	.7746	.7528
		% of Total Sum	11.0%	11.5%
	VR	Minimum	6.5	5.5
		Maximum	9.0	8.5
		Mean	7.933	7.233
		Median	8.000	7.500
		Std. Deviation	.7528	.9424
		% of Total Sum	13.1%	11.7%
DTU	Manikin	Minimum	4.5	5.0
		Maximum	7.0	7.5
		Mean	5.967	6.100
		Median	6.000	6.000
		Std. Deviation	.6935	.7121
		% of Total Sum	9.8%	9.9%
	Cadaver	Minimum	5.0	6.0
		Maximum	7.5	8.0
		Mean	6.600	6.800
		Median	6.500	6.500
		Std. Deviation	.7838	.6492
		% of Total Sum	10.9%	11.0%
	VR	Minimum	6.5	6.5
		Maximum	9.0	8.0
		Mean	7.687	7.400
		Median	7.500	7.500
		Std. Deviation	.7754	.5071
		% of Total Sum	12.7%	12.0%
BMTU	Manikin	Minimum	4.5	5.0
		Maximum	7.5	7.0
		Mean	5.800	6.167
		Median	6.000	6.000
		Std. Deviation	.7746	.4880
		% of Total Sum	9.5%	10.0%
	Cadaver	Minimum	5.5	6.5
		Maximum	8.0	8.0
		Mean	6.767	7.333
		Median	6.500	7.500
		Std. Deviation	.7761	.5563
		% of Total Sum	11.1%	11.9%
	VR	Minimum	6.5	6.5
		Maximum	8.5	8.5
		Mean	7.633	7.500
		Median	7.500	7.500
		Std. Deviation	.6673	.6547
		% of Total Sum	12.6%	12.2%

CHAPTER 3

BUILDING EMPATHY IN YOUNG CHILDREN USING AUGMENTED REALITY: A CASE STUDY IN MALAYSIA

N.Zamin[1], F.A.Khairuddin[1], D.R.A.Rambli[2], E.N.M.Ibrahim[3], M.S.A.Soobni[4]

[1] University Malaysia of Computer Science and Engineering, Putrajaya, Malaysia
[2] Universiti Teknologi PETRONAS, Seri Iskandar, Perak, Malaysia
[3] Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[4] ARLETA Production, Cyberjaya, Selangor, Malaysia

Emails: norshuhani@unimy.edu.my, fuadah@student.unimy.edu.my, dayangrohaya.ar@utp.edu.my, emma@tmsk.uitm.edu.my, mohdsuhairi@gmail.com

Abstract

Empathy is the feeling that a person can step out virtually from his/her own world and enter the internal world of another person. In simple notation, empathy means the ability to 'feel with' other people, to sense what they are experiencing. Empathy is different than sympathy. It is a hard-wired capacity many of the people today is lacking. A psychological study has found that many people are suffering from Empathy Deficit Disorder (EDD). EDD gets severe by the increasingly polarized social and political culture especially in the under developed countries. Lack of empathy and social wellness can be very damaging to the families, organizations and countries. This research investigates how compassion can be trained as a coping strategy to build social wellness using augmented reality on our young generations. Smart and empathic citizens are the key to the success of Industrial Revolution (IR) 4.0.

Keywords: Empathy Deficit Disorder, Augmented Reality, Empathy, Smart Citizens.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (35–284)

3.1 Introduction

There is a growing concern on the loss of empathy in today's society. A study conducted at University of Michigan [1] has found that college students today are showing less empathy than previous decades, a 40% decline in fact since 1980 with a steep drop in the last decade. That is considered as an alarming number. A lack of empathy graduates will not be successful change makers in the industries. A research in [2] has found that there is an increase in social isolation because of the drop-in empathy. Since 1970s, Americans have become more likely to live alone and less likely to assimilate with the societies. Several other social studies also found that socially isolated community can take a toll on people's attitude towards others. They are less generous and more likely to take advantage on others. Loss of empathy effects the socio-economics of a country too. Research shows that countries and regions in which there is little trust and respect outside one's own family tend to lag in economic development and growth [3]. Lack of trusts leads to a higher poverty level and crime rate of a country. The less people trust each other, the more they need for safety measures and regulations. Violence are created from less empathetic societies because they fail to think what is right or wrong. Thus, empathy need to be fostered from home as a secured foundation [4-5].

3.2 Motivations

Our research is inspired by the socio-economic problems in our country MALAYSIA. Malaysians are currently living in hardship due to weak economy. Government intervention in our economy has increased the power of political action while reducing private action. This is a moral crisis. The increased cost of living has forced our fellow Malaysians to work round the clock. According to the 2012 Vacation Deprivation Survey by Expedia, Malaysia ranks fourth to having the most dedicated workforce with 90% of employees working even when they are on vacation. On average, Malaysians clock in about 40 hours a week at work which is equivalent to eight hours a day, based on a five-day work week. Some citizens are having multiple jobs just to survive the urban living. Parents are working long hours and have less attachment and bonding with their children.

3.3 Literature Review

Virtual Reality (VR) is used to describe a three-dimensional, computer generated environment that can be interacted and explored by the user. VR provides the access to experiences things outside the classroom space, for example like an immersion into a refugee camp. These technologies give the opportunity to the users to immerse themselves in any activity faster without many risks and do it more interactively than before.

A good example of a company that produces empathy games through VR is the Minority Media. The company has become the catalyst for a burgeoning video game genre called empathy gaming where players are forced to confront real human issues like bullying, alcoholism or depression. The co-found of Minority Media, Earnest Webb said they are trying to put people in a different mind-set and perspective through VR and taking the advantage of the educational possibilities [9].

Big technology companies such as Google, Apple, Facebook, and Microsoft are aiming for victory in the battle for AR. Each of them is working towards countering the others work to stay on top of the charts. With the launch of Apple's ARKit and Google's ARCore, in 2017, developers now have access to some powerful frameworks for creating AR apps. It is now evident that AR has a high potential for growth as referred to Figure 3.1. Experts predict the AR market could be worth 122 billion by 2024 [10].

Figure 3.1 AR Market Predictions

Our literature studies have found several existing empathic applications using AR and are summarized in Table 3.1.

Table 3.1 Comparative studies on the existing AR applications for empathy development [6]

App Name	Description	Price	Reviews	Aged
AR Freedom Stories	Highlights seldom told African Canadian histories from the era of the Canada/US Underground Railroad including Harriet Tubman's efforts to bring American slaves to freedom in Canada.	Free	3/5	12+
School of Games AR: Preschool	This is an AR preschool game where it has an endless learning experience including listening to moral stories and reading comprehensions.	$4.99/ month	N/A	3 to 5
The Tortoise and the Hare	An interactive storybook app that uses augmented reality to incorporate kids' coloring into the 3-D story. The story itself includes the moral at the end.	$2.99/ month	3/5	5+

In Table 3.1, most of the applications are not freely available to the users unless they pay for it. Furthermore, all of them are in English language which does not support the effective learning among the preschool students in Malaysia since most of them are not fluent in English. However, as compared to our proposed app, it does not only involve storytelling, but the user need to decide what to do in a situation. This is a good approach to make them realize the consequence of their desired action. Moreover, the AR printed book and the animation in our app are purely in our local language, Malay to make it more personalized to our local culture and mother tongue. This is toe enable the app as teaching and learning aid at both schools and homes in Malaysia. Our proposed app is a freemium product whereby the app is provided free of charge, but profit is made through the sales of the AR book. The users only need to purchase AR book which will cost around USD10 each.

3.4 Proposed Approach

This research investigates the pedagogy of virtue teaching and learning for early childhood education and to develop the framework for virtue development using Augmented Reality (AR). The idea to integrate the use of digital technologies in the development of emotions and positive character traits is inspired by the advancement of technology that gives the greatest influence on how the children think. Research has found that digital applications such as video games can improve visual-spatial capabilities, cognitive skills and increase attentional ability and reaction times [7]. On the other hand, there are many violent video games are found to effect on empathy aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, empathy/desensitization, and pro-social behavior [8]. We are developing 2D empathetic games in simulated virtual reality environment that presents some situations that need the young users to respond with empathy. This serves as a role-play but in virtual environment. At this stage, we have developed three scenes according to the Malaysia's preschool curriculum on virtue learning in Malay language. Few empathy scenarios which will be implemented in the AR application. Each scenario will highlight a moral value so that the player will acknowledge and learn the pro-social values. the program will ask the player to choose a selection of answers to identify their empathy level. After that, the program will explain the situation and tell the correct to make things right in that scene. A printed AR book with object's marker will be provided to initiate the AR application.

Figure 3.2 and Figure 3.3 shows an example of a scene to teach the value of honesty when a child is caught for a trouble he/she has made. The app will prompt the player to select the right response related to the scenario. All scenes created were illustrated using simply PowerPoint software. Next, the young player needs to select a button as a response towards the played empathy scenario. Each button will play different scenario to show to player the impact of the button that they have chosen.

3.5 Results and Discussions

A test was conducted on ten preschool students aged four to eight years old and seven children with learning disabilities which includes children with autism and slow learners. Other than students, some parents and teachers from both preschool and special school also were involved during the field test. Interview was conducted to know the parents' feedback's on the proposed approach and the AR application.

Figure 3.2 An empathy scene

Figure 3.3 The response buttons

Figure 3.4 Among the Participants

User Acceptance Test (UAT) of the application was conducted to demonstrate that the app meets with the performance criteria. Results of field test that was done on 10 preschool students and 7 special school students at a school in Putrajaya, Malaysia shows the necessity to have such app as teaching aid in empathy pedagogy. The observation on the students

Figure 3.5 Testing on Preschool Students

while they were using the app was recorded, followed by the distribution of the feedback forms regarding the app and book.

Seventeen selected young children were given a freedom to explore the application by themselves and later, they were given a survey paper with five statements. They need to vote according to which scale they prefer the most for each statement. The voting was done by sticking the stickers inside the small box next to the emoji face. Table 3.2 shows the result of the survey form that consist of five statements.

Table 3.2 Overall Result of EMPARTI Evaluation Form

No.	Statement	School	Scale		
					
1.	I think EMPARTI book is pretty.	Preschool	0	0	10
		Special School	0	2	5
2.	I know how to use EMPARTI application.	Preschool	0	2	8
		Special School	0	1	6
3.	I like EMPARTI cartoons.	Preschool	0	1	9
		Special School	0	0	7
4.	I learnt many good virtues.	Preschool	0	0	10
		Special School	0	1	6
5.	I want to use this book again.	Preschool	0	0	10
		Special School	0	0	7

*Preschool: 10 students. Special school: 7 students

3.6 Conclusions

Empathy at the individual level can make real equality possible at the societal level. Our proposed Empathic AR application is different than the existing applications where it is tie with our local culture, language and current curriculum. We are currently in the testing phase of our prototype at selected public schools in Malaysia. The effectiveness of teaching and learning empathy via AR apps will be compared with the traditional methods through series of interviews and observations with the young children, teachers and parents. The results will be presented in future publications. There is a potential commercialization to introduce digital emphatic technology as a teaching and learning aid for special schools in Malaysia. The available empathy teaching and learning in Malaysian schools are undeniably lacking and unable to impart the understanding of the common senses in daily life due to lack of comprehension from many parties - educators, learner, parents, country's policy makers, etc. This phenomenon, in many scenarios can result in permanent serious socioeconomic problems that will totally shroud the children's future.

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CHAPTER 4

EFFECTIVENESS OF VIRTUAL REALITY MOCK INTERVIEW TRAINING

J. Garcia[1], J. Tromp[1,2], H. Seaton[3]

[1] State University of New York, Oswego, NY, USA
[2] Duy Tan University, Da Nang, Vietnam
[3] Aquinas Training, Inc., NY, USA
Emails: jgarcia2@oswego.edu, jolanda.tromp@duytan.edu.vn, hugh@aquinas.io

Abstract
Interviewing for potential employment is an anxiety filled process that affects many individuals. College students and long-term unemployed are among a demographic that is predominantly susceptible to this anxiety when seeking jobs. Traditional interview training sessions have shown much success in preparing students for employment interviews, increasing their popularity on college campuses. This study investigates the effectiveness of Virtual Reality mock interview training in decreasing participants self-reported. The results support the effectiveness of Virtual Reality interview training, further supporting the need for institutions to utilize these trainings.
Keywords: Virtual Reality, Interview Training, Anxiety, Usability.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (43–284)

4.1 Introduction

While seeking employment is necessary for survival in today's society, the process can be overwhelming. The lengthy, anxiety filled process, and the emotional response to rejection that come with it can seriously hinder and deter individuals from pursuing further employment opportunities. This negative feedback can lead to unhealthy anxiety, which in turn can lead to becoming another factor in being long-term unemployed. Traditional interview training sessions have shown much success in preparing for employment interviews, increasing their popularity on college campuses. Our research aims at finding out how effective Virtual Reality (VR) systems can be for mock interview training and the attitudes and opinions of the participants in terms of motivation to use VR for mock interview training.

4.2 Virtual Reality Training Literature Review

Post-Traumatic Stress Disorder (PTSD) has led to challenges for veterans trying to obtain competitive employment, especially pertaining to the interview portion of employment search process. In their study Smith, Ginger, Wright, Wright, Humm, Olsen, Fleming measured the effectiveness of virtual reality employment interviews for veterans (ages 18-65) who suffer from PTSD [1]. The participants of their study were United States veterans suffering from PTSD who were unemployed. These participants received up to ten hours of Virtual Reality Job Interviews Training (VR-JIT) session. The participants were required to complete pretest and post-test self-reports. They found positive correlations between the use of VR exercises and increased scores of these veterans measured by the resource experts. This positive correlation was most prevalent between the baseline neurocognition and advanced social cognition, meaning that the VR exercises were successful in improving veterans' communication skills. These findings support their hypotheses concerning the effectiveness of VR-JIT among veterans suffering from PTSD, supporting its use with this demographic.

In their study of 2014, Smith et al. used laboratory-training sessions involving VR-JIT to assess the usability factor of the software to observe if mock interview scores increased over time. The researchers found that the participants who utilized VR-JIT demonstrated larger improvement in job interviewing skills when compared to the control group [2]. This was determined after the individuals using the VR-JIT software underwent 10 hours of training using the simulator. The individuals who used the VR-JIT software also experienced an increase in the amount of time spent conducting themselves during a mock interviewing.

Aysina, Maksimenko, and Nikiforov developed the Job Interview Simulation Training (JIST), software that would systematically improve the job interviewing process for long-term unemployed individuals [3]. They aimed to evaluate the effectiveness of JIST in preparing long-term unemployed individuals for potential job interviews. JIST consisted of five sessions of simulated job interviews. The authors found in their study that participants rated JIST as an easy to use tool. They also found that JIST helped improve individual's communication skills when compared to the control group. Additionally, participants indicated an increase in confidence on their self-reports after utilizing JIST. While the authors felt confident in the effectiveness of their software, they believe that further research is required to see the true effectiveness of JIST software. Their work also concludes that there is a need to test JIST with different demographics.

4.3 Methodology

Our study investigates the use of VR mock interview training. Our hypotheses are that mock interview training in VR will lower interview anxiety, and that their attitude and opinion towards using mock interview training in VR as a positive addition to preparing for interviews and will want to continue using it in the future to prepare for interviews:

- $H1_0$: Participants will not indicate a change in anxiety on their post-test self-report than on their pretest self-report.
- $H1_A$: After concluding the virtual reality mock interview session, participants will indicate having lower anxiety on their post-test self-report than indicated on the pretest self-report.
- $H2_0$: Participants will indicate on their post-test self-report that they would not utilize virtual reality mock interview training tools for future interview preparation.
- $H2_A$: Participants will indicate on their post-test self-report that they would utilize virtual reality mock interview training tools for future interview preparation.

4.3.1 Participants

The participants of this study were ten students (*four male, six female*), between the ages of 19 and 24 (*mean 22*). This study required participants to use the Oculus Rift, a virtual reality (VR) Head Mounted Display (HMD), see Figure 4.1.

Figure 4.1 Oculus Rift Consumer Version 1

Participants were informed that use of the Oculus Rift Consumer Version 1 (CV1) may cause side effects such as: *eye strain, dizziness, disorientation, vertigo, nausea, and discomfort*. Participants were asked to notify the researcher if they experienced any of the mentioned symptoms, or any additional symptoms. Due to the use of the Oculus Rift for this study, participants who required eye glasses were excluded from participation of this study. While it is possible to wear glasses while using the Oculus Rift CV1, it can be uncomfortable.

4.3.2 Materials

The multi-user VR software application High Fidelity was used as virtual interview space for the mock interviews. High Fidelity is a VR application where users can immerse themselves in a self-created environment. See Figure 4.2 for an impression of two users engaged in a conversation in a virtual space.

Figure 4.2 Example of two users communicating in a Virtual Reality space

Together, the Oculus Rift and High Fidelity application were used to provided participants with the virtual environment for the interview setting. The CV1 Xbox like controller was used for participants to navigate through the virtual environment, but to do the task the need to navigate was minimal. Headphones were used to improve the participant's virtual experience, effectively fully immersing the user into the experience by providing the audio from the virtual world and to block outside noise while the interviewer (*researcher*) asked the participant interview questions (see Figure 4.3).

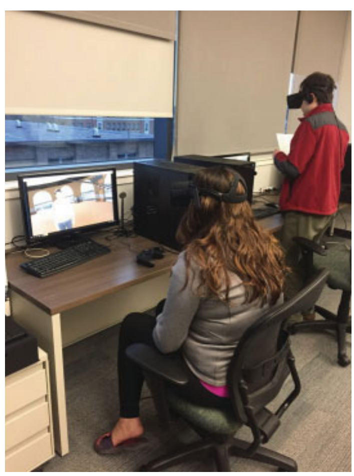

Figure 4.3 Image of Virtual Reality Interview Training Session

A microphone was used to support the dialog between the participant and interviewer (*researcher*). The software application Qualtrics was utilized to collect demographics, pretest self-report responses, and post-test responses from the participants. The use of Qualtrics was very helpful because it provided digital data collection, decreasing potential transcribing errors.

4.3.3 Procedure

This study utilized a repeated measures design to compare participants self-report responses before and after participating in the VR mock interview. First participants read and signed the informed consent document, then they were asked to complete the demographics form and the pretest self-report using the Qualtrics software. Once the participant completed the pretest self-report, they were asked to put on the Oculus headset and headphones. The researcher assisted participants in properly adjusting the headsets for participants safety. Once the headset was securely on the participants head, the researcher put on the second Oculus headset and began to engage the participant in a mock interview. The researcher acted as the interviewer for the session and asked participants five popular interview questions from a prepared list of typical interview questions. Questions such as:

- ”*Can you tell me a little about yourself?*”,
- ”*What are your strengths*?”,
- ”*What are your weaknesses*”, etc.

Once the researcher asked all the interview questions and the participants answered them, they ended the interview session. The participant was then asked to remove the headset and headphones. Then, the researcher instructed the participants to complete the post-test self-response questionnaire. Once the participant submitted their responses, the researcher provided a debriefing.

4.4 Results

A paired-samples t-test was conducted to compare participants self-reported anxiety prior to the VR mock interview and after the VR mock interview. There was a significant difference in the scores for participants self-reported anxiety prior-to ($M = 2.8, SD = 2.348$) and post-to ($M = 1.40, SD = 1.897$) the VR mock interview; $t(9) = 3.096$, $p = 0.013$, see Table 4.1.

Table 4.1 SPSS output for Paired Samples T-Test comparing participants anxiety levels prior-to and post-to the VR mock interview

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Question9 - Question10	1.400	1.430	.452	.377	2.423	3.096	9	.013

These results reject the first null hypothesis ($H1_0$), demonstrating a change in anxiety prior-to and post-to the VR mock interview.

On the post-test self-report, participants were asked if they believe the virtual reality interview training session would be a useful tool to prepare for a real job interview. This was used to investigate the second hypothesis (H2). Of the ten participants, 50% indicated "*definitely yes*", 20% indicted "*probably yes*", and 30% indicating "*might or might not*", see Figure 4.4.

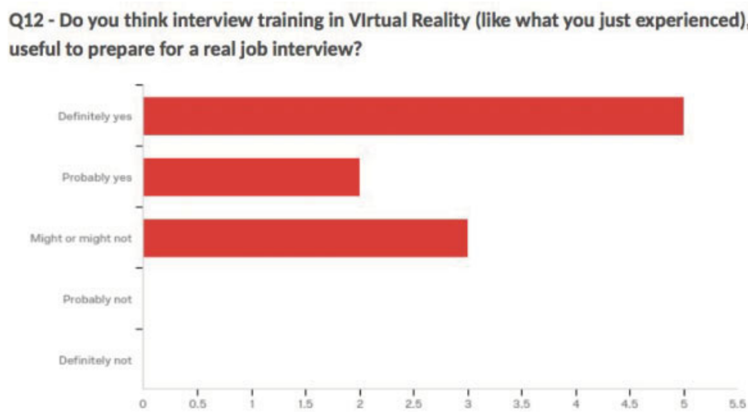

Figure 4.4 Participants response to measure 12

Participants were also asked if they would continue to use VR interview training as a method to prepare for real job interviews. 70% of participants indicated "*probably yes*" and "*definitely yes*", 30% indicated "*probably not*", see Figure 4.5.

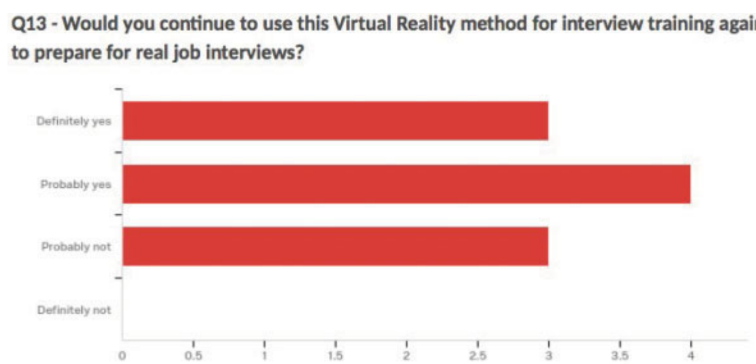

Figure 4.5 Participants responses to measure 13

4.5 Disscussion

The purpose of this study was to investigate the effectiveness of VR mock interview training in decreasing interview-anxiety in college students. Additionally, we wanted to know about the participants' perceived usefulness of VR mock interview training, and participants self-reported likeliness of continuing to use VR mock interview training as a method to prepare for real job interviews.

The results from the paired-samples t-test support the researchers first hypothesis ($H1$), further supporting the use of VR interview training as an effective tool for decreasing interview-anxiety and increasing interview preparedness. These findings are in agreement with the work of Aysina et al. and Smith et al. regarding the effectiveness of VR interview training, but with a different demographic (*college students*), adding to the overall effectiveness of VR interview training across various demographics. The second hypothesis ($H2$) was also supported by participants responses to questions twelve and thirteen. The results obtained from this study demonstrate an interest by college students in utilizing VR mock interview training to prepare for future interviews. These findings could be used at universities by students, faculty, and staff, to advocate for VR interview training programs.

Limitations of this Study: The biggest limitation of this study was that most of the participants had never experienced virtual reality technologies. The novelty of using this technology could have caused participants to provide better ratings on their post-test self-report. Additionally, the use of this software could have caused the participants to feel anxious and uncomfortable. Due to the recent interest in multi-user VR applications, the VR software available is still in a beta phase, and not developed specifically for the purpose of conducting interview training sessions. The experience of practicing for an interview in VR can be made more realistic by creating a VR interview room that looks like a typical interview room in the real world, to assess whether transfer of the learned skill will be more likely.

4.6 Conclusions

The results of this study support previous research investigating the effectiveness of VR interview training. While these findings support the claims that VR interview training is an effective tool, the limitations should be considered. Future research is needed investigating effectiveness of VR interview training on a population that has had prior experience to virtual reality technologies, thus eliminating novelty as a possible confounding variable. However, these results should be used to advocate for VR interview training sessions on college campuses and with long-term unemployed individuals, as these trainings assist individuals practice for real interviews. College graduates face an extremely competitive job search after completion of their degrees. The long-term unemployed population are also face an extremely competitive job market. The long-term unemployed are another, highly vulnerable population, that will benefit from extra training to help them enter the extremely competitive job market. These technologies can aid students and the long-term unemployed in better preparing for potential interviews, thus giving them an advantage. Additionally, these trainings have shown effectiveness in various demographics, demonstrating a need to also advocate for these training in additional agencies, such as the government. With high unemployment, VR interview training sessions could benefit many in preparing to re-enter the workforce. Advances in virtual reality technologies have allowed for great growth in various sectors, such as medical, educational, and commercial. By investigating these technologies for other domains, we can provide quantitative data to help advocate for further investments in these technologies. The complete report of the research described above can be found in [4].

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CHAPTER 5

AUGMENTING DENTAL CARE: A CURRENT PERSPECTIVE

Anand Nayyar, Gia Nhu Nguyen

Duy Tan University, Da Nang, Vietnam
Emails: anandnayyar@duytan.edu.vn, nguyengianhu@duytan.edu.vn

Abstract In recent years, there has been an increasing interest in applying Augmented Reality (AR) in diverse medical applications. Augmented Reality technology is regarded as combination of virtual information in addition to real-world information which opens wide possibilities in various medical activities like Surgery, Education, Consultancy and even basic diagnosis. Augmented Reality is utilized in various medical surgeries like Laparoscopic Surgery, Brain Surgery, Plastic Surgery, Heart Surgery etc. Surgeons are even making use of Medical Augmented Reality to increase the vision power to undertaken medical procedures which is regarded as high-end advancement over conventional surgical methods. In Dentistry, Augmented Reality is increasing its roots by providing applications and AR/VR based equipment's for oral and maxillofacial surgery, dental implant, Orthognathic surgery and even other clinical applications. The objective of this chapter is to summarize basic history, definition, features of Augmented Relaity and highlight various AR technologies contributing towards betterment in dentistry.

Keywords: Augmented Reality, Dentistry, AR Technologies, Image-Guided Surgery, AR Dental Simulators, AR Dental Apps.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (51–284)

5.1 Introduction

Augmented Reality (AR) [1, 2] is a strong variation of Virtual Reality (VR) / Virtual Environment (VE). Augmented Reality and Virtual Reality (VR) industry has touched $1.1 billion investment in 2018 and it is expected to reach $4 billion by 2022 and AR and VR are considered as foundation stepping stones for future computing. Virtual Reality technology completely steps a user inside a virtual synthetic environment, the user can see almost everything in virtual sense like happening in real world. In comparison to VR, Augmented Reality technology takes information generated from computers like images, audio, video or touch inputs and transforms completely into a real-time environment. Augmented reality creates a strong foundation to enhance user experience in five senses, especially Visual Sense. Augmented Reality enables the user to see the real world, via virtual objects combined with the real world. These days, Augmented Reality is producing strong advancements to various fields like Gaming, Advertising, Entertainment, Military, Retail and Marketing, Education, Travel and Tourism, Automobiles, Fashion, Industry/Manufacturing and especially Medical. Augmented Reality Technologies is revolutionizing medical / healthcare and is providing surgeons/ doctors with state of the art AR based Apps, Visual Equipment's for diagnosing patients. Considering the state of the art technologies adapted by medical areas like Eye Surgery, Heart, General Medicine, Dentistry, Brain Surgery etc, AR Technologies see a bright future in this area.

AR Technologies in Dentistry especially in Oral and Maxillofacial Surgery, Dental Implant, Orthodontics, Radiology, Clinical Applications and Education is widely adapted. The focus of this chapter is to focus on wide range of technologies available for Dentistry to assist Dental Practitioners for adaption for betterment of patient's oral health.

5.1.1 Origin of Augmented Reality

Since the origin of mankind, human beings have done a lot in environment altering and improvising. Early works surround regarding modifying and enhancing the surroundings via physical objects addition in form of structures etc. Example, Humans cleared jungles, modified rocks to sit on and make some tree shapes decorations to improvise everything. In the later stages, they added information to the surrounding environment via images in form of paintings on cave walls etc for educational purpose to indicate a location or story telling etc.

With more progress, more tools and techniques were discovered for shaping the environment. But some changes were easy and some too hard to alter. With more progress and integration of technology, new ideas became more popular, and ideas were represented symbolically (*Drawing*) or Symbolically (*Map*). During this stage, the world was surrounded by lots of physical structures. Ideas were proposed in form of paintings, dance, music, sculpture and many more. During this phase, the mapping technology was also improvised.

During industrial age, rapid and significant improvements were seen in construction, deconstruction and physical structures modification. But the rate at which the physical entities were modified was very large i.e. it took months to years to modify something to the physical structure. Changes to physical world remained in physical realm, i.e. any sort of modification in environment was manifested with different physical entities occupying space and weight. So, in order to make a piece of information available to specific physical space, the best way is to create a physical model-based artefact which contains the entire information. Example: If there is a requirement to present the Vehicle Maximum Speed required on the specific road, a physical poll containing a photo of speed limit would be placed for effective user information. In the few years, it was decided to add certain keyword-based sign information which gives more depth information to the drivers driving on the road. The transformation keep on happening for years to add some Physical Street based cameras for identifying the speed limit of the vehicle, add the speed sign with some Computer based LED Screen.

With the advancements in Information technology, the information started representing digitally. With the utilization of computers, tons of information can be stored, retrieved, updated in small period of time and will occupy very little space. With utilization of IT based Technologies, more powerful ways were generated to augment the real-environment. With the power to store and update information with various devices like Smart Phones, Tablets, Laptop computers connected to pervasive network, interconnected devices enabled smart living for humans. With the passage of time, increase in ability of smart phones power, cheap price, small size, simulations were possible and the word ”*Virtual*” evolved. Example: Nowadays, lots of apps are available on smartphones, where you can play the musical instrument as such like physical instrument.

3D Computer graphics generation in real-time enabled users to create virtual scenes with as such replica like real-world physical environment. With the evolution of Virtual Reality Systems, 3D Movies and Advanced Simulations, full rendering can be performed of virtual objects. 3D TV’s and VR Gaming Headsets like KINECT, PS VR, the body actions can be mediated via devices through joysticks, mice and buttons. The GPS Navigation devices have made it possible to have pinpoint location of anything anywhere in the world. With GPS, one can locate anything from simple Coffee Shops, to popular sites nearby by just typing keywords like ”*coffee shops near me*”. Each of these technologies have taken mankind to step further and with digital enhancements, the users are able to interact better with real world. In order for mankind to alter and improvise the world in digital form, without any physical alteration, a plethora of ideas and technology innovations are required for significant change.

5.1.2 History of Augmented Reality

Augmented Reality has its origin way back in 1901 in a novel titled ”*The Master Key*” by L. Frank Baum where he introduced the concept of Augmented Reality but the exact name i.e. AR was not cited. He proposed the concept of Augmented Reality as a gift the central character receives from a demon.

The following Table 5.1 lays a strong foundation highlighting the Origin of Augmented Reality.

5.2 Augmented Reality Technology in Medical Technology

New invention and technology is proposed with prime objective *Life Simplicity*. Augmented reality has wide potential to play a significant role in Healthcare Industry. Technologies like Computer based AXIAL Tomography has provided a significant platform to doctors to have deep insight of the human body. Telehealth facilitates doctors and patients to have live communication even in remote areas. With Heads-up displays, vital information of the patient can be provided to doctors in matter of seconds. Emergency rooms and ICU units are now equipped with AR technology for EMR and imaging.

Table 5.1 The foundation highlighting the Origin of Augmented Reality

Year	Description
1968	Debut made by Augmented Reality. Ivan Sutherland, computer scientist developed the very first VR & AR head mounted display called "HMD" system titled "The Sword of Damocles". It makes use of computer generated graphics to visualize wireframe drawings to the user.
1974	Artificial Laboratory was established by "Myron Krueger" titled "Videoplace". The lab was equipped with state of the art Projectors, Video Camera and other equipment's for strong user interface.
1990	The term "Augmented Reality" was coined and used by Tom Caudell and David Mizell. Both of them configured airplane wiring wear HMD to project entire working of airplane.
1992	Virtual Fixtures was proposed by Lousi Rosenberg- The first real time AR Functioning device for training U.S. Airforce Pilots. Researchers from Columbia University proposed HMD with advanced trackers called "KARMA- Knowledge based AR for Maintenance Assistance".
1994	First fully functional AR theatre was designed by Jullie Marlin called "Dancing in Cyberspace" providing the dancers with facility of Virtual Objects on real-time stage.
1999	NASA X-38 Spacecraft took flight via enhanced visual navigation system for mapping data of maps for providing advanced navigation during flight tests.
2000	ARToolkit- Open Source AR Library hit the market proposed by Hirozaku Kato combining virtual graphics with real time making use of video tracking to overlap graphics on Video camera.
2009	ARToolKit with enhanced features was launched and integrated with Web Browsers.
2013	Google proposed AR based project for real time interaction for users called "Google Glass"- First working prototype of AR wearable technology
2016	AR/VR Market touches $4.4 billion dollars and first ever AR game "Pokemon Go" was launched with whopping revenue of $1.2 billion dollars. Major companies like Facebook, Sony, HTC, Samsung launched products like Samsung Gear, Facebook Oculus.
2017	Eye Tracking technology introduced. Phillips proposed 4K / 8K displays with AR integration. Face Tracking technology by Apple in iPhone X boosted AR technology
2018- Till Date	More than 1000 Apps hit Google, Apple and Windows Store.

Augmented Reality (AR) and Virtual Reality (VR), nowadays are combined with Artificial Intelligence technology which is changing the entire face of healthcare industry. According to Deloitte's 2018 Technology, Media and Telecommunications Predictions Report, near to about 1 Billion smartphone users have created at least a single AR based content in 2018 and 300 million users are doing monthly and number can even increase to tens of millions by end of this year.

Augmented Reality is defined as, Live Direct or Indirect view of a Physical, Real-world environment whose elements are termed as Live Direct or Indirect View of a Physical, Real-world environment whose elements are termed as "*Augmented*" by computer-generated or real world extracted sensory input like sound, video, graphics or data based on GPS".

An AR system can be termed as system with following set of features:

- Combines Real and Virtual Objects in real-time operational environment and performs live interaction with the end users.
- Registers Virtual and Real time objects in reciprocal manner.

In order to design and implement a AR system, the system should be fully integrated with: virtual and real data sources, tracking sensors, image processing, object recognition algorithms, feedback mechanisms with strong backbone support of Machine Learning, Deep Learning and Mixed Learning.

Healthcare Industry is currently regarded as No: 1 industry in AR technology adoption with more and more healthcare applications are developing, evolving and releasing with passage of time. AR Technologies are integrated with wide range of medical applications like Surgery, Anatomy, Dentistry, Education, Simulation, Chronic Diseases detection and General Observation. According to EdTechReview, considering AR roots in healthcare and education, the industry is expected to touch $659.98 million by 2018.

5.3 Existing Technologies in Medical / Healthcare Technology

AR technology provides a strong base to surgeons and other medical practitioners with latest and all relevant information regarding patients. AR can itself be used very easily by patients for self-education and quality treatment. VR [29] plays a significant role for creating 3D simulations used by doctors and medical students for real-time diagnosing of patients on chronic cases.

The most suitable examples for AR in medicine are: NuEyes- An AR based smart hands-free electronic glasses designed for blind people built using ODG R-7 platform facilitating the people with low vision to recognize nearby things and easily perform routine tasks. It can be wirelessly operated or via voice commands.

BrainPower- software technology designed by MIT revolutionized AR based devices like Google Glass/ Samsung Gear into AI system to assist people in brain related issues like Autism. Accuvein- smart AR projector to display all the patient's veins on the skin in real time. Microsoft Hololens- Smart AR device is providing surgeons to easily perform spinal surgeries via Scopis platform.

In addition to the above, AR technology is also applied to other medical fields like Psychological disorder, rehabilitation, Prosthetics, Ultrasounds, Blood transfusion and many more [6]. In the near future, AR with mix blend of Internet of Things (IoT) will facilitate 3D model development for accurate planning of surgeries and will train future doctors anywhere and everywhere.

5.4 Augmenting Dental Care- AR Technologies assisting Dentists for Dental Care

With the explosive growth of elderly population and growth in world economy, the concept of Oral Health has increased at steady pace, and various dental and oral heath care issues are becoming significantly important. The global market for dental equipment's is expected to touch $30 Billion U.S. dollars. In addition to this, WHO (*World Health Organization*) statistics show that almost 60% of the school going children worldwide, 100% adults and 20% of the population ranging from 35-44 years have dental problem. With the increase in number of old-age population, coupled with elderly people, the treatment rate is very low [3-5].

Dental care also shares unique features with other medical specialist units but also has distinct qualities. It is also significant field where AR technologies are applied successfully and nowadays, dental treatment via AR assistance in diagnosing, education and surgeries is shining by leaps and bounds. In this section, AR technologies with respect to Oral and Maxillofacial Surgeries, Dental Implant, Orthognathic Surgeries, Clinical Applications and Dental Education will be elaborated.

5.4.1 Augmented Reality Technologies in Oral and Maxillofacial Surgery

Oral and Maxillofacial Surgery [7, 8] provides a strong base bridge between general medicine and dentistry and is mostly concerned with the diagnosis and treatment of diseases effecting patient's mouth, jaws, face and neck. The surgeon performs diagnosis and management with regard to facial injuries, head and neck cancer, facial pain, impacted teeth, cysts and jaws tumours as well as other issues concerning mouth ulcers and infections.

Figure 5.1 Oral and Maxillofacial Surgery- Before and After Results

5.4.1.1 Main Operations

A range of Oral and Maxillofacial surgical operations are carried out via Anaesthesia or Conscious Sedation. The following are types of operations concerned with Dental Oral and Maxillofacial Surgery:

- Facial Injuries, retraction of complex craniofacial structures and other tissue injuries.
- Orthognathic surgery for correcting facial disorders.
- Pre-implant surgery like retaining facial or dental prostheses.
- Impacted teeth removal.

In order to accurately perform Oral and Maxillofacial surgeries, understanding of complex anatomy of craniofacial structures with high precision is required. AR Technology well fits for this purpose and nowadays, is highly recommended for performing Maxillofacial surgeries. In order to perform surgery, AR technology assists Dental surgeons via AR Navigation and AR Guidance systems. AR navigation systems provides complete information of the patient via virtual scheme is mixed with real scene with 2D HMD (*Head Mounted Display*) worn by surgeon. AR visualization systems, autostereoscopic 3D image overlays are utilized for image and stereo tracking. AR guidance systems provides real-time intraoperative information and projects 3D images on laparoscopic images to mark surgical incisions.

5.4.1.2 AR Visualization Technology

Improvised Anatomical Visualization: Researchers from Shanghai Ninth People's Hospital and State Key Laboratory proposed a system for visualization improvement of complex anatomical area via AR technology. The technology facilitates, scanning of patient skull using 3D CT and all images imported into Mimics CAD/CAM software resulting in generation of 3D model of skull of patient. A Dental cast and occlusal splints is built via acrylic resin.

Figure 5.2 3D Patient Skull Generation

On this technology, AR technology is applied for image orientation for live viewing of surgery and usage of X-Ray gets eliminated.

AR based Guidance systems provides 3D representations of patient's body in more intuitive manner using HMD's or eyepieces.

Microsoft HoloLens[1]: Mixed Reality smart glasses proposed by Microsoft for smart guidance systems and work in efficient manner for Dental Surgeries.

HoloLens is connected to dynamic and well adjusted cushioned inner headband for moving up and down. It is fully equipped with sensors related hardware which includes cameras and processors. It is fully equipped with Accelerometer, Gyroscope and Magnetometer. It is fully equipped with IEEE 802.11ac Wi-Fi and Bluetooth 4.0 for connectivity.

Microsoft HoloLens is gaining worldwide attention by Dental Surgeons with a Project titled "*HoloDentist*" which combined Microsoft HoloLens and Dentistry. With HoloDentist based Mixed Reality, improvised communication can happen between dentist and patient and the device is able to create 3D model of the mouth and provides pinpoint 3D visualization for surgery planning. It also provides service collaboration and remote support to the patients.

VUZIX Blade[2]: Vuzix blade provides smart AR technology in terms of Voice control, Touchpad, Head Motion Sensors, Remote Support and is equipped with Wave-Guide Technology. It provides smart display with see-through viewing experience using Waveguide optics and Cobra II display engine.

With VUZIX Blade smart AR Technology, dentists are able to map 3D model and visualization of the patient for carrying out facial treatments and other teeth surgeries.

[1] https://www.microsoft.com/en-us/hololens
[2] https://www.vuzix.com/

5.4.2 Augmented Reality Technologies in Dental Implant Surgery

Dental Implant surgery is an effective procedure for replacing the tooth roots with metal, screw like posts and replacing the damaged or missing teeth with artificial teeth with replica of original teeth's. Dental Implant surgery is tedious surgery and perfectly depends on the nature of implant and jawbone condition.

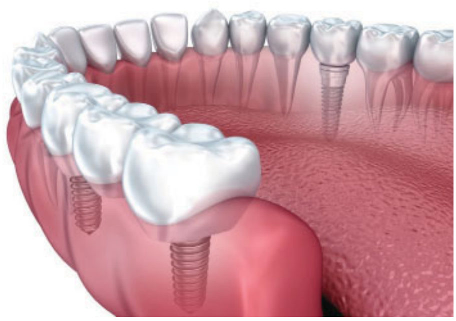

Figure 5.3 Dental Implant Surgery via Screw fitted on Jawbone

5.4.2.1 Types of Dental Implants

There are two types of Dental Implants [9]:

- *Endosteal*: This dental implant treatment is supported via screws, blades or cylinders placed inside jawbone via precision surgery. This type of implant includes addition of 1 or more than 1 prosthetic teeth.

- *Subperiosteal*: Under special patient conditions, those having not proper jawbone height, subperiosteal implant is recommended. Under this surgery, implants are placed on jawbone top via metal framework in middle of gum to hold artificial tooth.

Considering Dental Implant- only five procedures are followed: Single Tooth Replacement; Multiple Teeth Replacement; Full Teeth Replacement; Sinus Augmentation and Ridge Modification.

5.4.2.2 AR Technologies for Dental Implant Surgeries

Implant Positioning System based SDK's: AR technology has supported dental implant surgery way back in the year 1995 via dental implant positioning systems. AR also facilitates teleplanning and precision surgical navigation for dental replacement and placement.

AR ToolKit: an open source library for creating AR applications using video tracking capabilities to determine real camera position and calibrate to square physical markers or natural feature markers in real-time. It was designed and proposed by Hirokazu Kato and was regarded as first AR based SDK system.

Features: AR Toolkit facilities tons of features via HMD displays for tracking real-time dental patient via stereo camera, planer images detection, square marker generation and Optical HMD's for dentists to carry out implant surgeries.

5.4.2.3 AR based Dental Implant Surgical Navigation Systems

AR Surgical Navigation systems were developed fully equipped with retinal imaging display.

- RPHMD: Yamaguchi et al. [11] proposed smart navigation AR system for dental implant by combining Retinal Projection HMD (RPHMD) and AR techniques for overlaying pre-operative simulation to provide real-time view to surgeon. The graphics were represented by OpenGL library. Overall Image accuracy provides best results for the surgery.

- AR-SNS [12]: AR based Surgical Navigation systems (AR-SNS) was proposed by Chen et al. It was designed and developed by using optical see-through HMD to assist dental surgeons in safety and reliability in patient's surgery. The system proposed is highly smart and efficient enough for instrument calibration, registration, HMD calibration and provides prevision 3D virtual model of complex anatomical structures to doctor's HMD. The device has pinpoint accuracy of 0.809 +/- 0.05 mm and 1.038o +/- 0.0.5o in diagnosing patient's health.

- AQ-Navi Surgical Navigation System [13][3]: was designed to improvise dental implant surgeries via precision guidance to dentists of surgery location via electro-optical technology. It is used to perform pre-planning surgical implantation procedure to identify and track the location of drill to be done during surgery. The system provides add on features like accurate positioning, avoiding damages during complex anatomy jaw structures of patients and enhanced assistance. It provides the dental surgeons with 2D and 3D patient images with regard to anatomy, drill position and dental implant. It makes use of IR tracking system composed of emitters, camera, tracking data processor and dental HMD location.

- Image Guided Implant Dentistry System (IGI)[4]: Image Guided Implant Dentistry System [14] is regarded as most advanced AR based system for dental implant surgeries to make use of 3D Imaging and Motion tracking technology in combined manner. It ensures better safety to patient's health via CT Scan and Computerised Surgical Navigation system. It provides 3D model of patient's anatomy structure and even assist dental surgeons for precision drilling during surgeries. The system is fully integrated with TRAX system which is advanced combination of hardware like: *Camera, LED array and also combines DentSim simulator for accurate tracking of the Drilling position*.

5.4.3 Augmented Reality Technologies in Orthognathic Surgery

Orthognathic Surgery / Corrective Jaw Surgery [15] is regarded as combination of orthodontic surgery and general surgery for treating all sorts of jaw and dental abnormalities. It is regarded as jaw corrective surgery whose primary goal is to straighten, realign the jaw as well as correct all sorts of skeletal deformities in patient's oral health. It is regarded as sub-specialist branch of oral and maxillofacial surgery and the surgery revolves with improvising both functions and mouth appearance and sometimes breathing way correction of the patient.

[3]https://www.taiwan-healthcare.org/
[4]https://image-navigation.com/igi/

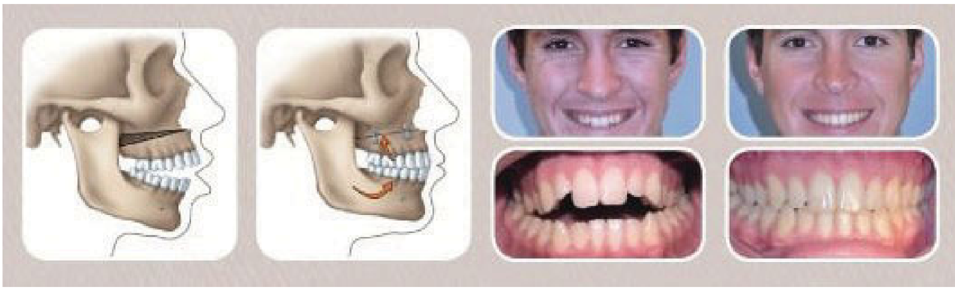

Figure 5.4 Orthognathic Surgery

Various conditions leading to Orthognathic Surgery are: Birth defects, Jaw pains, inefficient mouth gestures while breathing, Trauma, Protruding Jaw and Receding Lower Jaw and chin.

The Treatment of Orthognathic Surgery involves four phases: Planning, Presurgical Orthodontic Phase, Surgery, Post-Surgical Orthodontic treatment.

5.4.3.1 AR Technologies for Orthognathic Surgery

AR applications are most widely utilized till date in performing Dental Orthognathic Surgeries as well as general Orthognathic surgeries. The First AR based Orthognathic surgery was performed in 1997 by Wagner et al. in facial skeleton osteotomy via Head Mounted Display (HMD). The technology aided surgeon with best visual information of the patient during surgery.

5.4.3.2 AR Based Tracking Technologies

ManMos (*Mandibular Motion Tracking System*) [16, 17], a mixed reality-based system for performing precision orthognathic surgery was proposed by Kanagawa Dental University, Kanagawa, Japan. The system makes use of dental cast and a computer-generated 3D maxillofacial model based on CT Scan DICOM data. The system is highly efficient in order to synchronize the dental cast model movements via 3D model of patient.

5.4.3.3 AR based Applications for Orthognathic Surgery

- Zhu et al. [18] conducted a feasibility study using ARToolKit for mandibular angle oblique split osteotomy, using occlusal splint for AR registration. The study was conducted on 15 patients and the virtual images of the mandible as well as cutting edge plane both overlaid the mandible real-model. Under this study, the patients undergone various treatments like tomographic scan and dental casts. Occlusal splint was used by dental surgeon for marker fix and was tracked by ARToolKit.

- Suenaga et al. [19] evaluated AR navigation system for providing markerless registration system using stereo vision in Orthognathic surgery. In this study, stereo camera was utilized for performing all functions like tracking and markerless registration and tomography consisted of 3D model of Jaw of patient. The pilot study resulted in precision detection of teeth incisal edges with error of transmission less than 1 mm. The study concluded that 3D contour matching is best for Teeth information viewing even with complex anatomies.

- Badiali et al. [20] proposed a novel localiser-free HMD for assisting dental surgeons in Orthognathic as well as Maxillofacial surgery. The system proposed is to perform accurate virtual planning overlay of the real-patient and proposed a method to determine the performance of waferless, AR-based Bone Repositioning. The method was tested via Vitro Testing on live human skull of patient and study stated accurate detection of repositioned maxilla. The overall study demonstrated a mean error of 1.70 +/- 0.51 mm.

5.4.4 Augmented Reality Apps in Dental Applications

As compared to various AR based Navigation, Visualization and other HMD based displays, various AR based Mobile Applications are gaining ground and providing strong base for dental surgeons to take patient's treatment to next level. In this section of chapter, various AR based Apps designed especially for assisting dental surgeons are enlisted:

- *Janus Health AR*[5]: Janus Health AR app [21] makes use of machine learning technology to detect the patient's mouth and replaces the patient's mouth with 3D overlay masked besides the lips. Apart from recognizing the mouth, the app is able to detect almost 200 different types of smiles best fit for the patient. It also resizes the height, width, thickness and curvature of the teeth of patient making the patient look like natural way. Overall the complete landscape of the patient's mouth is depicted via this app. The app gives live rendering dental modification of the patient's teeth using front camera of Phone or Tablet. The AR is highly efficient to simulate various teeth shades ranging from OM1 to 3M4 on Vita 3D Master Shade.
- *Kapanu AR Engine*[6]: Kapanu AR engine [22] is currently maintained and formulated by ETH Computer Lab. The App works via 3D matching of the person's mouth and scan all set of patient's teeth. The app can determine the exact teeth positions, shapes, size and even spaces between the teeth and app gives a natural output on the screen itself, what the patient should look like with complete dental surgery transformation. The app is connected to strong information database comprising 3D models of natural teeth postures already implemented in dentistry. The app makes use of Machine Learning approach to display the data and different options. The app gives almost 100% results with the patient's teeth matching with natural smile and best mouth postures.
- *WHITEsmile App*[7]: Another Dental AR based app for improvising cosmetic result of teeth whitening with immediate effect. The app has high end machine learning based algorithms for whitening teeth in real time and even on new or existing photos on phone or tablet with high precision. The app has high end shade simulation with automatic light environment detection on the image.

5.5 Augmented Reality in Dental Education

In addition to Virtual Reality, Augmented Reality is attracting interest with regard to Medical Education especially, Dental Education.

[5] www.getjanus.com/
[6] www.kapanu.com/
[7] www.whitesmile.de/whitesmile-app/

By integrating AR based technology in real-education environment, new opportunities will come to life. Currently, AR is providing deep roots in medical education especially Laparoscopic surgery, Echocardiography and neurosurgery and slowly and steadily Dental Education is also adapting AR technologies.

Figure 5.5 Dental Simulation

In Dental Education, pre-clinical training for dental students is a mix of theoretical teaching and live patient exercise in laboratory which is quite costly, time consuming and not highly efficient. Even with successful completion of pre-clinical training, the student is not able to treat the patient with enough competent skills. New AR based technologies address these problems and in recent years, various computer-oriented simulation tools and systems are designed for assisting and developing pre-clinical dental interns with professional competencies with aid of: Intelligent Tutoring Systems, Dental Simulation, Virtual Reality Technologies, Web 2.0 and even social networking tools. In recent years, Artificial Intelligence is also incorporated in varied technologies to improvise the quality of teaching, live patient treatment and performing precise surgeries. These new technologies provide comprehensive access to learning resources, quality interaction and cost reduction in overall training.

5.6 Augmented Reality based Education Technologies for Dentistry

5.6.1 DentSim

DentSim[8] [23] is regarded as industry leading AR based dental simulator, assisting students for improvising dental treatment skills. DentSim fully integrates with traditional lab

[8]www.dentsimlab.com/

equipment's and enable students to work on mannequins in real-time using computer aided systems providing equivalent hands on real-time patient treatment environment. DentSim is fully equipped with advanced cameras with GPS tracking capability providing students with real-time 3D view of the work along with feedback of the operations performed.

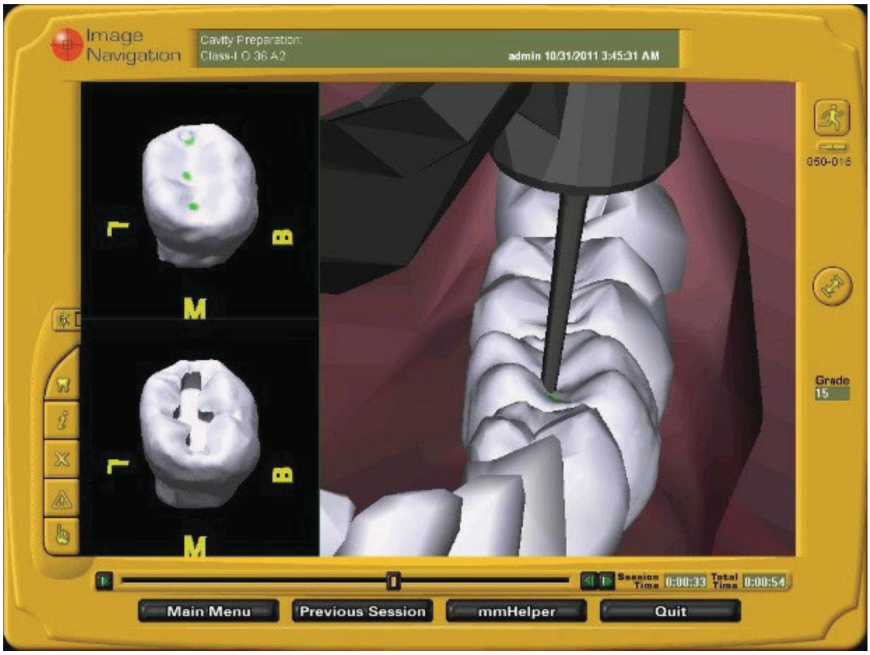

Figure 5.6 DentSim Real Time Root Canal Treatment Simulation

DentSim provides the following unique features to dental students:

- Knowledge acquisition using multimedia assistance with high end audio-visual content and high degree of interaction.
- Enables students to work on personalized programs via digital tutor function.
- 2D knowledge is transferred into 3-D spatial work and 3D images can be analysed for all sorts of errors.
- Efficient quality control and real time feedback to the students and next generation dental education.

5.6.2 The Virtual Dental Patient: System for Virtual Teeth Drilling

AIIA[9] Laboratory Computer Vision and Image Processing Group, Department of Informatics, Aristotle University of Thessaloniki Greece, proposed Virtual Dental Patient: A system for Virtual Teeth Drilling [24] to assist dental students to get fully acquainted with teeth anatomy, teeth drilling equipment's in addition to various real-time challenges in

[9] www.aiia.csd.auth.gr/

handling patient's teeth drilling. In addition to this, Virtual Dental patient is regarded as efficient tool for assisting experienced dental surgeons for planning a real tooth drilling by getting familiar with patient's anatomy, landmarks identification, approach planning and identifying prevision position of actual drilling activity.

The Virtual Dental Patient has following unique features:

- A head/Oral cavity model is designed using 3D points on different head tissues using modelling techniques. A 3D surface model is designed using 1392 points and 2209 triangles using cryosections and CT data of patient using Visible Human Project designed by National Institute of Health, USA. The complete model comprises of entire face, gums, palate, teeth, tongue, cheeks, lips, larynx and uvula. The model is animated via MPEG-compatible facial animation player.
- Virtual Tooth Drilling is performed using 3D structures representing drilling tools and can enable the surgeon to learn almost any type of drilling. Four shapes i.e. Spherical, Cylindrical, Cylindrical-conical and conical are used using 3D mathematical morphology using Phantom haptic device designed by SensAble Technologies. Tooth drilling is performed using varied dental models stored in database constructed via digitalization and post processing of teeth morphology.

5.6.3 Mobile AR Systems for Dental Morphology Learning

Juan et al. [25] proposed Mobile Augmented Reality System for Dental Morphology learning. The system is designed and developed using Unity 3D[10] and Vuforia SDK[11]. Vuforia makes use of computer vision techniques for recognizing and tracking various fiducial elements in real time like: *Image Targets, Frame Markers, Multi-Image Targets, Cylinder Targets, Virtual Buttons or Word Targets*. The app uses mobile camera to track the image and capture the position and camera orientation relative to the center of the image target. After capturing the image, the system transforms the image into Virtual Object. The screen can be used to rotate, zoom in, zoom out the image. The system makes use of AR technology for identifying: Triangular Ridge, Marginal Ridge, Buccal Cusps, Lingual Cusps, Fosse and Grooves and Supplemental grooves. The App was tested using 38 Undergraduate, 6 Master Students and 11 Employees and study reported that understanding the morphology structure was better in the students and results showed a whopping success rare of 4.5/5 in overall evaluation.

5.6.4 Periosim

Haptic-Based 3D Virtual Reality Teaching and Training Simulator[12]. PerioSim [10, 26-28], a VR (*Virtual Reality*) simulator was designed was developed at University of Illinois, Chicago with join collaboration with Colleges of Dentistry and Engineering. The simulator is highly efficient in simulating clinical periodontal procedures like periodontal probing, detecting subgingival calculus using periodontal explorer and other subgingival topographies. It facilitates dental students to learn diagnosing and treating periodontal diseases with aid of 3D virtual human mouth and tactile sensations via touching teeth surface, gingivae and calculus using precise virtual dental instruments.

[10]https://unity3d.com/
[11]https://www.vuforia.com/
[12]www.dentalhygienistsimulator.com/

The Simulator has three types of Virtual Dental Instruments:

- *Periodontal Probe*: It assists the students to measure pocket depth, determine the health of tissue.
- *Scaler*: Enables the students to feel virtual calculus on root surface. It aids in removing plaque and calculus from gum line.
- *Explorer*: Overall observer to see, whether plaque removed completely or not.

5.7 Conclusion

In this Chapter, the complete history, Origin and utilization of Augmented Reality in Medical applications is stated. The chapter states in depth, utilization of Augmented Reality in Dentistry focused towards various branches of dental treatments like Oral and Maxillofacial Surgery, Dental Implant Surgery, Orthognathic Surgery and Dental Education. In addition to this, various AR based simulators available for educating dental students and experienced dental surgeons are also enlightened. AR technology is expanding in other areas of Dental Care like Orthodontics, Endodontics via technological advancements. Augmented reality technology is enhancing its roots day-by-day by assisting dental surgeons and students in different surgeries, Anatomy understanding and even Implants and these days, AR technology is considered far more superior as compared to traditional dental treatment methods. In the near future, with technologies like, Robotics, Mixed Reality, 3D Printing / 4D Printing, Machine Learning, Deep Learning, Haptics and even Internet of Things/Everything, AR applications in dentistry are expected to become even more advanced as it can be observed today and will assist dental surgeons for precision treatment to patients and build professional and skilled dental surgeons.

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CHAPTER 6

REVIEW OF VIRTUAL REALITY EVALUATION METHODS AND PSYCHOPHYSIOLOGICAL MEASUREMENT TOOLS

M.A. Munoz[1], J.G. Tromp[2], Cai Zhushun[3]

[1] University of Granada, Spain
[2] Duy Tan University, Vietnam
[3] State University of New York, USA
Emails: mamuoz@ugr.es, jolanda.tromp@duytan.edu.vn, zcai@oswego.edu

Abstract

This chapter describes how scientific experiments can help to make informed design choices for the Virtual Reality interface design and vice versa, Virtual Reality can help scientific research, such as psychotherapy and physiotherapy to improve medical treatment and understand the functions of the brain better in response to virtual experiences that aim to mimic the real-world experience, but can take place in the laboratory environment. The chapter consists of an overview of the steps in the process of developing a VR setup, showing where and how evaluations take place. It describes the Human-Computer Interaction design and evaluation methods, including psychophysiological measurements and tools, when they can be used, and it discusses some of the factors that can jeopardize the quality of experiments in VR

Keywords: Virtual Reality, Evaluation, Psychology, Neuroscience, Measurement tools.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (69–284)

6.1 Science Can Help Inform Virtual Reality Development

To achieve VR systems that are highly usable and satisfactory, a user-centred approach is employed in an iterative cycle of refinement of the design and evaluation of the new Virtual Reality (VR) setup. A user-centred approach to design means making design choices with respect and support for the needs of the actual end-users. Different design and evaluation methods have been developed, with the end-user experience at the core. These methods are relevant and useful at different stages of the development cycle. For instance, a user task analysis and system task analysis start early on in the development process and will form the basis for the evaluation criteria. The VR setup is created in an iterative cycle of refinement of the design VR setup, via many smaller evaluation efforts, based on empirical measures of the usability of the design. This type of evaluation needs to take place at strategic points throughout the development process. This type of evaluation is most informative if it is done with real representative end-users if at all possible. And if it is possible to observe the user while interacting with the VR setup in a realistic setting of use that will also improve the quality of the observations of the user in action.

The process of VR Development follows the steps below, and keeps repeating in an iterative manner, until the final configuration has been reached and/or time and finances run out, see Figure 6.1. For more detailed descriptions of the framework for VR development, see [15] and for a more detailed description of the VR development process and the appropriate evaluation methods during the VR development cycle, see [44].

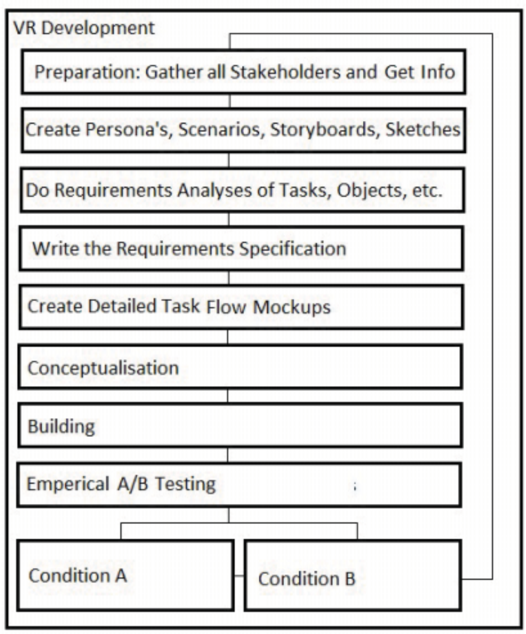

Figure 6.1 The iterative process of VR Development

For VR researchers, psychology is a valuable tool to investigate the cognitive, behavioral and physiological changes during navigation in VR environments (VEs), and analyze the information to inform the (re)design of user experience and user interface, to make their

VEs more compelling and effective. In the last few years, psychophysiological methods have started to be used to research several psychophysiological concepts that have been observed in relation to VR exposure, such as Presence and Immersion.

The use of psychophysiological techniques allows us to directly capture, measure, analyze and store autonomic nervous system (ANS) activity recordings. It provides researchers and developers of VR systems access to the quantifiable and recordable experience of their desired end-user. Psychophysiology used in combination with other evaluation methods, will provide a complex, detailed account of both conscious and subconscious processes, that can be quantified and compared in empirical studies, for example of fundamental topics for VR such as Presence and Immersion [1].

Psychophysiology as a research methodology was defined around 1964, when in the Opening Editorial of Psychophysiology, Ax [2] offered a short description and the guidelines concerning the research of interest to psycho-physiologists. Albert Ax stated: "*Psychophysiology is a research area which extends observation of behavior to those covert proceedings of the organism relevant to a psychic state or process under investigation and which can be measured with minimal disturbance to the natural functions involved. Psychophysiology provides a method for bringing both physiological and psychological aspects of behavior into a single field of discourse by which truly organismic constructs may be created*".

6.1.1 Objectives of Evaluations

An evaluation usually has a goal, a set of acceptance criteria. We are interested in the VR user response to the interface or to the VR experience itself. We examine how participants respond to different VE experiences or interactions with elements of the VE. We measure how well they utilise all its functionality, many errors they make. We check to see whether they are able to comprehend and use all the interface elements. In general and specific terms, we are interested to know how and if the application meets its development goals. We want to know if the application is usable and useful, whether it is a commercial VR setup or an experimental VR setup, it has to work and it has to work well. See Figure 6.2 for a overview of the term "*usability*" in relation to other similar terms and sources for potential interface acceptance criteria.

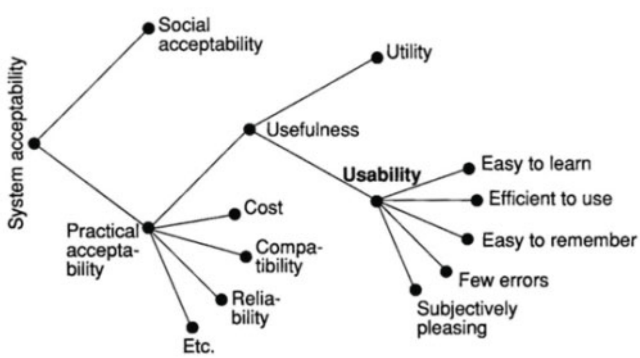

Figure 6.2 Usability and other potential acceptance criteria, Nielsen's Usability Diagram.

The process of evaluation has the following recommended steps, see Figure 6.3. Specific care must be taken to protect the participants in VR experiments from harm, such as simulator sickness, epileptic fits, and other effects of exposure to this new technology, and it is recommended to adhere strictly to the guidelines for ethical research for VR, for instance see [26].

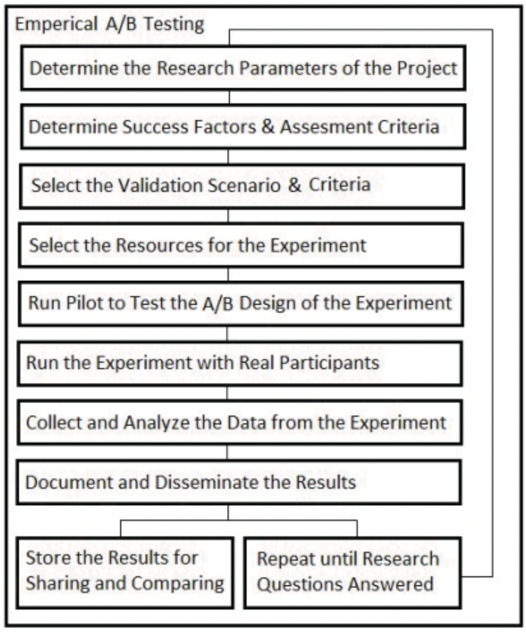

Figure 6.3 The process of empirical evaluation

For empirical testing, one of the requirements is to assign participants to different conditions in a random fashion, so that we can rule out that any differences observed between and within the groups in the different conditions, are caused by preferential assignment of individuals to the different conditions of the experiment. There may also be more than two conditions (*A/B*), necessary to address certain research questions, so that we may have three (*A/B/C*), or four (*A/B/C/D*) groups i.e. experimental conditions, and some research designs could call for even more. More information on Human-Computer Interaction design and evaluation methods can be found in [19, 30] and specifically for VR [15, 40, 43, 44]. The main evaluation goals for VE interface testing and measuring human response are:

- *Navigation*: Does the user know how to get around the VE and the approach and orient to objects in the VE with ease and efficiency?

- *Recognition*: Does the user recognize the objects, the other users (*if available*) and the task interactions in the VE with ease?

- *Interaction*: Does the user recognize and understand how to interact efficiently and satisfactory with the interactive objects and other interactive elements in the VE?

- *Side Effect and After Effect*: Does the user experience any side effects or after effects of the VE experience or the VE interface (*hardware and software*); these could be desirable (*such as after training in the VE*) or undesirable (*such as nausea caused by the VE experience, leading to simulation sickness*)?

There are a number of known factors which may influence the success of evaluations [14]. Problems during the evaluation that can confound the outcome of the evaluation are:

- *Major bugs and gaps in task-flow*: There may be a lack of fidelity which makes functionality difficult to recognize for the user, or problems with the validity of the VE itself, cause a break-down of the task-flow for the user.

- *Interface to the application*: The interface to the VE may give problems to the user, so that they are unable to get on with their actual task, the task inside the VE, or vice versa, the task in the VE may be so complicated that no matter how well the UI is designed the user will struggle.

- *Application not ready to test with end-users*: The actual users may not be able to help test prototypes because it may be hard for them to understand which functionality is still being developed and which is ready, which may or may not match the expectations of the anticipated user population, or the user used for the tests are different from the real end-users of the application. This can be particularly problematic if there are major differences in the areas of aptitude and motivation.

- *Simulation sickness*: Movement or interaction with(in) the VE causes users to feel nausea and simulation sickness due to rapid movements outside of the users control or due to the task asking for rapid head movements from the user.

To ensure that the VR systems has good usability, each task-action and sub-action that is part of the total VR experience has to be designed and tested carefully with reference to the intended users and their skills, knowledge and task-requirements. This can be facilitated by developing task (*and sub-task*) analyses (TAs), that are recommended to be made at each iterative stage of the development process and task that is being designed.

6.1.2 Test Often and Test Early

Different evaluation methods are appropriate at different points of the development cycle, because some methods can be used before the application is ready enough to test with real end-users. See table 1 for an overview of the methods and their associated parameters for selection. In all design elicitation and evaluation methods it is advisable to use real representative end-users, where possible. Sometimes a method can be adapted or tailored to a specific development phase or used in multiple phases, it all depends on the available resources. Some methods are more suitable to phases than others, for instance, some can be used to perform early evaluation of the task flow and the actions and sub-actions, until all steps of the task have been documented and assessed. This type of early evaluation method uses a task analysis as input and does not require end-users, and it applies a Cognitive Walkthrough (CW) and / or a Heuristic Evaluation (HE) to the steps of the task. The CW and HE methods are further described in [19, 30]. Some methods can be used multiple times during the different phases of the development process. Once a stable design has been developed, empirical experiments can be done. As long as the application is not stable when it is being used for a test with real end-users, you risk preparing everything for a certain time, only to find out that the application has crashed beyond a quick repair.

Table 6.1 Overview of Design and Evaluation methods and recommended time and setting for using them

	METHODS	EARLY DEV	PROTO TYPE	STABLE APP	Time & Effort Needed	End-Users Needed
1	Interview	✓			Low	✓
2	Diary keeping	✓			Medium	✓
3	Survey	✓			High	✓
4	Attitude & Opinion Questionnaire	✓	✓	✓	High	✓
5	Sketches	✓			Low	
6	Focus Group	✓	✓		Low	✓
7	Persona Descriptions	✓			Low	
8	Storyboarding	✓			Medium	
9	Ethnographic Observation	✓	✓	✓	High	✓
10	Scenario Descriptions	✓	✓		Medium	
11	Hierarchical Task Analyses	✓	✓		Medium	
12	Functionality Matrix	✓	✓	✓	High	
13	Paper Prototyping	✓	✓		Medium	✓
14	Scenario Building		✓		Medium	
15	Task Allocation	✓			High	
16	Use Case Descriptions	✓	✓		High	
17	Cognitive Walkthrough	✓	✓	✓	High	
19	Heuristic Evaluation		✓	✓	Medium	
20	Controlled Testing			✓	High	✓
21	Side Effects & After Effects	✓	✓	✓	Low	✓
22	Transfer Effects to Real World		✓	✓	High	✓
23	Physiological Effects		✓	✓	Low	✓
24	Psychological Effects			✓	Medium	✓
25	Health & Safety tests		✓	✓	Low	✓

The most typical Human-Computer Interaction design and evaluation tools are briefly described below. The numbers correspond to Table 6.1 and the overview of the design and evaluations met, there are many descriptions of these methods online, so where possible we have provided a link to a longer explanation. hods.

1. An interview is *a conversation with a purpose*. This process is for researchers to collect user data, including their needs, wants, expectation, etc. There are three types of interview: structured, semi-structured, and unstructured; with different types of questions: closed-end questions, yes or no question, and open-end question. Each of them is good for either comparing individuals or getting more insights, depends on the need of researchers[1 2].

[1] http://designresearchtechniques.com/casestudies/semi-structured-interviews/
[2] https://www.nngroup.com/articles/interviewing-users/

2. Diary keeping is a method for researchers to collect temporal or longitudinal qualitative data from the end user in a natural context of the interaction. The data includes but not limited to thoughts and experience of using systems[3].

3. A survey is a commonly used tool for researchers to reach a wide range of users. Researchers can include closed-end questions and open-end questions in the survey to collect quantitative and qualitative data[4][5].

4. Attitude & Opinion Questionnaire is designed for researchers to find out user's attitude and opinions toward certain ideas throughout the research process. The questionnaire is usually built using Likert Scales, which contain multiple opinion statements that can be used to measure attitudes and opinions when combined together[6].

5. Sketching is a method that researchers use in the early design stages. Researchers use simple tools such as pencil and paper to produce design sketches. The key is to strike for quantity, not quality. Using this method, multiple design idea can be generated within a short time, then share and discuss with other researchers and users[7].

6. Focus Group is a method that requires 6-9 users having a discussion about their concerns about the design. Focus group helps researchers to get an autonomous reaction of users and some group dynamic[8].

7. Persona is a fictitious user that has the characteristics and needs of the specific user group (data from user research). Researchers can use persona to create user empathy among the research team[9][10].

8. Storyboarding is a design tool that is made of sequential art which portrays the story of a user using the design. It is a helpful tool for a researcher to gain user empathy by walking in their shoes[11].

9. Ethnographic Observation is a method to observe users in their life rather than in a lab. This observation method can help researcher gain insights of users using the system in a natural environment[12].

10. Scenario Descriptions is a description of a user using a system. It helps researchers to have a good understanding of users requirement[13].

11. Hierarchical Task Analysis is a method to analyse users task-step and all the subtasks necessary to complete a certain task. It can be used to analyse the interaction between a user and a system in a objective way[14].

[3] http://uxpamagazine.org/dear-diary-using-diaries-to-study-user-experience/
[4] http://uxpamagazine.org/writing-usable-survey-questions/
[5] https://www.nngroup.com/articles/qualitative-surveys/
[6] https://legacy.voteview.com/pdf/Likert_1932.pdf
[7] http://uxpamagazine.org/design_like_da_vinci/
[8] https://www.nngroup.com/articles/focus-groups/
[9] https://www.nngroup.com/courses/personas/
[10] http://uxpamagazine.org/current-customers/
[11] https://uxplanet.org/storyboarding-in-ux-design-b9d2e18e5fab
[12] https://www.experienceux.co.uk/faqs/what-is-ethnography-research/
[13] http://infodesign.com.au/usabilityresources/scenarios/
[14] https://www.uxmatters.com/mt/archives/2010/02/hierarchical-task-analysis.php

12. Functionality Matrix is way to show a collection of main function in the system in a prioritized manner[15].

13. Paper prototype is a sketch on a paper that mimics digit representation. it is the fastest and cheapest prototype a researcher can build. Not only an interaction tool, paper prototype can also used as a tangible document that can includes notes for future design[16].

14. Scenario Building is a method that researchers used to think about possible future in a systematic and creative manner[17].

15. Task allocation needs to be done to create a system with good balance of user task and system task. Methods for tasks allocations are context analysis, task analysis, mandatory allocation, provisional allocation, and evaluation[18].

16. Use Case Description is a written description of how a user finish certain task in a system, begins with the user goal, and end with user's goal is fulfill. Some use case will be chosen by the project team as requirement of the system[19].

17. Cognitive Walkthrough is a task-specific method for a researcher to test whether a new user can complete a task in a giving system. It is very cost-efficiency compared to other usability test[20].

18. Heuristic Evaluation requires few expert evaluators to assess a system using accepted evaluation principles. This method can help researchers diagnose system errors before release[21].

19. Controlled Testing is a widely used method by researchers in different fields. Researchers test the variables by controlling other confounding variables in an experiment[22].

20. The main Side Effects & After Effects of virtual reality is cybersickness. Its symptoms include but not limited to nausea, headaches, dizziness, fatigue, sweating and eye strain. For measuring cybersickness, researchers can use physical measurement such as heart rate, blink rate and electroencephalography, or subjective measurement using Simulator Sickness Questionnaire[23].

21. Transfer Effects to Real World: VR training is one of the main focus in VR development community. Thus it is essential to understand how skills learned in VR are transferred to the real world environment[24].

[15] http://www.scottburkett.com/process-improvement/jad-creating-a-functionality-matrix-107.html
[16] https://www.uxpin.com/studio/blog/paper-prototyping-the-practical-beginners-guide/
[17] http://www.pugetsoundnearshore.org/program_documents/ps_future_appenda-i.pdf
[18] http://www.usabilitynet.org/tools/taskallocation.htm
[19] https://www.usability.gov/how-to-and-tools/methods/use-cases.html
[20] https://www.interaction-design.org/literature/article/how-to-conduct-a-cognitive-walkthrough
[21] https://www.interaction-design.org/literature/topics/heuristic-evaluation
[22] https://www.khanacademy.org/science/high-school-biology/hs-biology-foundations/hs-biology-and-the-scientific-method/a/experiments-and-observations
[23] https://dl.acm.org/citation.cfm?id=2677780
[24] https://www.researchgate.net/publication/12516600_Training_in_virtual_environments_Transfer_to_real_world_tasks_and_equivalence_to_real_task_training

22. The Physiological Effects: Some specific tasks such as performing a surgery and welding tasks needs complex and precise muscle moments. Thus it is important to measure physiological effects of VR training. Researchers can use electromyography (EMG) as a measurement tool to get feedback from user's muscles during VR trainings[25].

23. Psychological Effects: Multiple researches have shown that psychological Therapies combined with VR technology is effective on reducing stress and treating psychological disorders. Researchers can use different measurement that already exists in the field of psychology to measure the psychological effect of VR[26][27].

24. Health & Safety tests: Researchers has found VR technology can improve engagement of safety training and improve memorability of its content[28].

25. Usability Questionnaires: the after scenario questionnaire (ASQ), Post-Study System Usability Questionnaire (PSSUQ) and System Usability Scale (SUS) are some of the standardized and ready to use questionnaires, that provide a quick *benchmark* tool, for comparing usability scores of different designs (A/B testing).

    - ASQ: after scenario questionnaire is a 7-point-scale questionnaire to measure user's usability satisfaction towards a system. users can fill out the questionnaire after they finish a task in a scenario[29].
    - PSSUQ: the Post-Study System Usability Questionnaire is an questionnaire to measure usability of a system in a scenario based study. It contains sixteen 7-point scale questions and should be taken by users after they finish all the tasks in a study[30].
    - SUS: The System Usability Scale is a 5-point scale questionnaire for quantifying usability of a system. This is a light-weight questionnaire with only 10 general questions, therefore it can test a wide-variety of systems[31].

6.1.3 Testing Options in the Early Pre-Prototype Phase

During the early stages of development of the VR setup, in many cases there will not be a ready-to-use VE, to use for running tests. At this early point in the development process it can be very helpful for the future activities of the design and the team, if simulations are used to discuss and design the key features and interaction points. Once the design is sufficiently clarified (in terms of what the system should do and what the user should do and what the dialog is between them), a prototype (even if it is a series of sketches) can be made that can be used with representative end-users. A user under guidance from the experimenter, tries each step of the task-analysis and the experimenter makes notes about

[25] https://www.lincolnelectric.com/en-gb/equipment/training-equipment/Documents/Physiological_and_Cognitive_Effects_of_Virtual_Reality_Integrated_Training_13July2011.pdf
[26] https://www.researchgate.net/publication/226028654_Virtual_Reality_Exposure_Therapy_for_Anxiety_Disorders_The_State_of_the_Art
[27] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0187777
[28] https://ieeexplore.ieee.org/document/7817889/
[29] http://ehealth.uvic.ca/resources/tools/UsabilityBenchmarking/05a-2011.02.15-ASQ_and_PSSUQ_Questionnaires-no_supplements-v3.0.pdf
[30] https://www.trymyui.com/blog/2017/02/24/sus-pssuq-website-usability-surveys/
[31] https://www.trymyui.com/blog/2017/02/24/sus-pssuq-website-usability-surveys/

breakdowns in task flow that can be observed when the end-user tries to interact with the prototype.

6.2 Virtual Reality Can Help Inform Psychology and Science

Virtual reality (VR) is currently being applied in many health care services and appears poised to enter mainstream use-case scenarios for delivery of psychotherapy. Since the early 1990s, when Hodges and colleagues (1995; 1993) reported on a project that used virtual environments to provide acrophobic patients with fear-producing experiences of heights in a safe situation, VR has been proposed as a new medium for psychological therapy. The use of VR has been studied in others therapeutic conditions, including anxiety, obesity, chronic pain, eating disorders and addictions [9, 18, 29, 32, 39].

VR technology, with its unique ability to simulate complex, real situations and contexts, offers to psychologies and clinicians unprecedented opportunities of treatment and investigation with an exacting degree of control over relevant variables. The use of VR in psychology research offers several advantages:

- Controlled virtual environments allows naturalistic behaviors while physiological activity is monitored. This allows researchers to study physiological responses (*peripheral and central*) to situations which would simply not be possible to study out of laboratory '*in the wild*'.

- VR environments allow researchers to manipulate widespread number of environment variables, easily, economically and with high realistic level. The multimodal stimulus inputs provide realistic stimulation at once, involving affective, cognitive, and behavior systems more fully than the simple stimuli as imagen, sounds or tasks, increasing the potential to elicit psychological and behavioral responses.

- VR also offers maximal control over stimuli. Virtual environments can present combinations of stimuli that are not found in the natural world and researchers can execute changes in the environment that would not be possible physically. For instance, in order to treat phantom pain, VR is used to create a visual illusion of amputated limb whereby the limb appears to be wholly intact and without pain in virtual environment [13].

- VR technology offers the potential to develop human performance testing environments that could supplement traditional neuropsychological procedures and could conceivably improve accepted standards for psychometric reliability and validity of the measurements. Neuropsychological assessment of persons with acquired brain injury and/or neurological disorders serves a number of functions, including assisting in determining a diagnosis; provision of normative information on the status of cognitive and functional abilities; assisting in producing guidelines for the design of rehabilitative strategies; and creating data for the scientific understanding of brain functioning through the examination of measurable sequelae due to different types of brain damage or dysfunction [6, 45].

- VR provides opportunities to enlarge the actual limits of neuropsychological rehabilitation providing valuable scenarios with common elements for the patients, training them in rehabilitation of daily life activities and mental processes such as attention, memory, language skills, visual and auditory processing, spatial skills, executive functioning, logical reasoning and problem-solving [17, 31].

- The peripheral devices used to create interactive simulations, can be used as rehabilitation instruments in the treatment of several diseases, such as ischemic stroke, cerebral palsy or Parkinson's disease [5, 34]. Several studies have shown that when biofeedback is delivered through a display, sound, or haptic signal, it can serve as a correctional mechanism for the patient and as a monitoring mechanism for the therapist. VR displays can integrate biofeedback notifications into simulations just as games might use status bars, numerical displays, and written or spoken notifications. Thus, VR sensors data can be used as a mechanism to improve dynamic balance, functional mobility and strength for patients [1].

6.3 Types of Psychophysiological Measures and Tools

There are many types of measurements and tools for measuring psychophysiological signals. What follows is a description of some of these psychophysiological measures, measurements and measurement tools, including reference to how they have been used previously in other research and development settings.

6.3.1 Electrodermal Activity

Skin conductance response (SCR), or electrodermal response, is a physiological index of activity of the sweat glands. Skin conductance is quantified by applying a weak electrical potential between two points of skin and measuring the resulting current flow between them. Skin conductance measurements comprise background tonic (*skin conductance level*: SCL) and rapid phasic component (*Skin Conductance Responses*: SCRs) that result from sympathetic neuronal activity consequence of stimuli [3].

The recording of SCR has to be realize with silver-silver chloride electrodes to minimize polarization which can affect the subject's conductance. The electrodes are placed where the concentration of eccrine sweat glands is the highest-the palmar surface of the hands or fingers or the soles of the feet. The electrode jelly is the conductive medium between the electrodes and the skin. Commercial electrode jellies can be used for SC recording, but only if they have neutral pH [41].

SCR can be used as an objective index of emotional states, being used to examine implicit emotional responses that may occur without conscious awareness. Others researches have shown that SCR is also a useful indicator of attentional processing perse, where salient stimuli and resource demanding tasks evoke increased Electrodermal Activity (EDA) responses. In relation to VR, SCR have been found to correlate significantly with reported presence and realism [2].

6.3.2 Cardiovascular activity

The most popular measures of cardiovascular activity include Heart Rate (HR), interbeat interval (IBI), heart rate variability (HRV) and blood pressure (BP). The three first measurements are generated from electrical activity of the heart (electrocardiography: EKG) when electric impulse spreads across the muscle of the heart. Last one, is a mechanical response consequence of force originating in the pumping action of the heart, exerted by the blood against the walls of the blood vessels.

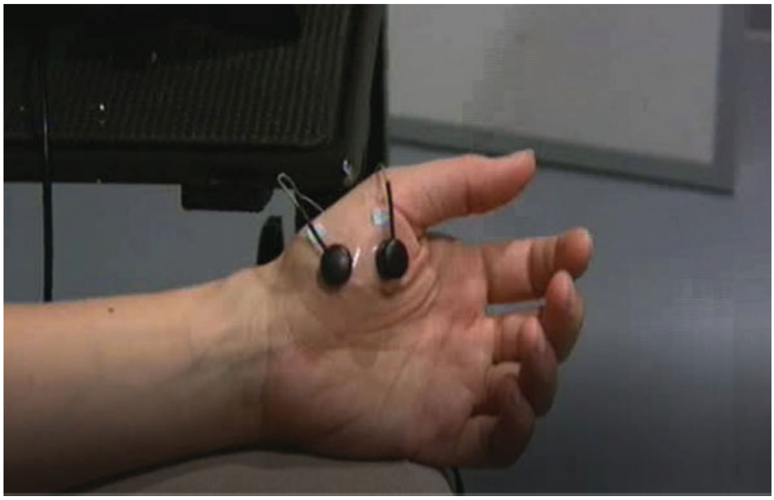

Figure 6.4 Electrode Placement to recording Galvanic Skin Response

The EKG recording has to be realize with silver-silver chloride electrodes together conductive jelly to facilitate the contact with skin. Although there is a standardized system for electrode placement on the limbs and chest utilized for medical diagnosis, all that is required for an EKG of quality is that two electrodes be placed on the skin fairly far apart. Psychophysical recording uses standard limb leads, designated as follows [41]:

1. One electrode on each arm;
2. Right arm and left leg;
3. Left arm and left leg.

Changes in HR have been related with emotional activity. It has been used to differentiate between positive and negative emotional states, such as relaxing, stress, afraid or angry. Dillon et al. [11] investigated the effects of content of a video clip (*amusement, sadness, neutral*) over HR. The results showed that HR was a greater lowering of HR for Amusement and Sadness material than for Neutral material. Likewise, virtual environments containing stressful versus non-stressful situations have showed that HR is significantly higher in the stressful environments [28]. Furthermore, HR has found to correlate significantly with sense of presence and reported behavioural presence as measured by a questionnaire [10, 16]. In general, it can be assumed that as the sense of presence in a VR increases, the physiological responses to the environment will become increasingly similar to those exhibited in a similar real environment [22]. Thus, mora cardiac reactivity is associated with high sensation of be there.

6.3.3 Muscular Activity: Facial Expressions

Electromyography (EMG) measures muscle activity by detecting surface voltages that occur when a muscle is contracted [41]. When used on the face, EMG has been used to distinguish between positive and negative emotions. EMG activity over the eyebrow (*cor-*

rugator muscle) region is lower and EMG activity over the cheek (*zygomatic muscle*) is higher when a stimulus is evaluating as positive, as opposed to negative [4].

In order to register EMG activity, it uses surface electrodes with low impedance and non-polarizing. Thus, commercial electrodes are either a combination of silver and silver chloride or carefully chloride silver. There are several commercial electrode jellies which can be used for EMG recording. The dimension of electrodes depends of muscle dimension. Small electrodes (about 4 mm) are recommend to facial recording, while higher to arm or legs recording (8 mm). The electrodes of a pair will record the difference in electrical potential between them originating in nearby, and to a lesser degree, distant muscle tissue. The two principal considerations to placement of the pair electrodes are [44], see Figure 6.5.

1. Both electrodes should be only the same muscle or muscle group, and
2. The pair should, where possible, be on a line parallel with the muscle fibers.

The muscle activity is an index of the physical embodiment of various mental states, such as emotions, stress, or fatigue. Facial EMG provides an index of internal emotional state when participants are in emotional environments [16, 27]. Moreover, clear evidence has recently emerged that facial EMG activity change in social situations or when the subject is interacting with a virtual character [36]. The Also, EMG technique has been applied in research on ergonomics and prosthetics. For example, EMG measurements have been used to study the effect of posture on performance in work at a computer [33]. Wearable EMG clothes can register the activity of leg muscles during standing and walking [42], and EMG can also be used as a control signal for prosthetic limbs or rehabilitation [29].

Figure 6.5 Electrode Placement to recording facial expressions with EMG

6.3.4 Electrical brain activity: Electroencephalography

Electroencephalography (EEG), provides electric brain activity in an affordable and non-invasive way. In addition, EEG is relatively easy to set up, suitable for recording outside a laboratory setting and cheaper compared with metabolic techniques, such as functional magnetic resonance imaging (fMRI) or Magnetoencephalography (MEG). Two types of measurements can be realized:

(1) Spontaneous EEG, changes in synchronization of neural activation;

(2) Event-Related Potentials, signatures of brain activity that are time-locked to a specific stimulus event, as the occurrence of incident in the virtual environment [41].

Today almost all EEG procedures use a variety of EEG helmets with up to 64 electrodes built into the helmet, referred to the International 10-20 system (Jasper, 1958). The name 10-20 refers to the fact that electrodes in this system are placed at sites 10% and 20% from four anatomical landmarks: the nasion (the bridge of the nose) to the inion (the bump at the back of the head just above the neck) and the left to right on pre-auricular points (depressions in front of the ears above the cheekbone) [41].

The EEG signal can be useful evaluating subject cognitive load and processing capacity in ecologically valid settings, such as flight simulators [25], during simulated driving [23, 46], and in safety-critical monitoring [24]. In last few decades, EEG activity has been used as an input for controlling a computer or other peripheral systems. Brain computer interface (BCI) system extract specific features of brain activity and translate them into commands that operate a device. Thus, a BCI system derives and utilizes control signals that allow to subjects make a selection or engage with virtual environment, computer cursor or a robotic wheelchair [7, 8].

6.4 Outcome of the Evaluation

The outcome of the evaluation will be a set of data, collected with the aim of answering a more of less explicitly stated hypothesis. The data is collected and analysed and a detailed report of documents the results. This report describes how well participants responded to the different elements of the VE experience, whether they were able to use all the UX/UI functionalities, and/or the goals of the experiment were reached.

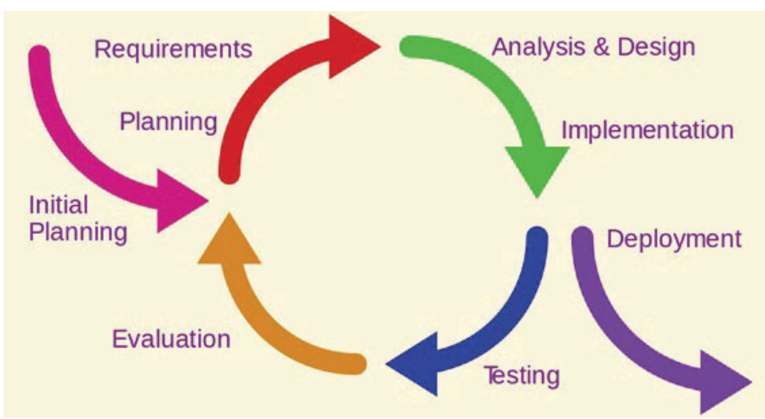

Figure 6.6 The development cycle, using Rapid prototype <> test cycles by the Interaction Design Foundation

The experimental data and other information is then stored for future reference, dissemination to the scientific forum, added to the requirements specifications to inform the design of the VE, and/or used to develop or refine, experimental empirical explorations of user responses to VR experiences of interest to researchers. The process of developing a VR setup is iterative and follows a cycle of continuous refinement and evaluations repeat until a final version has been reached or a final understanding of the human response to the VR experience has been reached. The final version is then ready for deployment. See Figure 6.6 for an illustration from the Interaction Design Foundation[32], showing the larger framework within which the development cycle takes place.

6.5 Conclusions

Apart from being objective and quantifiable, psychophysiological measurement data tends to be continuous, allowing for the assessment of characteristics that vary over time - such as varying degrees of presence or levels of immersion. It can provide a rich source of quantitative and qualitative data, benefiting from the opportunity and using a mixed design for the tests.

A challenge for the psychophysiological data measures and analysis process can be caused by the fact that it can be difficult to determine exactly what the detailed causal effects are, i.e. what is being measured. This is further complicated by the fact that we have not fully mapped out how our brains respond to VR and multiple factor will affect our experiences of it. For instance, difficulties with finding the interface controls and being able to control their orientation in the Virtual or Augmented Reality world may occur and the user may not be able to overcome them. This successful onboarding effect may confound the measurement of the effects of the experimental conditions. It is generally recommended to allow a new VR/AR user or new use VR/AR use scenario, or experiment, to start with some interaction training to create opportunity for them to develop a sense of self-identification with the virtual embodiment, avatar, or point-of-view and visual information from the VR/AR headset." Another problem with data collection can be caused by the novelty factor of the new technology, positively or negatively influencing people's opinions. Finally, the psychophysiological measurement tools my make it difficult or impossible to recreate a natural setting of use for the experiment, thus influencing the data that is being collected. For this and obvious reasons, this means that rigorous empirical designs of the experiments with statistical analyses of the data are essential.

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Part II

ARTIFICIAL INTELLIGENCE TECHNOLOGIES AND APPLICATIONS FOR HEALTH AND MEDICINE

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (87–284)

CHAPTER 7

STATE OF THE ART: ARTIFICIAL INTELLIGENT TECHNOLOGIES FOR MOBILE HEALTH OF STROKE MONITORING AND REHABILITATION ROBOTICS CONTROL

B.M. Elbagoury[1], M.B.H.B. Shalhoub[2], M.I. Roushdy[1], Thomas Schrader[3]

[1] Faculty of Computer and Information Sciences, Ain Shams University, Cairo, Egypt
[2] Consultant of Information Technology at Ministry of Interior, Riyad, KS
[3] University of Applied Sciences Brandenburg, D- 14770 Brandenburg, Germany
Emails: schrader@fh-brandenburg.de, miroushdy@hotmail.com, bassantai@yahoo.com, shalhoub@live.com

Abstract Medical expert system development is used in the early detection of diseases .And this project is a quantum civilized tremendous in the field of medicine being depends very heavily at the application of technology advanced computer-based expert systems and artificial intelligence systems and Systems retrieve data and images, as well as mobile computing as it contributes to this service programming smart in the early detection of stroke disease accurately and scientifically advanced from which the advancement aspect of health of Saudi society to lift the suffering of the thousands of patients who suffer, stroke diseases which contributes positively to the payment of health development and the development and robot rehabilitation of all members of society until they are enjoying good health and contribute effectively to the support and development of society in general.

The implementation of such a project would help in paying medical systems developed Arabia to compete at the regional level and the world to keep up and keep pace with the latest mechanisms therapy world and makes Saudi Arabia a model in the Arab region and the Middle East . Below, we show for the most important applications outstanding which provided by this pilot project. Building an expert system in the field of intelligent stroke diagnosis to help doctors and patients all over the Kingdom. Expert systems in the field of medical diagnostics remotely (*Telemedicine*) in order to take the doctors advice global level Medical highly accurate. Building an intelligent system to track the status of the patient in dangerous situations by mobile telephone technology and wireless communication systems in order to maintain the level of health in the Kingdom and also take advantage

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (89–284)

of the innovation research journal in the field Medical Informatics. Building a real-time mobile computing for the state of emergency by using technology Medical Sensors like EMG sensors. Develop a new innovative Rehabilitation Robotics system for PostStroke treatment of patients.

Keywords: Mobile Health, Telemedicine Robot Rehabilitation, Case-based Reasoning

7.1 Introduction

Stroke and cardio vascular diseases have a high incidence in countries such as: Kingdom of Saudi Arabia, Egypt and Germany, Romania, China and USA. Beside the early detection of high-risk persons, their monitoring and the detection critical, deathtrap events, their effective emergency management the rehabilitation process is difficult and cost intensive.

Stroke is an urgent case that may cause problems like weakness, numbness, vision problems, confusion, trouble walking or talking, dizziness and slurred speech. It may also cause sudden death. It is a leading cause of death in the United States. For these reasons, brain stroke is considered an emergency case as same as heart attack and needs to be treated immediately before causing more problems.

Although stroke is a disease of the brain, it can affect the entire body. A common disability that results from stroke is complete paralysis on one side of the body, called hemiplegic. A related disability that is not as debilitating as paralysis is one-sided weakness or hemi paresis. Many stroke patients experience pain in legs and hands. Therefore, patients' case emergency for pre-stroke detection as well as post-stroke rehabilitation treatment is very important for long time recovery and overall patient health management. Therefore, in this project we three main targets, first is patient emergency and stroke early detection through mobile health technology and then second phase we aim to address patient post-stroke rehabilitation through our new innovative design of rehabilitation robotics controller.

In first phase, we want to implement and develop a complete product through research and development of Mobile health system, Mobile Health in remote medical systems has opened up new opportunities in healthcare systems. Mobile Health is a steadily growing field in telemedicine and it combines recent developments in artificial intelligence and cloud computing with telemedicine applications. For these reasons, brain stroke is considered an emergency case as same as heart attack and needs to be treated immediately before causing more problems. In the recent research, what we witness is a high competition and new revolution towards mobile health in general, especially in field of chronic illnesses and emergency cases like heart attack and diabetics. However, today's Mobile Health research is still missing an intelligent remote diagnosis engine for patient emergency cases such as Brain Stroke. Moreover, Remote patient monitoring and emergency cases need intelligent algorithms to alert with better diagnostic decisions and fast response to patient care. This research work proposes a Hybrid Intelligent remote diagnosis technique for Mobile Health Application for Brain Stroke diagnosis.

Mobile Health in remote medical systems has opened up new opportunities in healthcare systems. It combines recent developments in artificial intelligence and cloud computing with telemedicine applications. This technology help patients manage their treatments when attention from health workers is costly, unavailable, or difficult to obtain regularly.

In fact remote monitoring - which is seen as the technology with the highest financial and social return on investment, given current healthcare challenges - is a focus for many of the pilot projects.

Mobile Health for patient tracking supports the coordination and quality of care for the benefits of rural communities including the urban poor, women, the elderly, and the disabled. This would promote public health and prevent disease at the aggregate level.

Some stroke disorders affect the nerves (*e.g. Stroke*) and cause problems with thinking, awareness, attention and lead to emotional problems. Stroke patients may have difficulty controlling their emotions or may express inappropriate emotions. So that brain stroke is considered an emergency case that needs to be treated immediately before causing more problems.

In the first phase of the proposed research proposal aims to develop a new intelligent mobile health applications based on new artificial intelligent technologies in the field of brain stroke by proposing an intelligent mobile health application based on EMG sensor which provides a significant source of information for identification of neuromuscular disorders.

In final (second) phase of the research, we want to develop a new innovative robotics controller for patient's rehabilitation. The rehabilitation points towards the intense and repetitive movement assisted therapy that has shown significant beneficial impact on a large segment of the patients. The availability of such training techniques, however, are limited by:

- The amount of costly therapist's time they involve,
- The ability of the therapist to provide controlled,
- Quantifiable and repeatable assistance.

These limitations are quite important in Saudi Arabia. Rehabilitation robotics systems are a very important problem, especially in the therapeutic domain of stroke patients. This is due to:

- The complexities of patients' treatments procedures such as physiotherapy
- Since Electromyography (EMG) detects muscle response during different actions, it gives useful identification of the symptoms' causes. Such disorders that can be identified by EMG are neuromuscular diseases, Nerve injury, and Muscle degeneration. The dealing with Electromyography (EMG) signals provides significant source of information for identification of neuromuscular disorders.
- A robot-assisted rehabilitation can provide quantifiable and repeatable assistance that ensure consistency during the rehabilitation and
- A robot-assisted rehabilitation is likely to be cost-efficient.

Rehabilitation robotics refers to the use of robotic devices (sometimes called "*rehabilitators*") that physically-interact with patients in order to assist in movement therapy.

Rehabilitation robotics is directed to improve mobility and independence in daily life of patients. It uses specific ex-excises related to the therapeutic problem and patients practice movements. The rehabilitation robotics controls this automatically. The pattern of movements follows a theoretical concept developed and disseminated by respected authorities. However, now the proof of evidence for each concept is missing. Especially, no validated data to compare different therapeutic strategies are missed. The health economical demand is to demonstrate the effectiveness of robotics and rehabilitative procedures [1].

Two important issues that the current robot-assisted rehabilitation systems do not address: they are limited by their inability to simultaneously assist both arm and hand movements (signal evaluation and robot steering is quite complicated using signals from arm, hand or body (head, neck, shoulder). Current robot-assisted rehabilitation systems can comprehensively alter with limits the task parameters based on patient's feedback to impart effective therapy during the execution of the task in an automated manner.

Moreover, the third important problem of current robot-assisted rehabilitation systems is intelligent robot control. Behavior control for an autonomous robot is a very complex problem, especially in the rehabilitation and medical domains. This is due to the dynamics of patients muscle movements and real-time EMG patient signal feedback.

7.2 Research Chapter Objectives

Stroke is an urgent case that may cause problems like weakness, numbness, vision problems, confusion, trouble walking or talking, dizziness and slurred speech. It is a leading cause of death in the United States. For these reasons, brain stroke is considered an emergency case as same as heart attack and needs to be treated immediately before causing more problems.

The main objective of the proposed research is to propose a Hybrid Intelligent remote diagnosis Technique for Mobile Health Application for Brain Stroke diagnosis. Another objective is monitoring human health conditions based on emerging wireless mobile technologies with wireless body sensor.

The research work focuses also on delivering better healthcare to patients, especially in the case of home-based care of chronic illnesses.

On the other hand, our designed prototype investigates the implementation of the neural network on mobile devices and tests different models for better accuracy of diagnosis and patient emergency.

Integration of mobile technology and sensor in development of home alert system (mhealth system) will greatly improve the lives of elderly by giving them safety and security and preventing minor incidents from becoming life-threatening events.

7.3 Literature Review

7.3.1 Pervasive Computing and Mobile Health Technologies

Health monitoring is considered one of the main application areas for Pervasive computing. Mobile Health is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers [1]. Mobile Health applications are receiving increased attention largely due to the global penetration of mobile technologies. It is estimated that over 85% of the world's population is now covered by a commercial wireless signal, with over 5 billion mobile phone subscriptions [2].

Joseph John Oresko [3], proposed a real-time, accurate, context aware ST segment monitoring algorithm, based on PCA and a SVM classifier and applied on smartphones, for the detection of ST elevation heart attacks. Feature extraction consists of heartbeat detection, segmentation, down sampling, and PCA. The SVM then classifies the beat as normal or ST elevated in real-time.

Qiang Fang [4], proposed an electrocardiogram signal monitoring and analysis system utilizing the computation power of mobile devices. In order to ensure the data interoperability and support further data mining and data semantics, a new XML schema is designed specifically for ECG data exchange and storage on mobile devices. Madhavi Pradhan [5], proposed a model for detection of diabetes. Their proposed method uses a neural network implementation of the fuzzy k-nearest neighbor algorithm for designing of classifier. The system is to be run on smartphone to facilitate mobility to the user while the processing is to be done on a server machine.

Oguz Karan [6], presented an ANN model applied on Smartphone to diagnose diabetes. In this study, three-layered Multilayer Perceptron (MLP) feedforward neural network architecture was used and trained with the error back propagation algorithm. The back propagation training with generalized delta learning rule is an iterative gradient algorithm designed to minimize the root mean square error between the actual output of a multilayered feed-forward neural network and a desired output.

Peter Pes [7], developped a Smartphone based decision support system (DSS) for the management of type 1 diabetes in order to improve quality of life of subjects and reduce the aforementioned secondary complications. The Smartphone platform implements a case-based reasoning DSS, which is an artificial intelligence technique to suggest an optimal insulin dosage in a similar fashion as a human being would.

Jieun Kim [8], proposed a Case-Based Reasoning approach to match the user needs and existing services, identify unmet opportunistic user needs, and retrieve similar services with opportunity based on Apple Smartphone.

M.I. Ibrahimy [9], applied feed-forward ANN with back-propagation learning algorithm for the classification of single channel EMG signal in the context of hand motion detection.

7.3.2 Rehabilitation Robotics for Stroke Patients

The use of robots for facilitating the motion in rehabilitation therapy to stroke patients has been one of the fastest growing areas of research in recent years. The reason for this growth is the potential to provide effective therapy at a low, acceptable cost. It is known that by exercising the affected part, it could recover some degree of functionality [24, 29]. A Robot could be used for replicating the exercises provided by the therapist, but it also has the potential to reproduce other regimes that would not be easily carried out by a human being. Some of the robots with these abilities are the MIME System from VA Palo Alto that allows the movement of the affected and the unaffected limbs [31], and the the ARM and GENTLES [2] projects. On the other hand, a rehabilitation robotic system driven by pneumatic swivel modules was presented in [26, 27]. This robot is intended to assist in the treatment of stroke patients by applying the proprioceptive neuromuscular facilitation method. Other examples of commercial robots for therapy are the InMotion Arm Robot, based on the pioneering MIT-Manus [23], and the ARMEO [15] series system. Recently, some works have been focused on gait and balance rehabilitation for stroke patients. They are able to support patient's body, while he or she maintain a nearly natural walk and can concentrate on other activities. Within the group of gait rehabilitation, the walkaround system helps to walk to people who have suffered from hemiplegia or other diseases that require assistance in posture [34]. Other highly developed devices for rehabilitation and gait balance are WHERE I and WHERE II. WHERE I is a mobile robot that assists with gait, it contains one rotational degree of freedom arm manipulator that adjusts to different heights and sizes and supports the body. WHERE II is a mobile vehicle that consists of four pneumatic bars that are adjusted to each side of the body [21]. There are commercial robots for children called SAM and SAM-Y that help in gait rehabilitation.

7.4 Description of the Research Telemedicine Platform

The target of this project is the development of an intelligent hybrid rehabilitation robot controller based on a Telemedical platform for a portable rehabilitation robot monitor system. The Telemedical platform allows to manage the monitoring of high-risk patients of cardio-vascular diseases, detect critical events and control the rehabilitation process using wireless sensors and robots. The proposed system consists of:

1. Various wireless sensors, used in an adaptable, scenario based setting.
2. A mobile processing unit for signal processing and feature extraction.
3. A mobile device as data transmitter controller.
4. A Robot controller unit for intelligent behavior control of the robot.
5. A robotic arm unit for interaction with the patient.

7.4.1 A State of the Art Telemedicine Robot Rehabilitation System

Stroke is a leading cause of disability in the world, and yet Robot-assisted and telemedicine technology is currently available for individuals with stroke to practice and monitor rehabilitation therapy on their own. Telemedicine uses common technologies that provide conduit for tele-consultation exchange between physicians, nurses and patients. The third phase of our proposed product is to develop a hybrid rehabilitation robot controller and a telemedicine in a portable rehabilitation robot monitor system with 3-D Exercise Machine for Upper Limb, coordination, range of motion and other relevant perceptual motor activities. The aim of this study is to evaluate a device for robotic assisted upper extremity repetitive therapy; the robot will have four degrees of freedom at shoulder, elbow and wrist; the robot EEG and EMG sensors feedback position and force information for quantitative evaluation of task performance. It has the potential of providing a repetitive automatic of supplementing therapy. The telemedicine system will consist of a Web-based library of status tests and Single Board computer Monitor, and can be used with a variety of input devices, including a feedback joystick, infrared emitter sensor Bar to integrated therapy games Stepmania and Wii, assisting or resisting in movement. The system will enable real-time, interactive integration of medical data, voice and video transmission in the wireless Telemedicine environment.

Robot-assisted therapy refers to the use of robotic devices (sometimes called *rehabilitators*) that physically-interact with patients in order to assist in movement therapy [6, 7]. Virtual reality (VR) is an emerging and promising approach for task-oriented biofeedback therapy [8, 9] Embedded telerehabilitation system used virtual reality and a pair of wireless networked PCs. It is intended for rehabilitation of patients with hand, elbow, and shoulder

Figure 7.1. Shows the full system units, wireless telemedicine unit, signal processing and feature extraction units, robot controller unit system, along with wireless sensors that consist of EEG, ECG and EMG sensors along with telemedicine server. Mobile device and robotic arm.

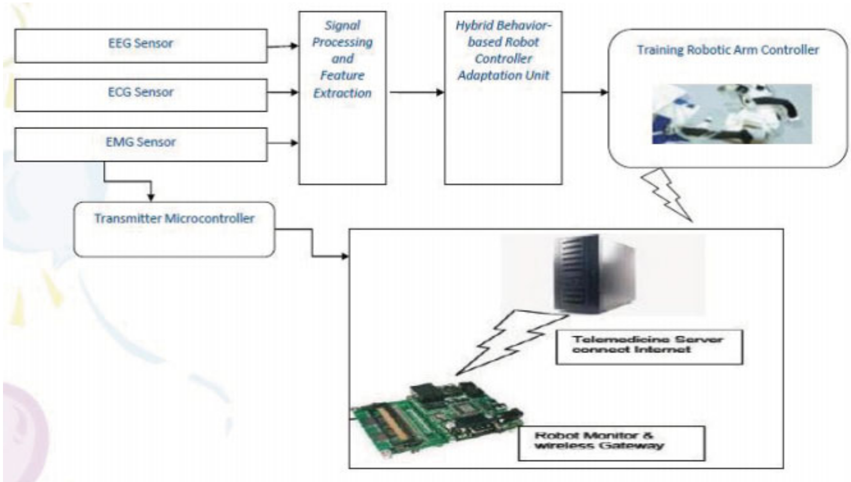

Figure 7.1 Intelligent Telemedicine Rehabilitation Robotic Architecture

This model reflects not only the intelligent robotic control as only one aspect of the problem but also the monitoring of high-risk patients and covers the whole process of patients with cardio-vascular diseases and stroke. It also reflects the mobile signal processing and feature extraction unit along with the Intelligent Behavior Controller of the Robotics unit to alter real-time patients' feedback to impart effective therapy during the execution of the task in an automated manner.

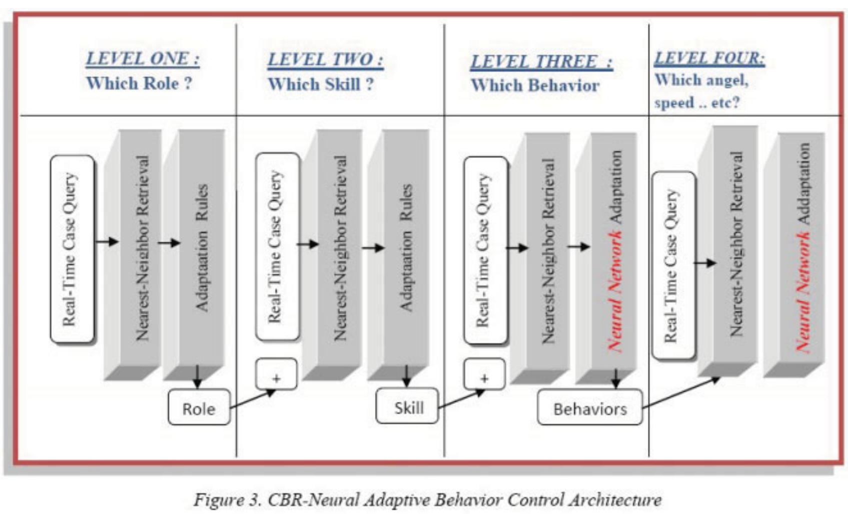

Figure 7.2 Hierarchical Intelligent Behavior Control for Robot

Figure 7.2 shows the details description of the Intelligent Behavior controller of robotic unit using case-based reasoning (CBR) and neural networks, which are recent and important Artificial Intelligence technologies. Also, due to the integration of mobile devices such as cell phones and tablet pc mobile network operators can offer an additional service of monitoring and rehabilitation management. First consultations with Egyptian providers showed their deep interests for such a telemedical management system including additional values such as satisfaction of secure life data management, crisis intervention and rehabilitation improvement by individualization of the therapeutic interaction and intervention.

7.4.2 Wireless telemedicine module with robot

The increased availability, miniaturization, performance and enhanced data rates of future mobile communication systems will have an impact and accelerate the deployment of mobile telemedicine system and services within the next decade. The expected convergence of future wireless communication, wireless sensor networks and ubiquitous computing technologies will enable the proliferation of such technologies around tel-rehabilitation services with cost-effective, flexible and efficient ways. Wireless LAN (WLAN) is implemented as an extension to or as an alternative for wired LAN to make the communication more flexible and powerful. We integrated wireless LAN interface between sensor network and robot monitor.

7.4.3 Wireless intelligence sensor network extract user's biofeedback signal

Many physiological processes can be monitored for biofeedback applications, and these processes are very useful for rehabilitation services. Biofeedback is a means for gaining control of our body processes to increase relaxation, relieve pain, and develop healthier, more comfortable life patterns. Biofeedback is a broader category of methods. These methods use feedback of various physiological signals, such as EEG electroencephalographic or brainwave, electrical activity of muscles (EMG), bladder tension, electrical activity of the skin (EDA/GSR), or body temperature. These methods are applied to treatment or improvement of organism functions as reflected by these signals which can be detected by the wearable health-monitoring device.

A wearable health-monitoring device using Body Area Network (BAN) usually requires multiple wires connecting sensors with the processing unit, which can be integrated into user's clothes [10, 11]. This system organization is unsuitable for longer and continuous monitoring, we integrated intelligent sensor into wireless body area network as a part of telemetrically monitoring system. Intelligent wireless sensors perform data acquisition and processing. Individual sensors monitor specific physiological signals (such as EEG, ECG, EMG, and Galvanic Skin Response (GSR)) and communicate with transmitter microcontroller and wireless gateway. Wireless gateway can integrate the monitor into telemedical system via a wireless network. Three channels of ECG, four channels of EMG, two GSR and up to 16 channels of EEG monitoring create a bulk of wieldy wireless channel that can significantly normal activity and expose user's medical condition to assist rehabilitation.

7.5 A proposed intelligent adaptive behavior control to rehabilitation robotics

Behavior-based control [1] has become one of the most popular approaches to intelligent robotics control. The robot's actions are determined by a set of reactive behaviors, which map sensory input and state to actions. Despite of the behavior-control part, most of robotics systems use classical behavior-control architectures. These classical architectures can cover all sensory input states of complex environments and thus limits the robot ability to adapt its behaviors in unknown situations. Recently, some AI techniques such as neural networks, neural networks have been applied successfully to behavior-control of mobile robots [4]. However, research on control of rehabilitation robots using AI is still in initial stage [10].

Figure 7.2 An Intelligent Behavior Controller Software Architecture to Rehabilitation Robotics. As shown This architecture presents an intelligent behavioral control model that depends on case-based reasoning. It consists of a hierarchy of four levels, the first level is to decide robot role. The second level is to decide which skill to execute. The third level is to determine the behaviors of each skill and the fourth level is to adapt lower-level behaviors as distance and angels of motions. We have designed this architecture before for German team robot, humanoid soccer [1] and we want to apply it as the main intelligent controller of rehabilitation robot because it shows successful results [2].

- As shown, each level applies CBR cycle to control and adapt its behaviors.
- The first two phases apply adaptation rules to adapt behaviors.
- The last two phases apply the learning capabilities of NN to learn adaptation rules for performing the main adaptation task.

Case-Based Reasoning (CBR) suggests a model of reasoning that depends on experiences and learning. CBR solves new cases by adapting solutions of retrieved cases. Recently, CBR is considered as one of the most important Artificial Intelligent (AI) techniques used in many medical diagnostics tasks and robotics control.

Level One: Robot Role

1. Input Real-time new *Role_case*.
2. Retrieve most similar *Role_case*.
3. Use *Adaption Rules* to Adapt the solution of the *Role_case*.
4. Append the solution of the new *Role_case* to the next level.

Level Two: Robot Skill

5. Input the real-time new *Skill_case*.
6. Retrieve most similar *Skill_case*.
7. Use *Adaptation Rules* to adapt the solution of the *Skill_case*.
8. Append the solution of the new *Skill_case* to the next level.

Level Three: Robot Behaviors

9. Input the real-time new *Behavior_case* .
10. Retrieve most similar *Behavior_case*.
11. Train and Adjust *Neural Network* on adaptation rules to adapt the solution of the retrieved *Behavior_case*.
12. Append the solution of the new *Behavior_case* to the next level.

Level Three : Robot Primitive:

13. Input the real-time new *Primitive_case*.
14. Retrieve most similar *Primitive_case*.
15. Train and Adjust *Neural Network* on adaptation rules to adapt the solution of the retrieved *Primitive_case*.
16. Execute the final adaptive behavior solution of the new *Primitive_case*.

Figure 7.3 Intelligent Behavior Control Algorithm

Adaptation in CBR is a very difficult knowledge-intensive task, especially for Robot control. This is due to the complexities of the robot kinematics, which may lead to uncertain control decisions. In this work, we will propose a new hybrid adaptation model for behavior control of Rehabilitation Robot. It combines case-based reasoning and neural networks (NN's). The model consists of a hierarchy of four levels that simulates the behavior control model of a patient's motions robot. Each level applies CBR cycle to control and adapt its behaviors. The first two phases will apply adaptation rules to adapt behaviors, while the last two phases will apply the learning capabilities of NN to learn adaptation rules for performing the main adaptation task. The detailed Software Algorithm of the Intelligent Behavior control is shown in Figure 7.3.

7.6 Materials and Methods

The telemedical platform covers the process of monitoring, signal processing, and management of telemedical care. The following Figure 7.4 shows the general process of signal processing and feature extraction and interaction with the patient.

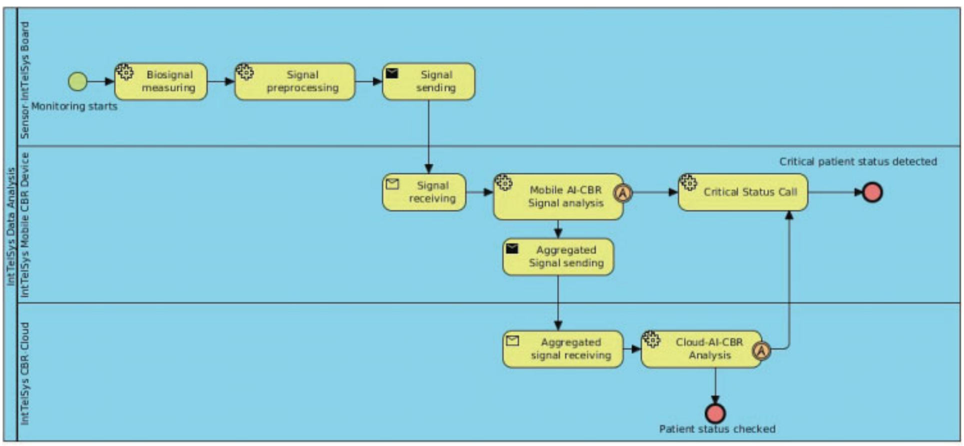

Figure 7.4 General process model for Telemedicine sensor data management

The clue is the distributed, level based sensor data evaluation process: the first level includes the sensor nodes themselves with a basic but very fast signal processing. Aggregated data will be sent to the mobile unit/device as second level, this will take real-time (EMG) data read through the mobile device which sends urgent event to the hospital server as shown in Figure 7.5. The system can also respond by immediate recommendation and sends patient data to responsible doctor or nurse. Moreover, the next processing step can be done. The second and third level (*server/cloud based signal processing*) covers intelligent data processing and decision support for interaction and robot control.

7.7 Conclusion Summary: Artificial Intelligence Technologies

First step in our system is Signal Acquisition phase. EMG wireless sensors include high performance analog filters for signal acquisition, anti-aliasing and instrumentation noise

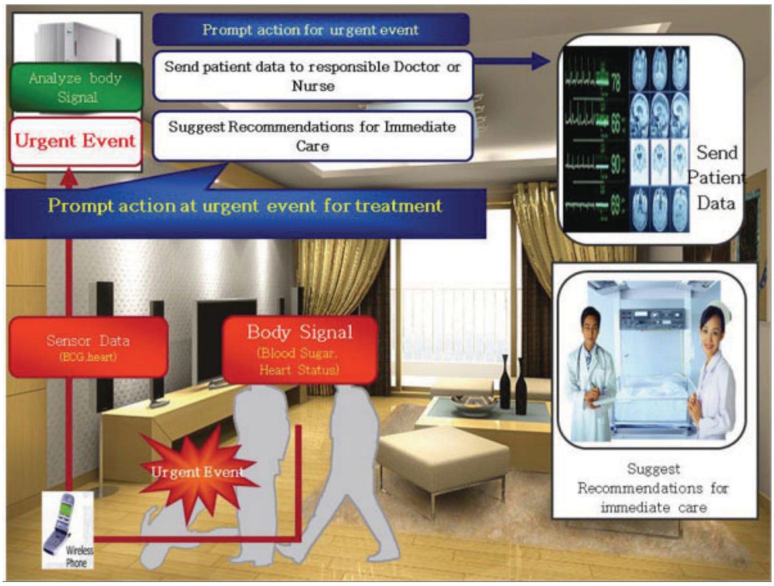

Figure 7.5 Mobile Patient Emergency for Stroke Patients to Nearest Hospital

management. Second step is Signal Pre-processing which means noise removal depending on noise type by applying some typical filtering techniques like band-pass filter, band-stop filter and then applying wavelet transform method. Third step is features extraction. This step is divided into two phases. First of them is analyzing data of Brain Stroke based on EMG sensors of muscles readings to enable extracting best features. Second phase is to select significant features for efficient classification since it determines the success of the pattern classification system. However, it is quite problematic to extract the best feature parameters from the EMG signals that can reflect the unique feature of the signal to the motion command perfectly. Hence, multiple feature sets are used as input to the EMG signal classification process. Some of the features are classified as time domain, frequency domain, time-frequency domain, and time-scale domain; these feature types are successfully employed for EMG signal classification. The next step is signal classification phase. Artificial Intelligence techniques mainly based on machine learning have been proposed for EMG signal classification. This technique is very useful for real-time application based on EMG signal. Classification step in our system is divided into four phases. First of them is to study and analyzing Neural Networks (NN) algorithms for EMG Data. Support Vector Machine (SVM) is a powerful learning method used in binary classification. The next phase is to analyze Case-Based Reasoning Retrieval Algorithms in Medicine. Case-Based Reasoning (CBR) suggests a model of reasoning that depends on experiences and learning. CBR solves new cases by adapting solutions of retrieved cases. The four processes of CBR Cycle [13] (*Retrieve, Reuse, Revise, and Retain*) describe the general tasks in a casebased reasoner. They provide a global external view to what is happening in the system.

The proposed research system aims to study and apply Artificial Intelligence technologies, mobile devices, and cutting edge technologies of Cloud-Computing and take advantage of research achievements in image processing and information communication technologies. The project will create adaptive, collaborative, and innovative cloud computing and mobile application system in Health-Care and environments for Intelligent Information System in Health-Care. To successfully achieve the research program goals, a research framework has been developed that consists of Six layers shown in the following figure. Various research issues and application systems are proposed to be studied and be developed. This is shown in Figure 7.6.

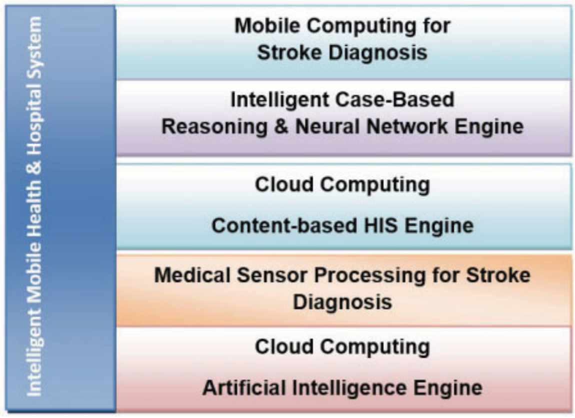

Figure 7.6 Artificial Intelligence Technologies Components

The technology foundation of the research framework will consist of studying mobile computing for stroke emergency diagnosis, intelligent case-based reasoning engine, cloud computing hospital management engine, medical sensor processing for stroke diseases, cloud computing artificial intelligence engine and cloud computing patient database engine.

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CHAPTER 8

ARTIFICIAL INTELLIGENCE FOR SMART CANCER DIAGNOSIS: A NEW TELEMEDICINE SYSTEM BASED ON FUZZY IMAGE SEGMENTATION

M.H.B. Shalhoub[1], Naif M. Hassan Bin Shalhoub[2], Bassant M. Elbagoury[3], Abdel-Badeeh M. Salem[3]

[1] Consultant of Information Technology at Ministry of Interior, Riyad, KSA
[2] Faculty of Medicine, King Abdel-Aziz University2, Jeddah, KSA
[3] Faculty of Computer and Information Sciences, Ain Shams University, Cairo, Egypt
Emails: shalhoub@live.com, bassantai@yahoo.com, abmsalem@yahoo.com

Abstract Micro-calcifications appearing as collection of white spots on mammograms show an early warning of breast cancer. Early detection is the key to improve breast cancer prognosis. This paper presents a new intelligent telemedicine framework that has been developed to improve the detection of primary masses and micro calcifications of the disease. Our main motivation is to provide remote services to radiologists and cancer patients. The proposed telemedicine framework is based on Service-oriented technology, where it uses in its application layer image compression by wavelet technique. Then image enhancement is applied on the image to prepare it for the segmentation. Finally, image segmentation is applied for the detection of the calcifications in the breast using Fuzzy C-Mean. The implementation of the system has shown a very good prototype result with integrated intelligent techniques and it has been tested with 326 mammogram breast cancer images with overall good results and this can serve as a real telemedicine platform for the cloud computing industry in the future

Keywords: Telemedicine, Service-Oriented Architecture, Mammograms, Image Compression, Image Segmentation.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (103–284)

8.1 Introduction

Telemedicine is a rapidly developing technology of clinical medicine, where medical information is transferred through interactive audiovisual media for the purpose of consulting [1]. Telemedicine can also be used to conduct examinations and remote medical procedures. Opportunities and developments of telemedicine discussed in states [2]. Also, Anna E.S. Klughammer [3] introduce improving breast cancer and cervical cancer screening in developing countries using telemedicine. Elvira M. Zilliacus et al. [4] introduce telegenetics of Tele-health cancer.

The term telemedicine encompasses an array of services:

- Specialist and primary care consultations may involve a patient *seeing* a health professional over a live

- Video connection or it may use diagnostic images and/or video along with patient data to a specialist for viewing later. This may be used for primary care or for specialist referrals. Recent surveys have shown a rapid increase in the number of specialty and subspecialty areas that have successfully used telemedicine. Major specialty areas actively using telemedicine include: dermatology, ophthalmology, mental health, cardiology and pathology. According to reports and studies, almost 60 different medical subspecialties have successfully used telemedicine.

- Imaging services such as radiology (*Teleradiology*) continues to make the greatest use of telemedicine with thousands of images *read* by remote providers. Digital images, sent to the specialist over broadband networks, are diagnosed with a report sent back. Radiology, pathology and cardiology are all using telemedicine to provide such services. It is estimated that over 400 hospitals in the United States alone outsource some of their medical imaging services . Radiological images include (*X-rays, CT, MR, PET/CT, SPECT/CT, MG.. etc*).

- Remote patient monitoring uses devices to remotely collect and send data to a monitoring station for interpretation. Such *home telehealth* applications might include using telemetry devices to capture a specific vital sign, such as blood glucose or heart ECG or a more sophisticated device to capture a variety of indicators for homebound patients. Such services can be used to supplement the use of visiting nurses.

- Remote medical education and consumer information can include a number of activities including: continuing medical education credits for health professionals and special medical education seminars for targeted groups in remote locations; the use of call centers and Internet Web sites for consumers to obtain specialized health information and on-line discussion groups to provide peer-to-peer support.

In this chapter, we focus on the third type of Telemedicine, which is Teleradiology. We propose an integrated teleradiology system, which is applied for breast cancer mammography images. This is because Breast cancer recent statistics shows that it is one of the major causes of death among women. Moreover, Mammography is the main test used for screening and early diagnosis, where the micro-calcifications appear in small clusters of few pixels with relatively high intensity compared with their neighboring pixels [5]. Also, S.Shaheb et el. [6] uses fuzzy logic for mammogram image segmentation.

In order to increase physicians' diagnostic performance, many researchers and companies introduce Service-Oriented Architecture (SOA) [7], which is a flexible paradigm for telemedicine phases development and computing.

In this paper, we introduce an integrated teleradiology system for breast cancer diagnosis. It is based on SOA and mammogram images compression, enhancement and fuzzy C-mean mammogram segmentation. The coming sections explain each module in details.

The rest of this chapter is organized as follows, In section 2, we present a brief background and related work. We propose our system architecture in section 3 and in section 4 the telemedicine system modules are presented. Results and discussion are given in section 5. Finally, conclusion and future work are given in section 6.

8.2 Background and Related work

Breast cancer image segmentation is the process of partitions an image to several small segments the main difficulties in image segmentation are, noise, bias field, partial volume effect (*a voxel contributes in multiple tissue types*). R.Ramani et al. [13] presents A Survey Of Current Image Segmentation Techniques For Detection Of Breast Cancer, where they discuss:

8.2.1 De-noising methods

Decreases the noise: In image pre-processing techniques ar necessary in order to find the orientation of the mammogram to remove the noise and to enhance the quality of the image[8].the pre-processing steps are very important in order to limit the search for abnormalities without undue influence from back ground of the mammograms. The main objective of this process is to improve the quality of the image to make it ready to further processing by removing the unrelated and surplus parts in the back ground of the mammograms [14].

1. Adaptive median filter: Adaptive median filter works on a rectangular region P_{xy}, it changes the size of P_{xy} during the filtering operation depending on certain conditions such as

- Z_{min} = minimum pixel value in P_{xy}.
- Z_{max} = maximum pixel value in P_{xy}.
- Z_{med} = median pixel value in P_{xy}.
- P_{max} = maximum allowed size of P_{xy}.

Each output contains the median value in 3 by 3 neighborhoods around the corresponding pixel in the input images. The edges of the image however are replaced by zeros [15]. Adaptive median filter has been found to smooth the non repulsive noise from 2D signals without blurring edges and preserve image details. This is particularly suitable for enhancing mammograms images.

2. Mean filter: The mean filter replaces each pixel by the average value of the intensities in its neighborhood.It can locally reduce the variance and is easy to implement [16].

3. A Markov random field method: In this method spatial correlation information is used to preserve fine details.in this method regularization of the noise estimation is performed. The updating of pixel value is done by iterated conditioned modes.

4. Wavelet methods: In frequency domain these method is used for de-noising and preserving the signal application of wavelet based methods on mammography 4. Wavelet methods In frequency domain these method is used for de-noising and preserving the signal application of wavelet based methods on mammography image makes the wavelet and scaling coefficient biased.This problem can be solved by squaring mammograms images by non central chi-square distribution method.

5. Median filtering: A median filter is a non linear filter is efficient in removing salt and pepper noise median tends to preserve the sharpness of image edges while removing noise. The various of median filter are i) centre-weighted median filter ii) weighted median filter iii) max-median filter, the effect of increasing the size of the window in median filtering noise is removed effectively.

6. Max-Min filter: Maximum and minimum filter attribute to each pixel in an image a new value equal to the maximum or minimum value in a neighborhood around that pixel. The neighborhood stands for the shape of the filter, maximum and minimum filters have been used in contrast enhancement.

8.2.2 Image Segmentation Overview

The main objective of image segmentation is to extract various features of the images which can be merged or split in order to build objects of interest on which analysis and interpretation can be performed. Image segmentation refers to the process of partitioning an image into groups of pixels which are homogeneous with respect to some criterion. The result of segmentation is the splitting up of the image into connected areas. Thus segment is concerned with dividing an image into meaningful regions. The image segmentation techniques such as thresholding, region growing, statistics models, active control modes and clustering have been used for image segmentation because of the complex intensity distribution in medical images, thresholding becomes a difficult task and often fails [17].

1. Region growing segmentation: Region growing is an approach to image segmentation in which neighboring pixels are examined and added to a region class if no edges are detected. This process is iterated for each boundary pixel in the region. If adjacent regions are found, a region merging algorithms is used in which weak edges are dissolved and strong edges are left intact. The region growing starts with a seed which is selected in the centre of the tumor region. During the region growing phase, pixels in the neighbor of seed are added to region based on homogeneity criteria thereby resulting in a connected region.

2. K-Means clustering method: The k-means algorithms are an iterative technique that is used to partition an image into kcluster. In statistics and machine learning, k-means clustering is a method of cluster analysis which can to portions n observation into k cluster in which each observation belongs to the cluster with the nearest mean [20-21]. The basic algorithms is given below

1. Pick *k* cluster center's either randomly or based on some heuristic.

2. Assign each pixel in the image to the cluster that minimum the distance between the pixels cluster centre.

3. Re-compute the cluster center's by averaging all of the pixels in the cluster. Repeat last two steps until convergences are attained. The most common algorithm uses an iterative refinement technique; due to this ambiguity it is often called the k-means algorithms.

8.3 Proposed System Architecture

The proposed system is based on the basic SOA [7], which is shown in Figure 8.1 and it can be divided into three levels:

- *Front-End layer*: Which includes the Client interface and the network connection.
- *Application Layer*: That includes the images processing which consists of image compression, image decompression and image segmentation. Also that layer contains the feature extraction part as well as the CBR (*Case-Based Reasoning*) module.
- *Finally the Back-end layer*: That contains the image database and the patients' database. The proposed system database consists of 326 mammogram images of different cases of breast cancer with different diagnosis. They were obtained from the MIAS (*Mammographic Image Analysis Society*) [8] database is used because it has complete information about abnormalities of each mammographic image like class of lesion, location, size. We have selected those images which included micro-calcifications.

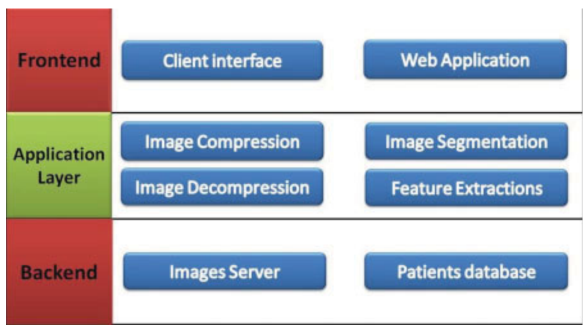

Figure 8.1 Basic Service-Oriented Architecture

SOA (Server Client Network) the move to service-oriented communication has changed software development. Whether done with SOAP (*Simple Object Access Protocol*) or in some other way, applications that interact through services have become the norm. For Windows developers, this change was made possible by Windows Communication Foundation (WCF). In our proposed work, WCF is implemented primarily as a set of classes on top of the. NET Framework's Common Language Runtime (CLR). This lets .Net developers build service-oriented applications in a familiar way. As shown in Figure 8.2. We use WCF service and configured it programmatically.

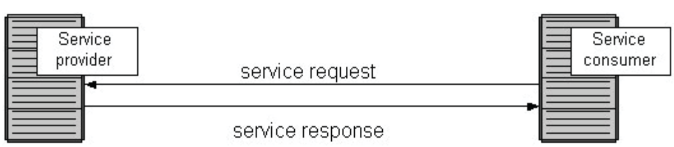

Figure 8.2 SOA Service Communication using WCF

SOA implementation based on WCF. In order to develop the telemedicine SOA framework, a server-client connection is established using WCF because it supports service-oriented cloud-computing development and also due to its inter-polarity with applications that supports other technologies. Their main process connection is shown in Figure 8.3.

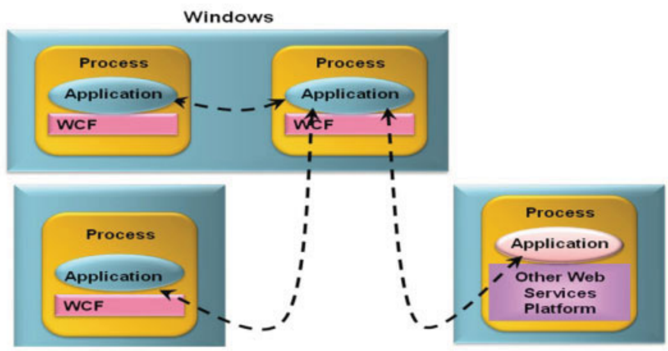

Figure 8.3 SOA implemented as WCF process and services

As shown, WCF allows creating clients that access services. Both the client and the service can run in a pretty much any Windows process- WCF doesn't define a required host. Wherever they run, client and services can interact via SOAP. The whole system is implemented by WCF console connection, Microsoft ASP.net interface and Matlab connection for coding. Creating a WCF service. Every WCF service has three primary components: A service class, implemented in C# as a CLR based language that implements one or more methods. A host process in which the service runs and one or more endpoints that allow clients to access the service. All communication with a WCF service happens via the service's endpoints. An endpoint includes an address (URLs) that identify a machine and a particular endpoint on that machine. It also includes a binding determining how this endpoint can be accessed. The binding determines what protocol combination can be used to access this endpoint along with other things, such as whether the communication is reliable and what security mechanisms can be used. Also, a contract name indicating which service contract this WCF service class exposes via this endpoint.

Creating a WCF client is even more straightforward. In the simplest approach, all that's required is to create a local stand-in for the service, called a proxy, that's connected to a particular endpoint on the target service, and then invoke the service's operations via the proxy.

Security aspects of WCF exposing services on a network, even an internal network, usually requires some kind of security. How can the service be certain of its client's identity? WCF provide the core security functions of authentication, message integrity, message confidentiality and authorization. All of these depend fundamentally in the notion of identity: who is this user ?. This can be done by directly invoking a WCF function. Therefore, establishing an identity is an essential part of using WCF security.

8.4 Telemedicine System Modules

In this section, we are going to describe the telemedical system components and mammogram algorithms in details, as shown in Figure 8.4. It consists of three main modules, Image compression, Image enhancement and Image Segmentation.

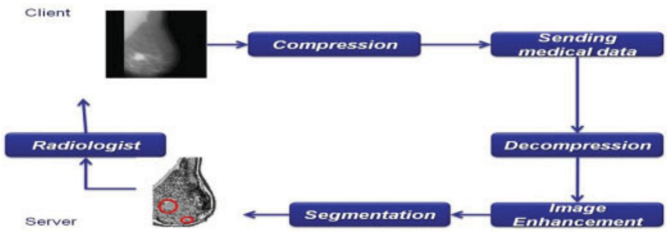

Figure 8.4 The Proposed Telemedicine System Modules

8.4.1 Image Compression

Mammogram images carry a lot of small features and details that are very important, they are also inherently voluminous so an efficient data compression techniques are essential for their archival and transmission. Image compression [9] is minimizing the size in bytes of a graphics file without degrading the quality of the image. We found that a common characteristic of most of images is that the neighboring pixels are correlated. Therefore most important task is to find less correlated representation of image. After surveying many algorithms for image compression, we have applied Discrete Wavelet Transform technique [9]. Figure 8.5 shows the block diagram of image compression sub-modules.

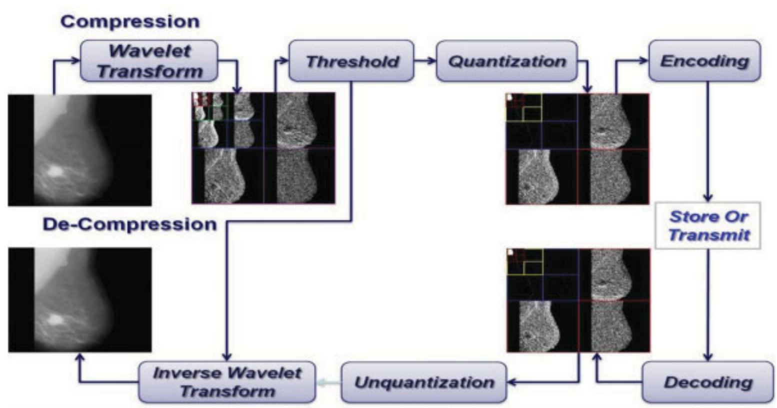

Figure 8.5 Block Diagram of Image Compression Using Wavelet Technique

Image compression using Discrete Wavelet Transform (DWT) has emerged as a popular technique for image coding applications; DWT has high decorrelation and energy compaction efficiency. One of the most important characteristics of DWT is multi-resolution decomposition. An image decomposed by wavelet transform can be reconstructed with desired resolution. When first level 2D DWT is applied to an image, it forms four transform coefficients. The first letter corresponds to applying either low pass or high pas filter to rows and the second letter refers to filter applied to columns, as shown in Figure 8.6.

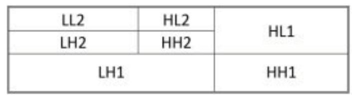

Figure 8.6 Two level wavelet decomposition

A quantizes simply reduces the number of bits needed to store the transformed coefficients by reducing the precision of those values. Since this is a many to one mapping, it is a lossy process and is the main source of compression in an encoder. In uniform quantization, quantization is performed on each individual coefficient. Among the various coding algorithms, the Embedded Zero Tree Wavelet (EZW) coding and its improved version the SPIHT has been very successful [10]. EZW is a progressive image compression algorithm, i.e. at any moment, the quality if the displayed image is the best available for the number of bits received up to that moment. Compared with JPEC the current standard for still image compression, the EZW and the SPIHT are more efficient and reduce the blocking artefact.

8.4.2 Image Enhancement and Region of Interest Segmentation

This section discusses image enhancement and Region of Interest (ROI) pre-processing segmentation algorithm [11] techniques. Figure 8.7 shows the main flowchart modules.

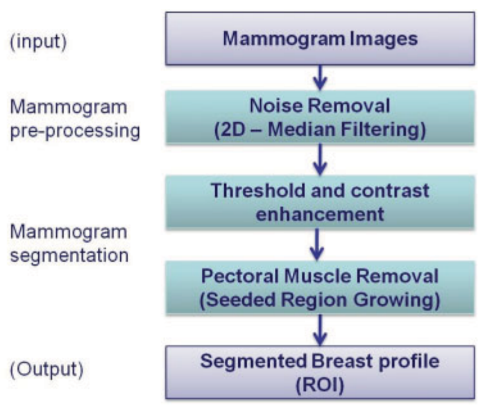

Figure 8.7 Image Enhancement and ROI segmentation flowchart

Image enhancement techniques [12] are used to emphasize and sharpen image features for display and analysis. General methods of mammographic image enhancement can be grouped into three classes: noise reduction, background removal, and contrast enhancement. Preprocessing steps include: a) noise removal, b) artifact suppression and background separation (Thresholding and Contrast Enhancement), c) pectoral muscle segmentation (Seeded Region Growing).

Digitization Noise Removal. The first step we apply is Median filter for noise removal. Digitization noises such as straight lines are filtered using a two-dimensional (2D) Median filtering approach in a 3-by-3 neighborhood connection. Each output pixel contains the median value in the 3-by-3 neighborhood around the corresponding pixel in the input images. The edges of the images however, are replaced by zeros (*total absence or black color*). Median filtering has been found to be very powerful in removing noise and isolated points from mammographic images without blurring edges. It is applied to remove the high frequency components in the mammogram image. The merit of using median filter is, it can remove the noise without disturbing the edges.

Algorithm . Median filters

BEGIN

Step1: Read the image from left to right.
Step 2: For each pixel get a 3X3 window with the pixel cantered in this window.
Step 3: Sort the values of the nine pixels that are in the window according to the gray level.
Step 4: Get the middle gray level value (median value) appearing in the sort
Step 5: Replace the pixel value with the new median value.
Step 6: Repeat the process over all pixels in image

END

Artifact Suppression and Background Separation. After applying the median filter algorithm, Radiopaque artifacts such as wedges and labels in mammograms images are removed using thresholding and morphological operations. Figure 8.8 shows a mammogram image with a Radiopaque artifact present. Through manual inspection of the all mammogram images acquired, a global threshold with a value $T = 18$ (normalized value, $T_{norm} = 0.0706$) is found to be the most suitable threshold of transforming the grayscle images into binary [0,1] format.

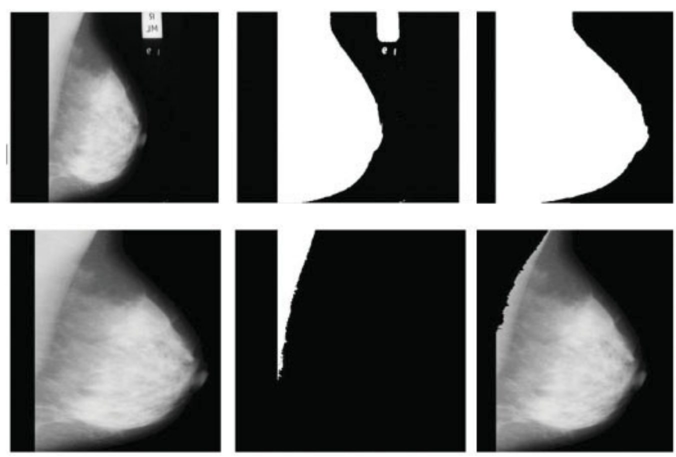

Figure 8.8 Results of Image Enhancement and Region of Interest Segmentation

After the grayscale mammorgram images are converted into binary, as shown in Figure 8.8. Morhological operations such as dilation, erosion, opening and closing are performed on the binary images.

The algorithm of Suppression of Artifacts, labels and wedges:

Algorithm . Suppression of Artifacts

BEGIN

Step 1. All objects present in the binary image in Figure 8.8 (threshold using, $T = 18$) are labelled using the `bwlabel` function in MATLAB. The binary objects consist of the radiopaque artifacts and the breast profile region as indicated in Figure 8.8.

Step 2. The *'Area'* (actual number of pixels in the region) of all objects (regions) in Figure 8 is calculated using the `regionprops` function in MATLAB.

Step 3. Next, a morphological operation to reduce distoration and remove isolated pixels (ndividual 1's surrounded by 0's) is applied to the binary images using the `bwmorph` function in MATLAB with parameter '*clean*'.

Step 4. Another morphological operation is applied the binary images to smoothen visible noise using the `bwmorph` function in MATLAB with the parameter '*majority*'. This algorithm checks all pixels in a binary image and sets a pixel to 1 if five or more pixels in a binary image and sets a pixel to 1 if five or more pixels in its 3-by-3 neighbourhood are 1's, otherwise, it sets the pixel to 0.

Step 5. The binary images are reoded using a flat, disk-shaped morphological structuring element (STREL) using the MATLAB `strel` and `imerode` functions. The radius of the STREL object used is $R = 5$.

Step 6. Next, the binary images are dilated using the same STREL object in Step6. Morphological dilation is performed using the MATLAB `imdilation` function.

Step 7. The holes in the binary images are filled using the imfill function in MATLAB with the parameter *holes'*. This algorithm fills all holes in the binary images, where a hole is defined as a set of background pixels that cannot be reached by filling in the background from the edge of the image.

Step 8. The resulting binary image obtained from Step 8 is multiplied with the original mammogram image using the MATLAB *immultiply* function to form the final grayscale region growing (ROI) segmented image.

END

Fuzzy C-mean Algorithm Segmentation: Traditional clustering approaches generate partitions where each pattern belongs to one and only one cluster. The clusters in a hard partition are disjoints.

The Fuzzy C-means algorithm, also known as fuzzy ISODATA, is one of the most frequently used methods in pattern recognition. Fuzzy C-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters [13]. It is based on the minimization of objective function to achieve a good classification. '*J*' is a squared error clustering criterion, and solutions of minimization are least squared error stationary point of '*J*' in equation (1).

$$J = \sum_{j=1}^{C} \sum_{i=1}^{n} \left\| Z^{(j)} - V_j \right\| \tag{8.1}$$

Where, $\left\| Z^{(j)} - V_j \right\|$ is the chosen distance measure between every point $Z^{(j)}$, and the cluster, V_j. The value of this function is an indicator of the proximity of the *n* data points to their cluster prototypes.

The algorithm is composed of the following steps:

Algorithm . Fuzzy C-mean Algorithm Segmentation

BEGIN

Step 1. Select *K* points into the space represented by objects that are being clustered. These points represent initial group prototypes.

Step 2. Assign each object to the group that has the closet prototype.

Step 3. When all objects have been assigned, recalculate the positions of the *K* prototypes.

Step 4. Repeat second and third steps until the values of the prototypes no longer change. The result is a separation of objects into groups, from which the metric to be minimized can be calculated.

END

Traditional clustering approaches generate partitions where each pattern belongs to one and only one, cluster. Hence, the clusters in a hard partition are disjoints. Fuzzy clustering extends this notion to associate each pattern to every cluster using a membership function.

Theorem FCM: if $D_{ik}A_i = \left\| Z^{(j)} - V_j \right\| > 0$, for every $I, k, m > 1$ and Z contains at least C different patterns, then $(U, V) \in M_{fmc} \times R^{C \times N}$ and J_{fmc}.

Following the previous equations of the FCM algorithm, given the data set Z, choose the number of cluster, $1 \leq c \leq N$, the weighting exponent $m > 1$, as well as the ending tolerance $\delta > 0$. The solution can be reached following the next steps:

BEGIN

Step 1. Provide an initial value to each prototype, $V_i, i = 1, .., C$. These values are generally given in a random way.

Step 2. Calculate the distance between the pattern Z_k and each prototype, V_i.

Step 3. Calculate the membership degrees of the matrix, $U = [\mu_{iK}]$, if $D_{ik}A_i > 0$.

Step 4. Update the new values of the prototypes, V_i.

Step 5. Verify if the error is greater than δ. If this is true, go to the second step. Else, Stop.

END

8.5 Results and discussion

In this analysis, the first procedure is determining the seed regions. When dealing with mammograms, it is known that pixels of tumor regions tend to have maximum allowable digital value. Based on this information, morphological operators are used as Dilation and Erosion to detect the possible clusters which contain masses. Image features are then extracted to remove those clusters that belong to background and normal tissue as a first cut. Features used here include cluster area and eccentricity. The Fuzzy C-means clustering algorithm is used as a segmentation strategy to function as better classifier and aims to class data into separate groups according to their characteristics. Figure 8.9 shows the resulted image of clustering. As shown, after extracting the Region of Interest (ROI) and then applying the morphological operators, the Fuzzy C-Mean algorithm cluster the image and have successfully detected the breast cancer masses in mammograms.

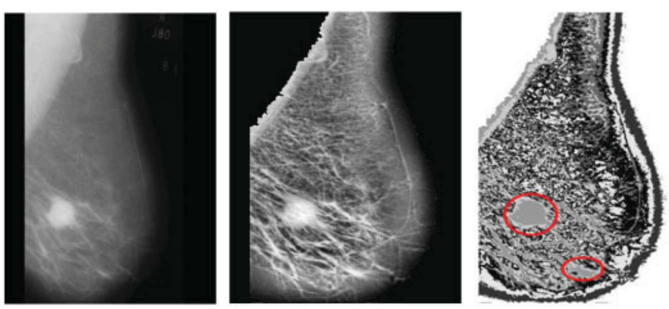

Figure 8.9 Mammogram images while applying steps of Fuzzy C-Mean algorithm steps. (a) Original image, (b) image with segmented ROI after applying the morphological operators, (c) The resulted image after clustering

8.6 Conclusion and Future Work

This paper proposed a new architecture of Telemedicine that can be introduce as an intelligent SOA for cloud-computing technology. The whole system can be divided into: Service-oriented architecture, Server-Client network (WCF), image compression, image enhancement and image segmentation. SOA main advantage is abstraction. Services are autonomous, stateless and separate from the cross-cutting concerns of the implementation. Also, we have used the Server-client network (WCF) which is one of the best techniques in connecting a network since it unification of the original . NET Framework communication technologies and explicit support for service-oriented development. Another strength of our proposed telemedicine framework is that we apply a wavelet image compression algorithm to ease the transmission for the mammogram images through the network. Wavelet technique is used since it is one of the most efficient algorithms in image compression that compress the image with highest percentage of accuracy that might reach a lossless compression. Moreover, image enhancement was used to prepare the image for segmentation through the removing of noise and unwanted objects from the image other than the breast, also mathematical morphological operators used to clarify the details of the image through some operations. Finally, image segmentation is used to detect microclacifications in the breast using the Fuzzy C-Mean algorithm that depends on clustering the image for the detection of microcalcifications which has higher dentistry that the surrounding tissue.

In our future work, we may pursue different areas of the research. The areas of research that could be pursued include image compression, enhancement and segmentation and mobile computing. Mobile computing technology can help the user capture the image by the mobile camera and send it through the network to the server to be segmented and diagnosed.

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CHAPTER 9

MOBILE DOCTOR BRAIN AI APP: ARTIFICIAL INTELLIGENCE FOR IOT HEALTHCARE

Bassant M.Elbagoury[1], Ahmed A.Bakr[1], Mohamed Roushdy[1], Thomas Schrader[2]

[1] Faculty of Computer and Information Sciences, Ain Shams University, Cairo, Egypt

[2] University of Applied Sciences Brandenburg, D- 14770 Brandenburg, Germany

Emails: miroushdy@hotmail.com, schrader@fh-brandenburg.de, ahmed.adel-bakr@vodafone.com

Abstract Mobile Health is a steadily growing field in telemedicine and it combines recent developments in artificial intelligence and cloud computing with telemedicine applications. Stroke is an urgent case that may cause problems like weakness, numbness, vision problems, confusion, trouble walking and talking. It is a leading cause of death in the United States. In the recent research, what we witness is a high competition and new revolution towards mobile health in general, especially in fields of brain stroke, chronic stroke illnesses and stroke emergency cases. However, today's Mobile Health research still missing an intelligent remote diagnosis engine for patient emergency cases such as Stroke. Moreover, Remote patient monitoring and emergency cases need an intelligent algorithms to alert with better diagnostic decisions and fast response to patient care. This research work proposes a Hybrid Intelligent remote diagnosis technique for Mobile Health Application for Brain Stroke diagnosis.

Keywords: Artificial Intelligence, Telemedicine, EMG signal Processing, Mobile Health, Brain Stroke, Neural Networks

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (117–284)

9.1 Introduction

Health monitoring is considered one of the main application areas for Pervasive computing. Mobile Health is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers [1]. Mobile Health applications are receiving increased attention largely due to the global penetration of mobile technologies. It is estimated that over 85% of the world's population is now covered by a commercial wireless signal, with over 5 billion mobile phone subscriptions [2].

Joseph John Oresko proposes a real-time, accurate, context aware ST segment monitoring algorithm, based on PCA and a SVM classifier and applied on smartphones, for the detection of ST elevation heart attacks [3]. Feature extraction consists of heartbeat detection, segmentation, down sampling, and PCA. The SVM then classifies the beat as normal or ST elevated in real-time.

Qiang Fang proposes an electrocardiogram signal monitoring and analysis system utilizing the computation power of mobile devices [4]. In order to ensure the data interoperability and support further data mining and data semantics, a new XML schema is designed specifically for ECG data exchange and storage on mobile devices.

Madhavi Pradhan proposes a model for detection of diabetes [5]. Their proposed method uses a neural network implementation of the fuzzy k-nearest neighbor algorithm for designing of classifier. The system is to be run on Smartphone to facilitate mobility to the user while the processing is to be done on a server machine.

Oguz Karan presents an ANN model applied on Smartphone to diagnose diabetes [6]. In this study, three-layered Multilayer Perceptron (MLP) feedforward neural network architecture was used and trained with the error back propagation algorithm. The back propagation training with generalized delta learning rule is an iterative gradient algorithm designed to minimize the root mean square error between the actual output of a multilayered feed-forward neural network and a desired output.

Peter Pes develops a Smartphone based decision support system (DSS) for the management of type 1 diabetes in order to improve quality of life of subjects and reduce the aforementioned secondary complications [7]. The Smartphone platform implements a case-based reasoning DSS, Which is an artificial intelligence technique to suggest an optimal insulin dosage in a similar fashion as a human being would.

Jieun Kim proposes Case-Based Reasoning approach to match the user needs and existing services, identify unmet opportunistic user needs, and retrieve similar services with opportunity based on Apple Smartphone [8].

9.2 State of the Art

9.2.1 Mobile Doctor AI App for Stroke Emergency in Haij Crowd

Mobile Health in remote medical systems has opened up new opportunities in healthcare systems. It combines recent developments in artificial intelligence and cloud computing with telemedicine applications. This technology help patients manage their treatments when attention from health workers is costly, unavailable, or difficult to obtain regularly.

In fact remote monitoring - which is seen as the technology with the highest financial and social return on investment, given current healthcare challenges - is a focus for many of the pilot projects.

Mobile Health for patient tracking supports the coordination and quality of care for the benefits of rural communities including the urban poor, women, the elderly, and the disabled. This would promote public health and prevent disease at the aggregate level [9].

Some stroke diseases which affect the nerves (e.g. Stroke) and cause problems with thinking, awareness, attention and lead to emotional problems. Stroke patients may have difficulty controlling their emotions or may express inappropriate emotions. So that brain stroke is considered an emergency case that needs to be treated immediately before causing more problems. The proposed work aims to make use of mobile health applications and artificial intelligent techniques in the field of brain stroke by proposing an intelligent mobile health application based on EMG sensor which provides a significant source of information for identification of neuromuscular disorders and transfer experience of expert doctors through Artificial Intelligence technology Case-Based Reasoning.

9.2.2 Proposed Architecture

In the presented research, we propose a New Stroke EMG based Real-Time AI Mobile HealthCare Solution as shown in Figure 9.1.

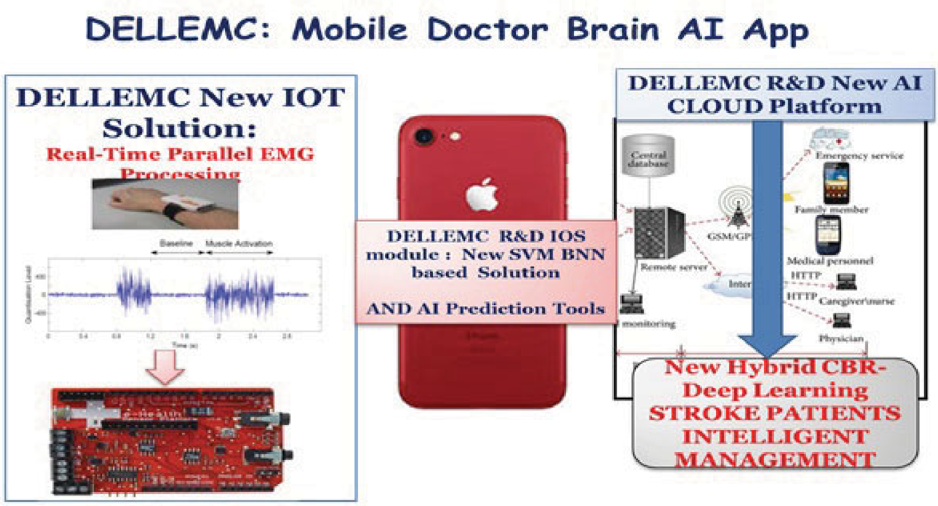

Figure 9.1 Mobile Doctor Brain AI App

In the coming figures, we illustrate the main research components for AI, Real-Time EMG sensor processing, IoT embedded technologies as shown in Figures 9.2 and 9.3.

Stroke is an urgent case that may cause problems like weakness, numbness, vision problems, confusion, trouble walking or talking, dizziness and slurred speech. It is a leading cause of death in the United States. For these reasons, brain stroke is considered an emergency case as same as heart attack and needs to be treated immediately before causing more problems.

The main objective of the proposed research is to Propose a Hybrid Intelligent remote diagnosis Technique for Mobile Health Application for Brain Stroke diagnosis.

Another objective is monitoring human health conditions based on emerging wireless mobile technologies with wireless body sensor.

Figure 9.2 Research Area 1: AI for Raspberry pi - system on chip

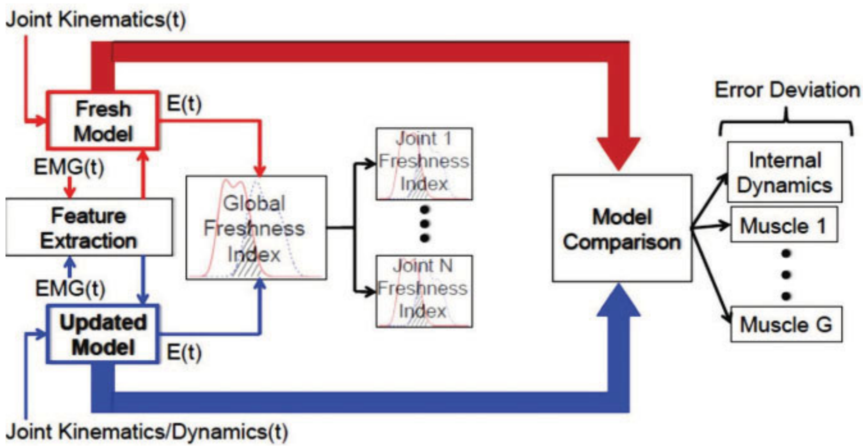

Figure 9.3 Research Area 2: AI Real-time EMG Human Motion Analysis

The research work focuses also on delivering better healthcare to patients, especially in the case of home-based care of chronic illnesses.

On the other hand, our designed prototype investigates the implementation of the neural network on mobile devices and tests different models for better accuracy of diagnosis and patient emergency. Integration of mobile technology and sensor in development of home alert system (M-Health system) will greatly improve the lives of elderly by giving them safety and security and preventing minor incidents from becoming life-threatening events.

9.3 Proposed System Design

9.3.1 AI Telemedicine Platform and Proposed System Architecture

Health monitoring is necessary for classifying disorders early and identifying their treatments. Since Mobile Health (M-Health) Care is one of the most interesting applications of mobile technology, it can be used to improve communications between patients and physicians. For this, M-Health is defined as integration of mobile computing and health monitoring. It enables the delivery of accurate medical information anytime and anywhere.

The proposed system includes a Hybrid Intelligent Remote Diagnosis Technique for M-Health Application in stroke diseases. This will focus on new trends of integrating artificial intelligence methodologies as neural networks (NN's) and case-based reasoning (CBR) into mobile telemedicine solutions and cloud platform as shown in Figure 9.4. The proposed AI Telemedicine platform covers the process of monitoring, signal processing, and management of Intelligent telemedicine care. The following figure shows the general process of signal processing and feature extraction and interaction with the patient.

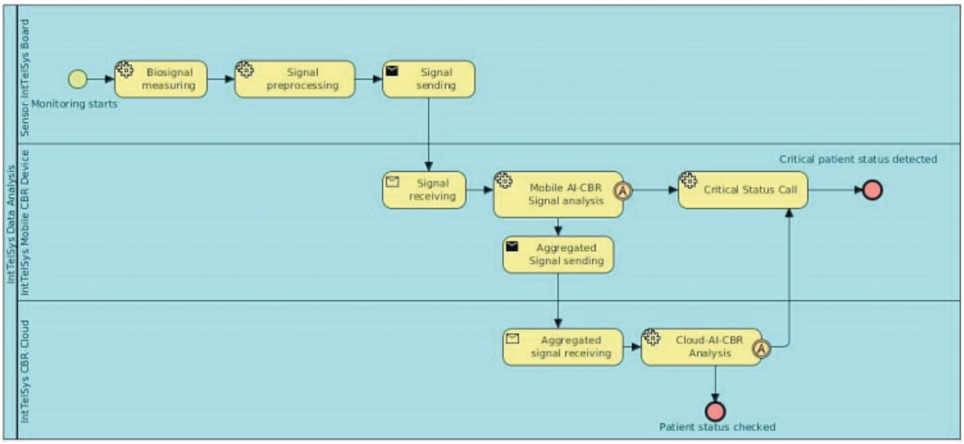

Figure 9.4 General process model for Artificial Intelligence Telemedicine sensor data management (Three Layers: Signal Processing, Mobile Data Aggregation with AI Engine an Cloud CBR Patients Expert system)

The clue is the distributed, level based sensor data evaluation process: the first level includes the sensor nodes themselves with a basic but very fast signal processing. Aggregated data will be sent to the mobile unit/device as second level, this will take real-time (EMG) data read through the mobile device which sends urgent event to the hospital server. The system can also respond by immediate recommendation and sends patient data to responsible doctor or nurse. Moreover, the next processing step can be done. The second and third level (*server/cloud based signal processing*) covers intelligent data processing and decision support for interaction and Telemedicine Management.

9.3.2 Wireless intelligence sensor network extract user's biofeedback signal

Many physiological processes can be monitored for biofeedback applications, and these processes are very useful for rehabilitation services. Biofeedback is a means for gaining control of our body processes to increase relaxation, relieve pain, and develop healthier, more comfortable life patterns. Biofeedback is a broader category of methods. These methods use feedback of various physiological signals, such as EEG electroencephalographic or brainwave, electrical activity of muscles (EMG), bladder tension, electrical activity of the skin (EDA/GSR), or body temperature. These methods are applied to treatment or improvement of organism functions as reflected by these signals which can be detected by the wearable health-monitoring device.

This system will take real-time (EMG) data and read through the mobile device which sends urgent event to the hospital server as shown in Figure 9.5. The system can also respond by immediate recommendation and sends patient data to responsible doctor or nurse.

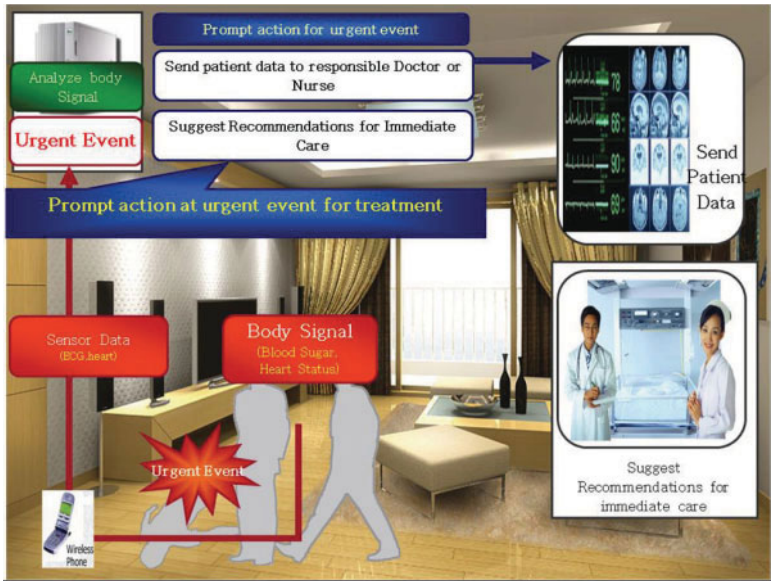

Figure 9.5 Patient Emergency Scenario for Stroke/Heart Attack Elderly and Expert Doctor Recommendations

9.4 Proposed Artificial Intelligence Techniques for New AI IoT Health-Care Solutions for Stroke Monitoring

9.4.1 Support vector machine (SVM)

Support Vector Machine (SVM) is a powerful learning method used in binary classification. It is a supervised learning model with associated learning algorithms that analyze data and recognize patterns. Its main task is to find the best hyper plane that can separate data perfectly into its two classes. Recently, multi-class classification was achieved by combining multiple binary SVMs. SVM architecture is shown in Figure 9.6.

The function of the hyper plane that classify training and testing data can be expressed as following

$$f(x) = sign\left(\sum_{i=1}^{N} \alpha_i y_i k(x_i, x) + b\right) \tag{9.1}$$

Where N is the number of training instances, x_i is the input of training instance and y_i is its corresponding class label, b is a bias, and $K(x_i, x)$ is the used kernel function which maps the input vectors into an expanded feature space. And The coefficients α_i are obtained subject to two constraints given in the following two functions:

$$0 \leq \alpha_i, i = 1, .., N \tag{9.2}$$

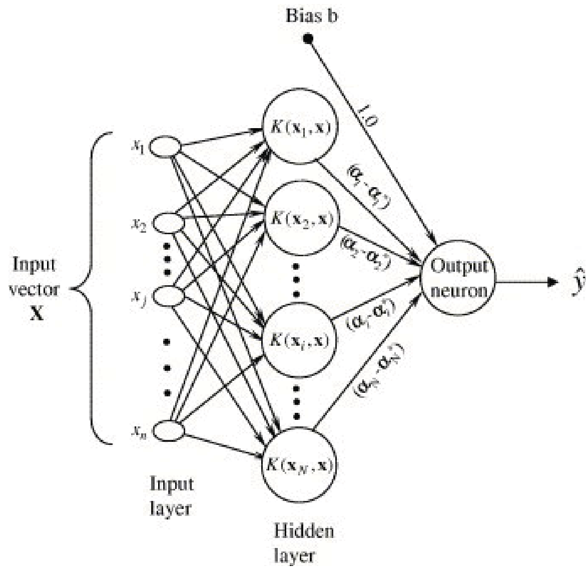

Figure 9.6 Architecture of support vector machine

$$\sum_{i=1}^{N} \alpha_i y_i = 0 \tag{9.3}$$

SVM algorithm is probably the most widely used kernel learning algorithm. It achieves relatively robust pattern recognition performance using well established concepts in optimization theory. Most common Kernel functions used in support vector machine classifier include linear, polynomial, radial basis and quadratic kernels are listed below [10].

The Linear kernel: is the simplest kernel function. It is given by the common dot product $< x_a, x_b >$ plus an optional constant *c*. Kernel algorithms using a linear kernel are often equivalent to their non-kernel counterparts. This kernel is only defined when the data to be analyzed are vectors.

$$K(x_a, x_b) = x_a^T x_b + c \tag{9.4}$$

Where x_a, x_b are objects from the dataset and *c* is an optional constant.

The Polynomial kernel: is a non-stationary kernel. It is well suited for problems where all data is normalized.

$$K(x_a, x_b) = (\alpha x_a^T x_b + c)^d \tag{9.5}$$

Adjustable parameters are the slope (alpha α), the constant term *c* and the polynomial degree *d*.

The Radial Basis Kernel function (RBF) is one of the most frequently used kernels in practice. It is a decreasing function of the Euclidean distance between points, and therefore has a relevant interpretation as a measure of similarity: the larger the kernel (x_a, x_b), the closer the points x_a and x_b

$$K(x_a, x_b) = exp\left(-\frac{\|x_a - x_b\|^2}{2\sigma^2}\right) \tag{9.6}$$

The adjustable parameter sigma (σ) plays a major role in the performance of the kernel, and should be carefully tuned to the problem at hand. $\|x_a - x_b\|$ is the Euclidean distance between the two objects $x_(a)$, x_b.

The Rational Quadratic kernel is less computationally intensive than the Gaussian kernel and can be used as an alternative when using the Gaussian becomes too expensive.

$$K(x_a, x_b) = 1 - \frac{\|x_a - x_b\|^2}{\|x_a - x_b\|^2 + c} \tag{9.7}$$

We made a comparative work [11] on EMG physical action Data set from the machine learning repository (UCI) [12]. We investigates the usage of support vector machine (SVM) classifiers with different kernel functions for identification of different hands and legs, normal and auto aggressive actions from EMG data, and made a comparison between classifications accuracies of each kernel function applied on different groups of actions. In those experiments we used polynomial, quadratic and radial basis function with different values of sigma which plays an important role in the classification accuracy.

The following table shows sample of published experimental results [11, 22]

Table 9.1 Sample of published experimental results

Kernel Functions	Actions				
	Knee / Pull	***Hammer / Header***	***Clapp / Handshake***	***Run / Hug***	***Elbow / Slap***
Polynomial	90%	78%	83%	84%	75%
Quadratic	89%	81%	93%	100%	78%
RBF sigma=10	87%	58%	72%	93%	70%
RBF sigma=1	90%	82%	94%	98%	83%

Accuracies obtained from applying RBF kernel function with different sigma values (ex. on kneeing and pulling actions) are showed in Figure 9.7.

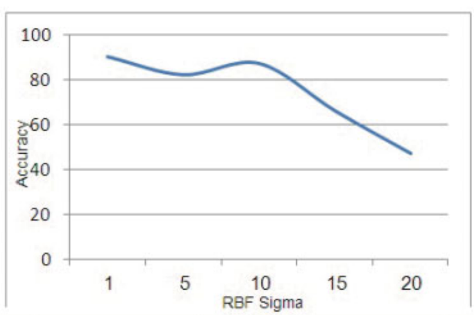

Figure 9.7 Classification accuracies for RBF kernel with different sigma values for Kneeing and Pulling actions

9.4.2 Case-based Reasoning

Case-Based Reasoning (CBR) suggests a model of reasoning that depends on experiences and learning. CBR solves new cases by adapting solutions of retrieved cases. Recently, CBR is considered as one of the most important Artificial Intelligent (AI) techniques used in many medical diagnostics tasks. CBR has already been applied in a number of different applications in medicine.

CBR Cycle [13]: The four processes Retrieve, Reuse, Revise, and Retain describe the general tasks in a casebased reasoner. They provide a global external view to what is happening in the system. The four tasks are decomposed into a hierarchy of CBR tasks the system has to achieve.

1. *Retrieval*: An important step in the CBR cycle is the retrieval of previous cases that can be used to solve the target problem. In this step the casebased reasoner retrieves the most similar case or cases to the input case according to a predefined similarity measure.

2. *Reuse*: in this step CBR reasoner evaluates retrieved cases in order to decide if the solution retrieved is applicable to the problem.

3. *Revise*: Revising (adapting) the solution manually or automatically and validating through feedback from the user.

4. *Retain*: Adding the confirmed solution with the problem, for future reuse, as a new case in the database.

CBR Cycle is shown in Figure 9.8.

Figure 9.8 Case-Based Reasoning Cycle

9.4.3 Particle Swarm Intelligence and ARX Model for Stroke Motion Estimation and Optimization

Particle Swarm Optimization (PSO) is population based stochastic optimization method inspired by social behaviour of bird flocking [22]. PSO exploits a population of individuals to probe promising regions of the search space. In the context, the population is called a swarm and the individuals are called particles. Each particle moves with an adaptable velocity within the search space, and retains in its memory the best position it ever encountered. In the global variant of PSO the best position ever attained by all individuals of swarms is communicated to all the particles.

Also In the statistical analysis of time series, auto-regressivemoving-average (ARMA) models [23] are essential for real-time EMG data analysis [11] and their dynamical behavior. The used commercial EMG sensor is Shimmer [24] as shown in Figure 9.9.

Figure 9.9 EMG Commerical Shimmer Sensor

9.5 Conclusion

This chapter proposes a new stroke EMG based Real-Time AI Mobile HealthCare Solution. The Hybrid Intelligent remote diagnosis technique for Mobile Health Application for Brain Stroke diagnosis based on the support vector machine, case-based reasoning, and particle swarm intelligence.

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CHAPTER 10

AN ARTIFICIAL INTELLIGENCE MOBILE-CLOUD COMPUTING TOOL: EXPERIMENTAL RESULTS BASED ON PHYSICIANS' AND PATIENTS' VIEWS OF CANCER CARE BY FAMILY MEDICINE

M. Hassan Bin Shalhoub[1], Mohammed H. Bin Shalhoub[1], Mariam Marzouq Al-Otaibi[3], Bassant M. Elbagoury[4]

[1] Consultant of Information Technology at Ministry of Interior, Riyad, KSA
[2] Faculty of Medicine, King Abdel-Aziz University, Jeddah, KSA
[3] Consultant of Family Medicine, Faculty of Medicine, King Abdel-Aziz University, Jeddah, KSA
[4] Faculty of Computer and Information Sciences, Ain Shams University, Cairo, Egypt
Emails: shalhoub@live.com, bassantai@yahoo.com

Abstract Intelligent Information Systems and Cloud computing in e-health sector such as teleradiology [1, 2] in remote medical systems has opened up new opportunities in healthcare systems. Artificial Intelligence and teleradiology are a steadily growing field in telemedicine, and they combine recent developments in decision support systems (DSS) and teleradiology images processing with Cloud-Computing e-health systems [3]. In the market today, what we witness is a high competition and new revolution towards DSS and Cloud Computing e-health (*Telemedicine*) sector in general. As, in last April 2011, Mobinil made a protocol with IT company for health [4]. After one month, Vodafone made another protocol with Ericsson for Mobile Health [5]. The possibilities of Artificial Intelligent in Medicine to enhance the e-health services in the region along with cloud-computing platform setting is going to be investigated by building new intelligent algorithms for remote diagnosis and then by evaluating their feasibility. The mission of this chapter is to investigate recent Artificial Intelligence technologies that are to propose a novel integrated Intelligent Remote Diagnosis system for Information System for Cancer diseases based on Cloud-Computing platform. This is to investigate artificial intelligent techniques, namely case-based reasoning (CBR) and neural networks (NN). Also, advances in cloud-computing and teleradiology data can be used for overall patient health management.

Keywords: Artificial Intelligence, Mobile-Cloud Computing, Intelligent Remote Diagnosis

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (129–284)

10.1 Introduction

Intelligent Cloud Computing Teleradiology [1, 2] in remote medical systems has opened up new opportunities in healthcare systems. Mobile teleradiology is a steadily growing field in telemedicine, and it combines recent developments in teleradiology images processing and networking with telemedicine applications [3].

In the market today, what we witness is a high competition and new revolution towards mobile health in general. As, in last April 2011, Mobinil made a protocol with IT company for Egyptians health [4]. After one month, Vodafone made another protocol with Ericsson for Mobile Health [5].

Since year 2000, we are international reviewers and researchers in the field of intelligent algorithms for cancer diagnosis and also medical imaging processing [6-9]. This is why; we believe that today's mobile health products still missing a real intelligent remote diagnosis engine for cancer remote diagnosis. Moreover, Complexities of cancer domains may lead to uncertain diagnosis decisions.

In this paper, we want to extend our experience to mobile teleradiology for cancer patients. Our main goal is to propose, a novel integrated Intelligent Remote Diagnosis system for Mobile Teleradiology. It will combine two main intelligent techniques, namely case-based reasoning [CBR] [10-12] and Neural Networks [NN]. Also, advances in mobile medical imaging retrieval as Context-Based Image Retrieval [CBIR] [13] and segmentation algorithms such as genetic algorithm [8], watershed algorithm, active contouring and cellular automata Grow Cut method will be important parts in our research proposal. In the coming parts of the proposal, we are going to state more clearly our main research objective and describe each technique in more details.

10.2 Background and State-of-the-Art

Wireless transfer of radiology images to a portable computer was reported early in emergency medicine [29]. With the advance of digital cellular phones and worldwide digital networks image transmission has been extended to major catastrophe sites and for purposes such as delivering information needed in post mortem recognition of bodies [29].

Wireless technology is identical to conventional teleradiology, with the obvious difference of using a radio frequency wireless network for the digital communication of radiographic images. There are four major disadvantages with wireless technologies: reliability, cost, security and speed. The obvious major advantage of such technology is the ability to view images virtually anywhere, from a hospital patient room to the quagmire of the battlefield.

Utilization of ICT (*information and communication technology*) in health care has moved from individual projects and services to a more comprehensive model. Instead of telemedicine, terms like telehealth, eHealth, on-line health and most recently connected health (Microsoft Corporation 2009) [29] have emerged.

eHealth is an umbrella term that gathers together ICT usage in health care (World Health Organization 2010). It includes major infrastructure services and at the other end also services targeted to individual citizens.

According to the EU eEurope action plan "*An information society for all*" eHealth could also seen as a derivative of eServices, in line with similar terms like e-Commerce or e-Governance (COM/2002/0263 final). The main political goal is to deliver more accessible and better services to citizens [29].

In the future health care environment teleradiology has a strong role as one of the services given [29]. It is a means of delivering care, but not a medical discipline in itself. One key issue is the well-established integration to other health information systems, especially RIS. From the point of view of users, usability and reliable functionality are key issues [29].

10.3 Development and Proposing a New Intelligent case-based Reasoning Decision Engine for Cacer Diagnosis

This section illustrates a prototype hybrid Intelligent decision support system namely Cancer-C for cancer diagnosis, which is applied to thyroid cancer. Cancer-C is based on the case based reasoning methodology.

The main aim of our research was to develop a new adaptation model, which uses much less adaptation knowledge. The model combines transformational and hierarchical adaptation techniques with ANN's. The ANN's are trained on transformational rules to learn how to make adaptation to avoid training with retrieved patient cases, which may have very similar features but completely different diagnoses. Also, to avoid the problem faced with other medical CBR system that uses a large set of transformational rules. A high performance rate of diagnosis is achieved at different ranges of similarities between the new case and the retrieved case. The average of the similarity ranges is [40%-100%].

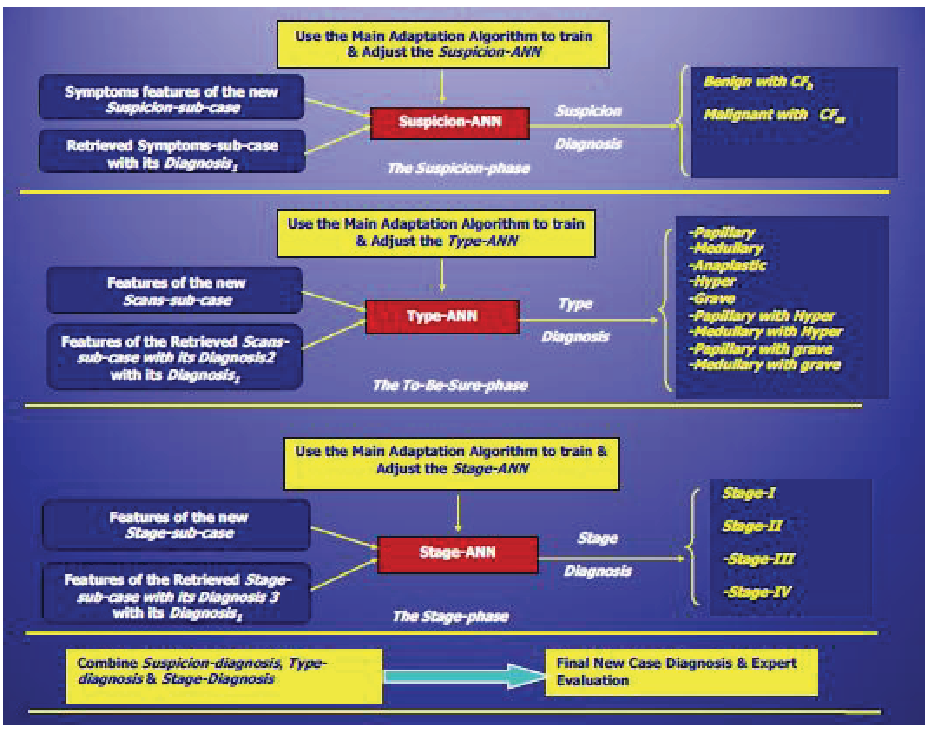

Figure 10.1 A hierarchical Case-Based Decision Support System for Cancer Diagnosis on three levels of medical expert

The model consists of a hierarchy of three phases, which simulates the expert doctors reasoning phases for cancer diagnosis. CF's are also added to reflect our expert doctors' feelings of cancer suspicion. Figure 10.1 shows the architecture of the proposed Case-Based decision support architecture.

In our current research work, we want to implement this system on mobile devices to act as a pre-diagnosis/diagnosis tool for Physicians and Patients. More experts will be involved and more cases will be collected for better accuracy and reliability of diagnosis decisions.

As shown a new patient case is diagnosed by using our proposed case-based decision support model, Case diagnosis is performed in a top-down fashion using a hierarchy of three phases, which simulates the expert doctor phases of cancer diagnosis, the Suspicion-phase is for diagnosing cancer suspicion, the To-Be-Sure-phase is for diagnosing cancer type and the Stage-phase is for diagnosing cancer stage. All the three phases are similar in their structure but they are different in their inputs and outputs. Each phase uses a single ANN. The final diagnosis of the new patient case is composed from the adapted sub-cases diagnoses of the three phases, all of which are then evaluated by the expert doctor.

10.4 Experimental Results of The Proposed System

Expert doctors in the National Cancer Institute of Egypt supplied our system case-memory with 820 real patient cases and a detailed analysis of thyroid cancer diseases. This is besides other cancer resources from the Internet.

As explained by our expert doctors, a typical patient case consists of 44 features, which are critical for the diagnosis. These features can be divided into groups of features.

Features of Suspicion sub-case	Features of Scans sub-case	Features of Stage sub-case
m-solitary	T3-abnormal	Age < 45
m-rapid enlargement	T4-abnormal	Age > 45
m-history of thyroid cancer	TSH-abnormal	Size < = 1 cm
m-hoarseness	FNA-papillary	1cm < =size < = 4 cm
m-dysphagia	Serum Calcium	localized in thyroid gland
m-diarrhea	Microsomal Antibodies	Bone metasis
m-flush	RAIU	MRI fixation to trachea
m-firm	Serum Calcitonion	MRI fixation to larynx
m-cold	FNA-medullary	Distant metasis to other part
m-solid	FNA-anaplastic	Localized in Thyroid gland
b-mutlinodular	T3-hyper	Lung Metasis
b-pain in neck	T4-hyper	
b-hyper symptoms	TSH-hyper	
b-smooth	Histopathology-pap	
b-warm	Histopathology-med	
b-cystic		
b-grave symptoms		

Figure 10.2 Frame scheme of the 44 real medical features of thyroid cancer

The first group contains 18 features of the initial symptoms of the disease. The second group contains 15 features of the lab-tests and scans results. The third group contains 11 stage features of the malignant disease, if exists. These groups appear to be mutually exclusive, so we decompose each case in the case-memory into sub-cases, which are the Symptoms-Sub-case, the Scans-Sub-case and the Stage-Sub-case. Figure 10.2. Shows a frame description of the 44 thyroid cancer features.

Performance Measures: We have designed two performance measures for our decision support system. They are diagnosis performance model and the adaptation performance [6].

Diagnosis Model Performance: In our cross-validation test, 80 cases of the 220 definite cases are used for testing and the other 140 cases are stored in the case-memory to be used for retrieval. Also, 300 cases of the 600 indefinite cases are used for testing, while the other 300 cases are stored in the case-memory to be used for retrieval. That is, a total of 380 cases are used for testing and a total of 440 cases are stored in the case-memory to be used for retrieval. Table 10.1 shows the diagnosis performance (*accuracy rate*) of our hybrid adaptation model.

The diagnosis performance at each phase is calculated as:

$$PhaseAccuracy = \frac{TC}{TT} \tag{10.1}$$

where, *TC* is the total number of test sub-cases diagnosed correctly and *TT* is the total number of test sub-cases used for testing.

At our first experiments the model shows an overall high accuracy but this because all features values are in binary.

Table 10.1, shows our algorithm performance. As shown, high retrieval performance is achieved for each set of cases. This high accuracy is due to the following main factors, which we fixed in our experiments: Usage of fixed features dataset that is well formatted and Use of Nearest-Neighbour retrieval algorithm [11].

Table 10.1 Retrieval Accuracy of the CBIR

Accuracy Rate	No. Of Test Cases	Average Retrieval Accuracy
1. Benign	200	**89%**
2. Malignant	**299**	**95%**

10.5 Conclusion

This chapter is to investigate recent Artificial Intelligence technologies that are to propose a novel integrated Intelligent Remote Diagnosis system for Information System for Cancer diseases based on Cloud-Computing platform. This is to investigate artificial intelligent techniques, namely case-based reasoning (CBR) and neural networks (NN). Also, advances in cloud-computing and teleradiology data can be used for overall patient health management.

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CHAPTER 11

ADVANCED INTELLIGENT ROBOT CONTROL INTERFACES FOR THE VIRTUAL REALITY SIMULATION APPLIED TO THE INDUCTION HARDENING PROCESS

Gal Ionel-Alexandru[1], Vladareanu Luige[1,*] and Shuang Cang[2]

[1] Institute of Solid Mechanics of Romanian Academy, Romanian Academy, Bucharest, Romania
[2] Northumbria University, Newcastle Business School, Faculty of Business and Law, UK
Emails: luigiv2007@yahoo.com.sg; luige.vladareanu@vipro.edu.ro; galexandru2003@yahoo.com

Abstract. The paper presents advanced intelligent control interfaces, for the virtual reality simulation of the robot mechanical structure Ro CIF VIP, using Unity3D, applied to the induction hardening process. A mechanical structure with 5 degrees of freedom, designed to be used for induction hardening process of building metallic profiles is proposed. All 5 joints of the proposed mechanical structure are prismatic, required to move a metallic profile through the inducer. The simulation was achieved using Unity3D software which provides the virtual environment needed for our purposes. To use the virtual simulation of the structure, we have had to build software components to help us gain access to the simulated components during the simulation. More components were added to implement the user interface and also the management backbone of the entire simulation. To analyze the experimental data, we have built our own system to save the joint values and the first 4 parameters of Interface class are values used for the advanced intelligent control interfaces. The experimental data of the reference and actual values for two gripping prismatic joints are also analyzed and presented graphically. All of the software components which are used to interact with the mechanical system or its joints have been configured individually, supplying environment or physical variables for each component. The results obtained lead to the development of advanced intelligent control interfaces for the 5 DOF robot, Ro CIF VIP, and its PID control law using this virtual reality simulation, and their testing before building the actual robot.

Keywords: Virtual environment; Simulation; Unity3D; Induction hardening.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (137–284)

11.1 Introduction

While metallic frame buildings are gaining popularity, the industrial process of building these structures is continuously being improved. For this, an approach is to use induction hardening for certain elements of the structure, to improve their strength and maximum load. But induction hardening is not an easy process to use, because of several parameters which need to be configured, one of these being the induction swipe speed. While other researches focus on different alloys to be hardened [1] or on the preheating process [2] before doing the induction hardening, other test the effect of high frequency induction on different applications [3-5]. Porpandiselvi et. al [6] achieved a new induction hardening process in which they use two different inverters to harden a required object with high and low frequencies. But Neumeyer et. al [7] managed to simulate the induction hardening, demonstrating how the profile temperature is time dependent and can be calculated using finite element analysis, and optimize power and frequency for the hardening process.

What we want to achieve in the end, by using the proposed mechanical structure, is a controlled system which can vary the velocity of the metallic profile while being subjected to the induction hardening process. In this paper we present the mechanical structure which will achieve the induction hardening, simulated using Unity3D. For this we have had to build our own virtual environment and import the 3D structure, while developing software modules to help with the simulation.

While Mahayudin et. al [8] is studying ways to visualize virtual environments by using Unity3D, Ruzinor et. al [9-11] have researched the way to simulate big virtual working environments, and Shin et. al [12] studies how to develop the 3D virtual environment and how to navigate through it for simulations on navigation in virtual scenarios.

Even if the researches using the virtual environment Unity3D are at the beginning, Chen et. al [13] have developed a virtual application for testing a 3D vehicle inside the Unity3D software. Also, research on virtual environment provided by Unity3D was not limited to terrestrial vehicles, but was also conducted on aerial UAVs [14].

Certain researchers have even used Unity3D to simulate through animation, testing of real robots by connecting them with the virtual environment through specific interfaces [15, 16], allowing the robot to experience different simulated scenarios.

11.2 Proposed Mechanical Structure

The proposed mechanical structure Ro CIF VIP [17] with 5 degrees of freedom is presented in Figure 11.1. The structure is made to apply induction hardening treatment on metallic profiles of length no more than 60cm. The structure can be divided into 4 main sections according to their designation. The first section contains two prismatic joints. One joint is for grabbing the metallic profile (top green part in Figure 11.1) when the user inserts it inside the machine, and the other is for sliding it down through the inducer (top yellow part in Figure 11.1). The second section is made out of the inducer and cooling system (the inducer has magenta color in Figure 11.1). At this point this section has no degree of freedom. The third section is similar to the first as it consists of two prismatic joints. The first one will grab the metallic profile (bottom green component in Figure 11.1) as it comes out of the inducer, and the second will slide the profile down through and out of the inducer section (bottom yellow component in Figure 11.1). The fourth and final section is the extraction system (blue part in Figure 11.1). This is made out of one prismatic joint and it will take out of the mechanical system the metallic profile when the induction process was completed.

Figure 11.1 Proposed mechanical structure of Ro CIF VIP with 5 DOF

11.3 Unit 3D Integration

For each prismatic joint described and presented in Figure 11.1, we have had to simulate it in the virtual environment. This was achieved by adding prismatic joints to all 5 degrees of freedom. Unity3D provides many tools for building a virtual simulation but it does not provide a specific prismatic joint component. This is why we have had to add one, ourselves.

The main advantage in working with Unity3D is that it provides the possibility to create new components, starting from existing ones or just starting from scratch. The other advantage is working with C# which is an advanced programming language. With this we have created several components of the simulation.

The component presented in Figure 11.2, is the Translation Joint class which implements a prismatic joint. We can see in this figure that the class has several fields of data and methods to compute different parameters or methods that allow external objects to access data information.

One important component of the Translation Joint class is the OnPositionChanged Event. This event, which is present in Figure 11.2, will be triggered every time the joint

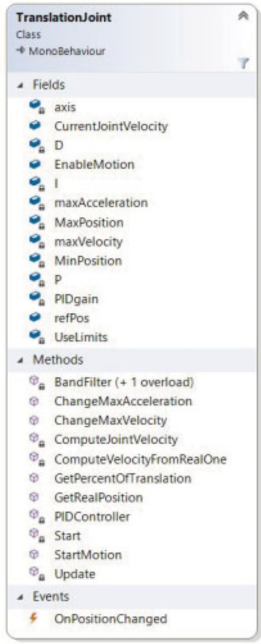

Figure 11.2 Translation Joint Class diagram

will move. This will allow any components to be executed when the joint is moving, to check if the position is close to a position constraint or to trigger a proximity sensor. With this component we can easily simulate proximity sensors, or just to detect when the joint is moving.

Figures 11.3 through Figures 11.5 presents the prismatic joint components added to the simulated mechanical components. As one can see, every component is configured differently, depending on each joint's parameters. In each figure, the top field states the name of the game object to which the joint component is attached. In this way, we can't make mistakes while configuring the component, because we always know which part is being configured. Also, in these figures there are several other components which we have not detailed, that contain the relative position of the game object (*Transform component*) and the physical parameters like mass and density (*Rigidbody component*). All of these components form just one small part of the entire structure, but when put together they form the virtual simulation of the entire mechanical structure of the robot Ro CIF VIP [18, 19] with 5 DOF.

Comparing Figure 11.2 which contains the Translation Joint class diagram with Figures 11.3 to Figures 11.5 one can see that every parameter is present and configured. Thus, we have computed and inserted the maximum velocity and maximum acceleration which the joint PID controller will use to filter these values. The axis parameter configures the axis on which the joint is moving. This means that we can tell the component the direction of motion, which can be just one axis or a combination of all 3. Also the sign is very important since it will provide the positive direction.

Two important parameters of the Translation Joint component are the Min and Max position. These values define the motion limits of the joint in Cartesian coordinates, given in the operational space. Based on these values we have defined the Ref Pos parameter which is presented as a sliding controller in Figures 11.3 to Figures 11.5.

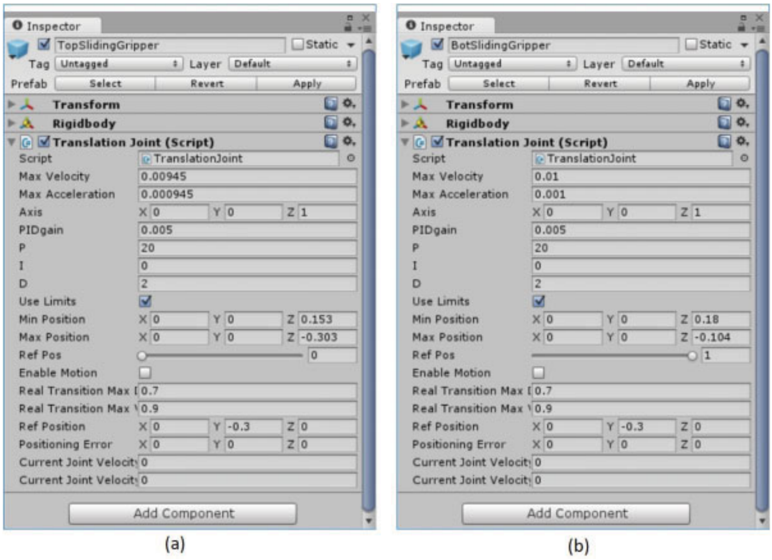

Figure 11.3 Top (a) and bottom (b) sliding prismatic joint

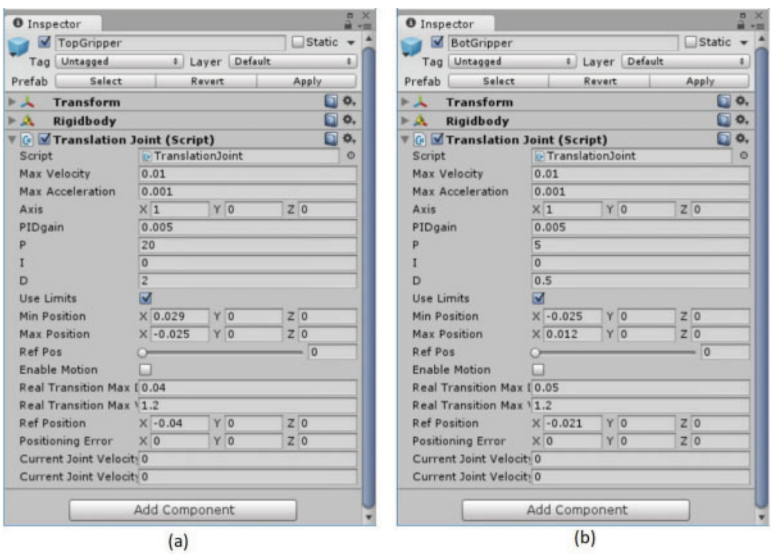

Figure 11.4 Top (a) and bottom (b) gripper prismatic joint

This parameter can define the target position as a percentage between the minimum and maximum limit values. This means that we can set the reference as the end position, since the maximum acceleration and velocity are limited, we can work with these parameters to define the Translation Joint motion to the desired position. Of course, we can disable the limits using parameter UseLimits and then the joint has to work with operational space reference points. This is required when a translation joint reference is given in Cartesian coordinates.

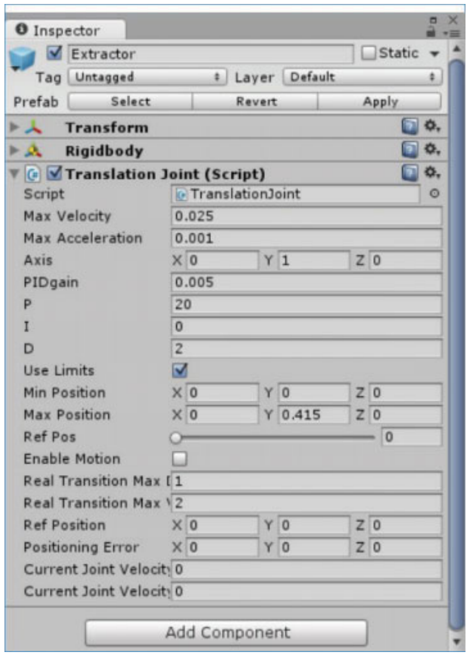

Figure 11.5 Extraction prismatic joint

To control the prismatic joints of our robot, we have implemented a PID controller. The control law will control the velocity of the joints, because we require a certain speed of the metallic profile going through the inducer. For this, every Translation Joint component, has 3 parameters: P (*proportional*), I (*integrative*) and D (*derivative*). These 3 parameters were configured for each joint individually. But because these particular joints have the same task, they will behave the same, so the parameters are identical for each two components: top and bottom sliding prismatic joints, top and bottom gripper joints. The extractor was configured as the sliding joints. Using these parameters, the PID controller will control each joint individually to achieve the desired reference velocity and position.

The second component called Interface is the GUI component of this virtual simulation, and it is initialized using the root object within the simulation. This means that this component does not depend on the robot behavior within the simulation scene, and will even be present if the robot is switched with another.

Figure 11.7 presents the class diagram of SimStarter object. Comparing with Figure 11.6, we identify the parameter responsible with linking the application with the robotic structure of Ro CIF VIP, named cifPrefab. This component stores the link to the prefab file that contains the entire robot structure from Figure 11.1.

Using this reference we can even add multiple robots in the same virtual environment.

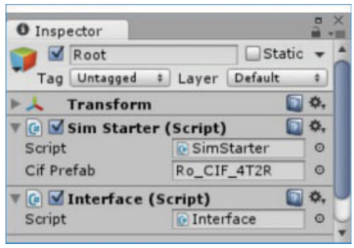

Figure 11.6 Root component which starts the entire simulation

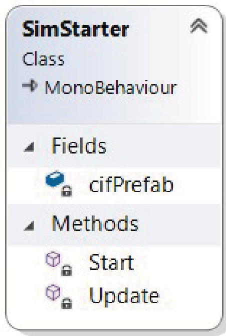

Figure 11.7 SimStarter class diagram

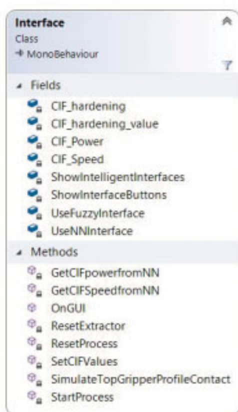

Figure 11.8 GUI Class which provides commands to the user

Figure 11.8 presents the Interface class diagram. This class has few variables, but has several methods called when the user presses a button to do an action. With the tools that Unity provides, we can build a good GUI in a short time that will fulfill our every need.

The first 4 parameters of Interface class are values required to use with the intelligent interfaces. These parameters will take the user input and compute the robot parameters required for the CIF process. The next 4 parameters are values required for GUI to switch between different states of the interface. This means that by pressing different buttons the GUI will change its appearance.

Figure 11.9 and Figure 11.10 present two states of the GUI. The first one is when the robot control section is shown, and the second when the entire structure of the GUI is presented to the user to use the intelligent interfaces for computing the robot control parameters.

Figure 11.9 GUI required for controlling the virtual simulation

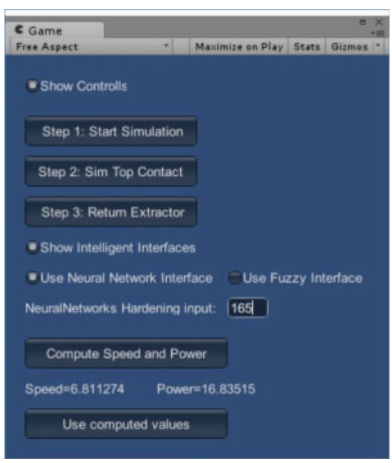

Figure 11.10 GUI used to compute CIF parameters using intelligent interfaces

The robot control buttons presented in Figure 11.9 control the CIF process in 3 stages. The first stage is the Start Simulation. This sends to the robot the *Ready* command which it interprets as a start button. At this point it will wait for the metallic profile to be inserted into the machine to grab it and start the CIF process. The second button which is defined as a second step is the Sim Top Contact button. This button simulates the metallic profile presence within the top gripper component. Because we have designed the robot with a presence sensor, we've had to add it into the virtual environment as well. After completing the second step by pressing the required button, the robot starts the CIF process and slides the metallic profile through the inducer. At the end, after the profile was extracted from the structure, the user can press the third button as the last step of the simulation which is the Return Extract button. On this action the metallic profile will reset its position at start and the whole process can be started again from step 1.

As presented in Figure 11.8, the Interface class has several methods that are called when a certain button is pressed from GUI, and are named suggestively.

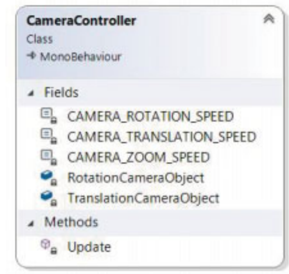

Figure 11.11 GUI Class for navigating through the virtual environment

One important component during the simulation is the camera controller. This component will allow the user to navigate through the entire virtual environment, and observe the simulation from every angle he sees fit.

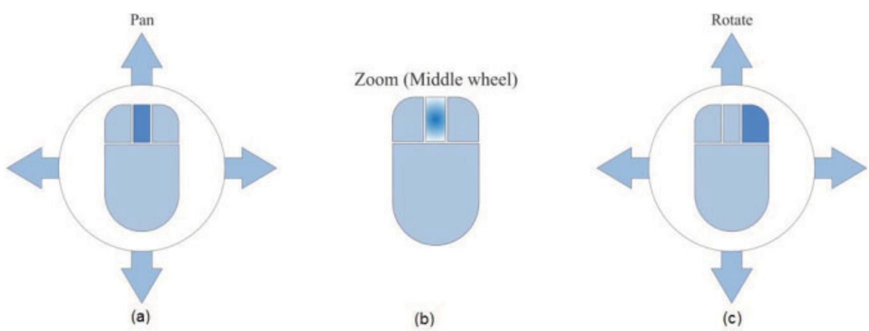

Figure 11.12 Pan (a), Zoom (b), and Rotation (c) navigation with mouse

The designed class for this feature is presented in Figures 11.11. As one can see, it has only one method called Update, in which all the inputs are tracked and has another five fields as variables. These variables are enough to move (pan), rotate and zoom in/out the camera within the virtual environment, achieving the navigation component of the virtual simulation.

Figures 11.12 present how the navigation controller can be used within the virtual environment by using the mouse buttons and movement. The navigation controller was designed to be used entirely with a mouse as follows. To pan inside the environment the user has to press the scroll wheel button and move the mouse. To zoom inside the virtual environment and better see the robot, the user has to use the mouse scroll wheel. To rotate around the robot, the user has to press the right mouse button and move the mouse until the desired angle is achieved. With these 3 operations the navigation inside the virtual environment was fulfilled.

While the GUI and navigation components are needed for the human interaction with the virtual environment, we still need some components to link everything together. These components are SimManager component and Ro_CIF_VIP component. They are presented in Figures 11.13 and Figures 11.15 as class diagrams.

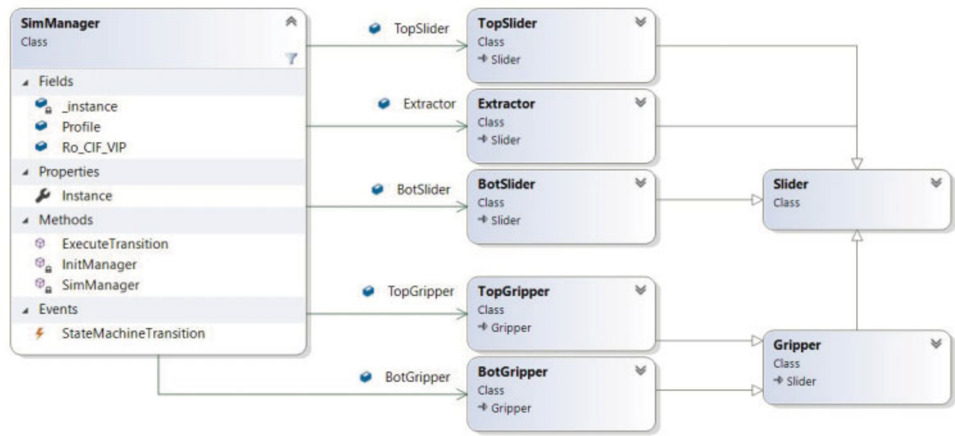

Figure 11.13 SimManager class diagram required for accessing the simulated components from within the app

The SimManager class is the backbone of the entire robot simulation. This is the place that links all the components, and with its help, any other component can get a reference to another, to use its data and properties. In this way, we can use the sensors attached on each component, to give automatic commands to the joints. By being the central component of the simulation, it has to be very well structured and clean. This is why there are no other components other that the initialization of each joint and the reference to each section of the mechanical system Ro CIF VIP.

Figures 11.13 also shows through arrows how the prismatic joint components inherit their data type from Gripper and Slider class. This means that every parameter and method developed inside the slider class is automatically present in the Translation Joint components and variables.

Figures 11.14 presents the structure and diagram of Slider class, which plays an important role in using the translation joints, because it facilitates setting new references and getting the joint values when called through the SimManager class instance.

The joint parameter of Slider class connects the class instance to a Translation Joint class instance, presented in figure 2. By doing this we can assign a certain instance of the prismatic joint to configure and monitor.

The triggerPoints and speciaTriggerPoints defined in the Slider class will provide a simulation for special sensor points in which the prismatic joints will have presence sensors that can trigger an action. These two parameters hold the list of such points defined in the operational space of each joint.

While SimManager is the central point of the simulation, Ro CIF VIP class is the one to link every component found in SimManager to the actual object within the simulation. In

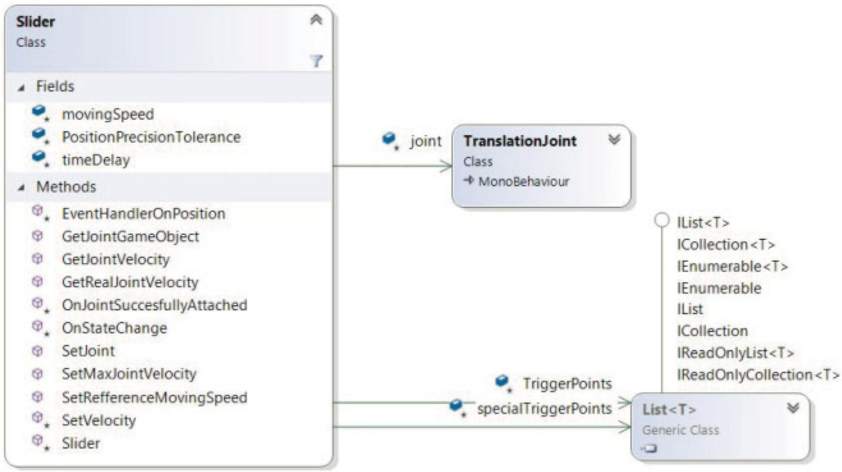

Figure 11.14 Slider class diagram inherited by each Translation Joint class

Unity, we can say there are two types of components or classes. The first type is the class which inherits the MonoBehaviour class and can be present inside the simulation, having parameters, like the TranslationJoint class. The second type is the type that does not inherit the MonoBehaviour class. The second type class must have appropriate variables and must be instantiated by a class that inherits MonoBehaviour directly or by a different class which at some point was initialized by one.

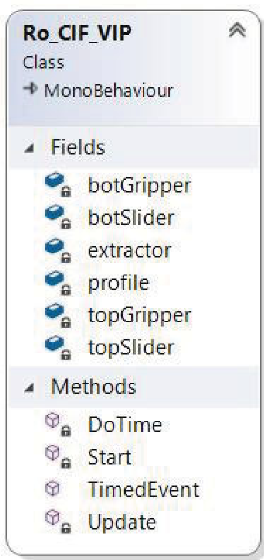

Figure 11.15 Ro CIF VIP class component required to link the simulated objects with the manager variables

Ro_CIF_VIP class is of the first type, and has a reference for each prismatic joint, plus the profile which is being moved. These references are assigned at design time, but can be changed during the simulation if we can find the reference to the objects required by the simulation.

To analyze the experimental data, we have built our own system to save the joint values. The central point of this is the SaveToXML class, presented in figure 20 as a class diagram. This class is responsible for recording the reference and real values of the monitored joint. After recording the joint data, the user has the possibility to save it into XML files. The recorded data will be saved into 3 fields: time since simulation start, joint reference value at that particular time and the real joint value. To save the simulation data, the user has to enable a trigger within the SaveToXML class, called SaveData. This is the same for saving the recorded data to a file by using the SaveToFile trigger.

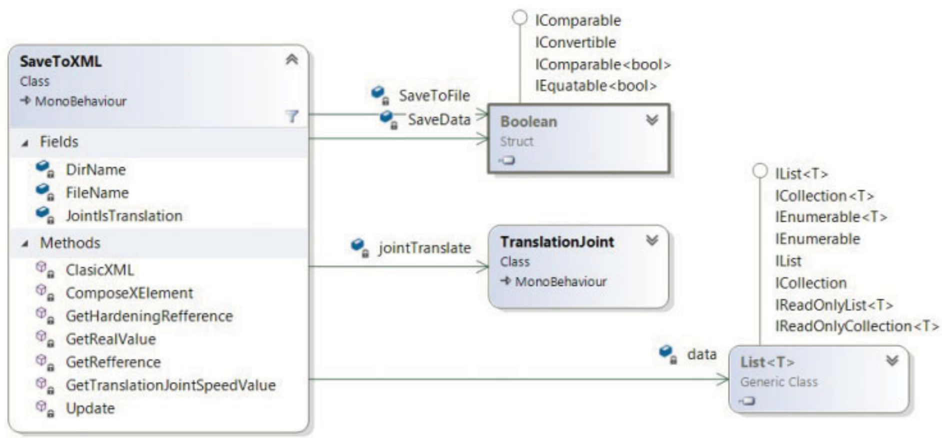

Figure 11.16 Save to XML experimental data, class diagram

Before recording any data, the user has to select the monitored joint. The joint reference will be stored in the jointTranslate field which is of TranslationJoint class type. At this point, to use the data export module, the user has to use the Unity3D project, as the GUI for the save commands is not yet implemented.

11.4 Results

After the virtual environment and simulation were completed we have tested the simulated CIF process. For this we have used constant reference values to send the prismatic joints to their new targets using constant speeds. To analyze the simulation results we have saved the joint data into XML files and then built graphs to better illustrate the joint motion according to the received reference values.

Figures 11.17 present the experimental data for the prismatic joints used for sliding the metallic profile through the inducer. As one can see, the reference starts at 0 values which is the starting position for the joints and converts to values 1 representing 100% of the translation motion. After the reference value is changed, the joint starts to move towards the end position in a constant speed, and lowers it near the end point so that it will not hit the limiter.

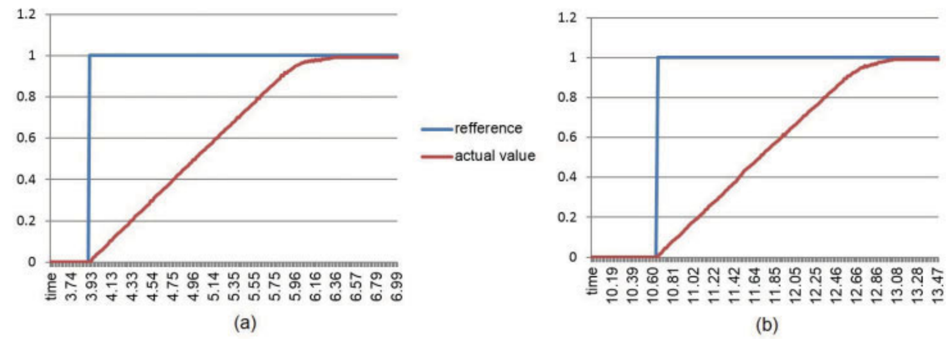

Figure 11.17 Saved data for Top Sliding (a) and Bottom Sliding (b) prismatic joint

Figures 11.18 present the experimental data for the two gripping prismatic joints, Top Gripper and Bottom Gripper. For these two joints the reference values has two moments when it changes. At first, the gripper will open, but each joint was built differently and the top gripper opens for reference of 0 and the bottom one opens for reference of 1. What we can see is that the time duration for closing and opening the grippers is around 1.5 seconds for the whole length of the joint. This means that the gripper will act faster when it will actually grip a metallic profile, since the distance for closing will be shorter.

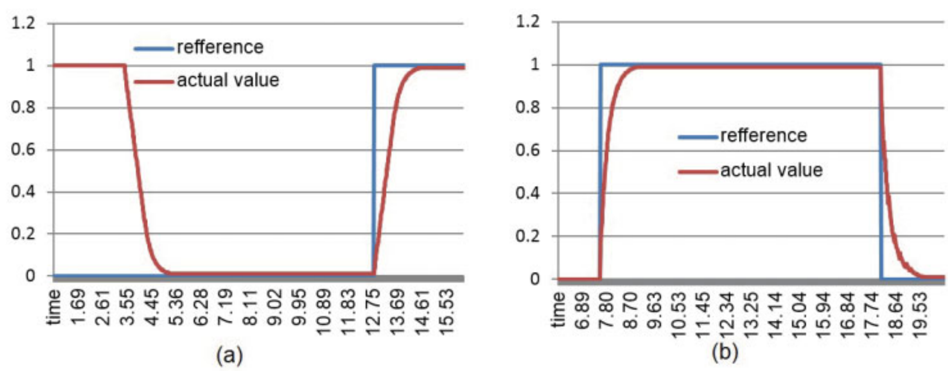

Figure 11.18 Saved data for Top Gripper (a) and Bottom Gripper (b) prismatic joint

Figure 11.19 present the saved experimental data for the extractor joint. This joint will extract the metallic profile from the robotic structure. Figure 11.19 shows the extraction and homing motion of this prismatic joint. Starting from the second 64, the extractor takes the metallic profile out of the structure and at second 70 the user presses the reset command which returns the extractor using a homing motion. We can see that for homing, the moving speed is doubled and that the joint velocity during both motions is constant up until the target position when it will slow down to not hit the limiters.

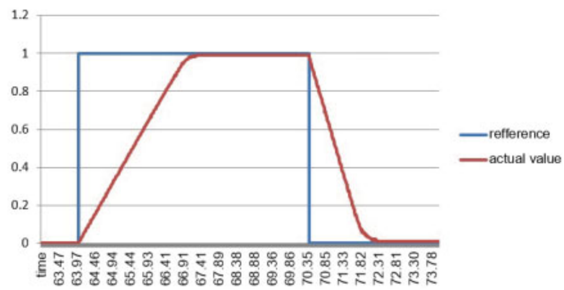

Figure 11.19 Saved data for Extractor prismatic joint

11.5 Conclusion

In this paper we have used the 3D model of a 5DOF mechanical structure (Ro CIF VIP) designed for induction hardening of metallic profiles, and simulated it using Unity3D. To achieve the simulation, we have had to build our own software components, at first to simulate a prismatic joint and after that to use it inside the virtual simulation. To use the virtual environment, we have built a user interface and a navigation component so that the simulation can be controlled by any user. But, to use all of these components, we needed a central point from where all of them could be called. This is why we have designed a manager, to link every part of the simulation, and provide software reference to each initialized component. By using Unity3D software, we have created a virtual simulation of the proposed mechanical structure with which we can test and simulate the induction hardening process, to detect structural anomalies and test future intelligent control methods. Following the conducted simulations, we have concluded that the built virtual simulation achieved its goal of testing the 5DOF robot, Ro CIF VIP, and its PID control law. Using this virtual simulation, we will be able to add more advanced intelligent control interfaces to test them before building the actual robot.

Acknowledgments

This work was developed with the support of Romanian MCI and MFE by Competitiveness Operational Programme (COP) / ”*Pro-gramul Operaional Competitivitate*” (POC), TOP MetEco AMBI-ENT project, ID P_39_383, contract 107/09.09.2016 and the European Commission Marie Skodowska-Curie SMOOTH project (H2020-MSCA-RISE-2016-734875).

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CHAPTER 12

ANALYSIS OF TELEMEDICINE TECHNOLOGIES

Vikram Puri[1], Jolanda G Tromp[1], Noell C.L. Leroy[2], Chung Le Van[1], Nhu Gia Nguyen[1],

[1] Duy Tan University, Da Nang, Vietnam
[2] State university of Newyork, Oswego, USA
Emails: purivikram@duytan.edu.vn, jolanda.tromp@duytan.edu.vn, nleroy@oswego.edu, levanchung@duytan.edu.vn, nguyengianhu@duytan.edu.vn

Abstract

Telemedicine, the use of novel combinations of Telecommunication technology and Information technology to provide clinical healthcare from a distance, is a promising new technology to overcome distance barriers and to improve access to medical services to geographically distant rural communities. Considering that more than half of the global rural population is excluded from healthcare, telemedicine applications offer a beneficial approach to improve the opportunity for timely healthcare, reduce the chances of disease developing further, and reduce the cost of consultations, thereby making healthcare more accessible for all. With the spreading adoption of telemedicine technology solutions, better outcomes for health and recovery from sickness can be expected. Telemedicine is therefore ultimately beneficial for rural or unreachable places where distance is still a barrier for access to the Health Services. Telemedicine technologies can be categorized based on usage. This chapter describes the latest research and current market developments regarding these technologies. Additionally, this chapter highlights the latest, state-of-the-art research findings from the development and deployment of these technologies. This chapter provides an in-depth analysis of Telemedicine technologies in terms of current open issues for future research and development.

Keywords: Telemedicine, Long-distance healthcare, Rural Healthcare, Primary Healthcare

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (153–284)

12.1 Introduction

Telemedicine [1] is a way to provide the medical information and services with the help of telecommunication technologies. Telemedicine is a bidirectional audio-video communication between healthcare service provider and a patient in their place of residence. Telemedicine is a exchange of electronics information from one location to other location for the treatment or improvement of the patient status according to the words of American Telemedicine Association (ATA) [2]. Telehealth care [3] [4] facilities provides a virtual physical presence of medical doctors to the Patient's home for the medical treatment and monitoring doctor to the Patient's Home for the medical treatment and monitoring of the patient and their vital signs. Due to two way communication, diseases can be detected by the medical doctors through the monitoring their vital signs and providing medical assessments through via Telehealth care system. From the last few decades [5, 6], telemedicine technologies are increasing day by day and embedded into related technologies which have already used in the hospitals, healthcare centers and patient home. Telemedicine technology is beneficial in many forms like exchange the medical information between doctors to doctor, doctor to patient with the live interactive audio video sessions. It also helpful to provide the medical consultation, health treatment suggestions according to the patient analysis report. In additions, the services origin from the telemedicine technologies provide facility to access the health education system and it also supporting self-management services via internet connected devices.

Figure 12.1 Telemedicine Technologies

12.2 Literature Review

Pacis, Subido, Bugtai [7] have reviewed the combination of Artificial Intelligence and telemedicine technology for the endless way of development in the field of medicine. They have faced a lot of challenges likes device and telemedicine programs are very expensive, maintain a stable internet connection for rural or underdeveloped areas. Security level between the connection is low and difficult to maintain a confidential call via internet or satellite communication. Due to some reason and condition medical electronics device will malfunctioned which directly impact on the patient monitoring. Fun Li, Wei Li [8], Guler, Ubeyli [12] have reviewed and compiled the different types of the telemedicine technologies like Smart system for the specific diseases, elderly assistant technology etc. They have discussed the following issues to implement the telemedicine technology, real time data acquisition, system reliability, energy conservation, interference communication, and data privacy and security. There are number of opportunities in the R&D for better development of the telemedicine technologies. Parmar, Mackie, Varghese, Cooper [9] have evaluated the benefits from the telemedicine technology, hindrance to adopt telemedicine and identify the research areas for the benefits of telemedicine technology. They also evaluate the HCV (Hepatitis C Virus) treatment with the help of telemedicine technology. According to the author studied, telemedicine technologies are less expensive but it need more number of systematic cost analysis. Johansson, wild [10] have reviewed about the acceptance and treatment outcomes regarding the telemedicine in the stroke management. Author studies 18 papers regarding the tele-strokes services which helps to better care as compare to traditional method. With the use of tele-stroke services, patients and teleservices provider got higher level of satisfaction. From these study, researcher says that more research is needed to explore the practical aspects of telemedicine technology. Bryant, Garnham, Tedmanson, Diamandi [11] have evaluated the research areas on the tele-psychology and tele-education and provide suggestion regarding the implementation of Information and Communication technologies (ICT) by social workers and also provide the mental health services. With the use of ICT based services, it creates a new way and shape for the social work education and to enhance motivation for ICT experts for work with rural local peoples and to develop more ICT based services for the remote community peoples. Navarro, Sanchez, Cegarra [13] have examined an important bridge between telemedicine technology and eknowledge of the patients through a survey is done from 252 patients of Hospital in Home Unit (HHU).This study helps to maintain a relationship between organizational learning and patients e-knowledge with the help of telemedicine technologies.

The studies discussed in this section illustrate that how telemedicine is beneficial for the improvement to the medical field. In this chapter , we will examine about various enabling technologies regarding the telemedicine technology till present.

12.3 Architecture of Telemedicine Technologies

Telemedicine applications consist of three modes:

1. Save and Forward
2. Tele-meeting
3. Video-meeting.

Save and forward, stores a patient's medical history and diagnosis report in a file with the help of Electronics Medical Records (EMR). The EMR software sends the report to the medical doctor for the advice. Telemedicine helps to reduce or bypass the typical problems of waiting-times and travel time, when taking an appointment with a medical consultant. However, this technique is not suitable in case of health problems that require immediate treatment.

Tele-meeting [28-30] is a consultation between the different parties discussions regarding the patient health through audio via Internet. It is also suitable as medium for a discussion between the patients and doctor about the medical treatment. Video Conferencing [31-33] have so far been found to be most beneficial and appropriate method for a long distance medical discussions. It used both audio and video and requires high bandwidth and the cost of equipment can be high if there is using Radio Frequency (RF) Components for the audio and video.

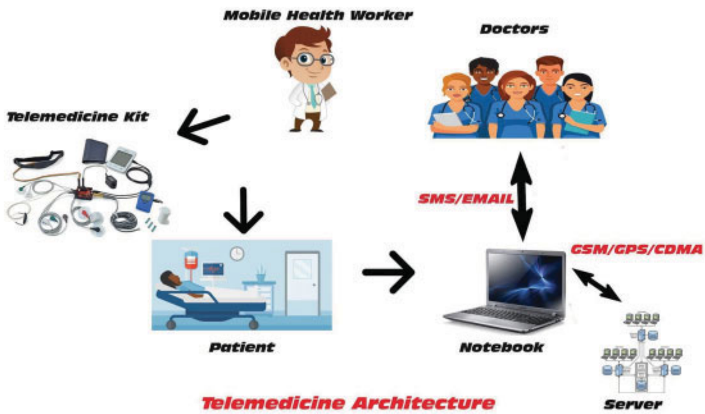

Figure 12.2 Telemedicine Architecture

12.4 Enabling Technologies for Telemedicine

12.4.1 Telehealth for Congestive Heart Failure

Currently, Heart Failure is become major problem and it is direct pathway to the unplanned emergency hospitalization. After the hospitalization from the heart failure, Persons have become more chance to re-admit again and it also decreases the rate of survival and quality of life [14]. The cost of caring is also very high for those patients who are suffering from the heart failure. In 2000 [15], Peoples had spent approximately 905 million euros in the hospitals for the treatment of heart failure. Telemedicine technology is an attractive solution for the reducing the rate of the hospitalization due to the Heart Failure [16] .With the help of telemedicine technology, we can avoid many existing implementation problems like improper health staff service model, improper alert management, improper audit for service, improper patient selection, lack of proper team structure and carefully re-design the telemedicine pathway to improve these implementation problems. Before implementing the telemedicine technology, telemedicine services are faced multiple barrier with different following themes (see Table 12.1):

1. User's related.
2. Health and Social Care organization related
3. Technology Related
4. Evidence / Economic Related.

Table 12.1 Multiple Barrier on different themes

Main Barriers	Reasons
1. Lack of Knowledge "How telemedicine will help [17]"	No interest regarding the telemedicine technology
2. No Clarification regarding the "How telemedicine work [18]"	No proper clarification regarding the how equipment is used in the telemedicine technology.
3. Peoples who face the problem like less confidence, short term memory and facing depression [19].	Spending a lot of time to understand the telemedicine technologies.

12.4.2 Telemedicine for the Veterans

On the basis of larger development, a telehealth program is introduced by the Veteran Health Administration (VHA) called Telehealth home care. This Program is embedded with the home telemonitoring to maintain care regarding the management of Disease cure technologies. A Survey is done with the use of this telehealth program. 17,025 patients are participated which have more than 2 mental or physical illness from the diabetes to depression [20]. Patients gets more satisfied level with the use of this program. 25 percent and 19 percent peoples gets reduces bed day care and hospital admission respectively. In 2012, a programs is designed for the remote monitoring of veterans. It is more beneficial for annual saving of $2000 per patient [21].These programs also qualifies 36 percent of the patients for the long term home care. In Addition, new admissions in the hospitals are also decreased by 38 percent in comparison with the last year records.

These Programs are the good example for the Telemedicine technology is beneficial and promising solution to maintain and reduces the effect of disease illness.

12.4.3 Tele-ICU (Intensive Care Unit)

Tele-ICU is called as a system that provides the intensive and critical care to patient via remote monitoring technology. Philips VISICU Platform [22] is based on the Tele-ICU which consist of three parts 1. Electronics Critical System 2. Smart alerts 3. Camera system for individual patient room. In the Tele-ICU, there is a central platform called "*eCare Manager*" which contains an electronic display which helps to monitor and analyze the medical data like blood pressure, oxygen level of the body, heart beat rate and body temperature and it also used machine and deep learning algorithm for pick up the emergency level signs. In the smart alert system, it is used as decision tool that helps to remotely monitor the changes in the patient's condition and make an appropriate advice according to the patient's reports. Tele-ICU [23] is as bidirectional audio-video communication to interact with the staff of ICU in- site as well as off- site and it is more beneficial when the patient is critically in the emergency situation.

Many Hospitals in the developed countries have implemented the tele-ICU for providing a better cure via critical care experts. Sentara Hospital [24] was the first hospital who had implemented the tele-ICU in the year 2000 at USA. Tele-ICU has implemented on more than 300 hospitals in the year of 2003 to 2013. Tele-ICU technology model depends on the various key points:

1. Number of patients accesses this service.
2. Patient acuity.
3. Mutual arrangement.

There are three types of general models which includes various combinations: In the first model, Patient is monitored without any interruption is said as ”*Continuous care model*”. Second model said as ”*Schedule care model*”, which is used for the periodic consultation at predefined schedule time. In the third model, ”*Reactive care model*” helps for visit or arrange meeting via virtualization.

12.4.4 Helping Patients Adhere to Medication Regimes

Millions of the peoples are suffering from the long-lasting diseases but they can properly manage with the use of prescribed drugs. The Conclude data from the experiments shows that those patients who can use technology for the treatment saves a lot of money as compared to non-technology usage patients.

Currently, the number of technology helps to make patient health better. Although, these technologies have a different way of working but beneficial for the patients to remind about medicines. Pill based software Alert system is a internet connected system which use to alert the patients regarding their medication and in case of remote caregivers, this system have ability to send the medical information via email.In the near future, pharmaceutical medicines are enabled with RFID tags or QR codes which is directly connected to the Cloud System. If some person can scan this information via smartphone, he/she gets the prescription regarding the medicine and also gives the information like Date of Manufacturing , Date of expiry and the contents of salts exist in the medicine.

Additionally, Connected Health Center, a subdivision of healthcare partner are exploited a trail to monitor the blood pressure and remind patients the medication via Wireless Pill Bottles.The result outcomes from this survey are 68 percent peoples have improved their medication with the use of Internet Connected devices and platforms. These technologies are the straightforward examples of Internet connected technologies improve the healthcare system , improving valuable results with low cost.

12.4.5 eReferral - reduces consultation time

eReferral [25] is a service model which helps for the integration of patient primary care and speciality care. In 2005 , first program is established at the US hospital when waiting and appointment time was increased from 2-3 months to more than 10 months. Currently this program has established with more than 40 speciality services. From the reference of this program, these type of service model covers major hospitals at San Francisco, England, Norway , Netherland , Australia. After the each implementation, usage of telemedicines services are improved and gets better results like short waiting time , reduce the crowd of visited patients and improved the satisfaction of the patients to meet the speciality doctor.

Now a days, this application is famous and doubled the usage as compare to the past decades. eReferral is an electronically bidirectional message in form of documents or PDF files which can exchange the expertise information between patient and viewer. Naseriasl , Adham , Janati [26] have reviewed the 4306 articles in the major research platforms like PubMed, Google Scholar, Scopus, Springer, Science Direct , SID and Iran Docs. Only 27 articles are satisfied to their findings.They find 17 e-referral system which have helps to improve the quality of communication between the doctor and patients , involve and integrate the medical and health centers , helps to reduce the wait time. Sadasivam [27] has integrating the e-referral system into the 137 regular clinical practical services which includes learn lesson to quit the smoking,implementation cost. With the help of this implementation, 86% of medical and 25.3% of dental practices have used the ereferral system.

The result from these survey have showed that e-referral system with telemedicine technologies are beneficial to reduce the fee cost of patients, waiting time, and most important thing satisfaction of the patient regarding their visit.

12.5 Conclusion

Presently, medical care are insufficient to fulfill the demand of health care providers and mismatch communication between the expertise doctors and remotely health care providers. Telemedicine technology provides a asynchronous bidirectional communication which can create connected health care platform model between expertise doctors, service providers and patients. This platform helps to improve the quality of medical services and to reduce the expensive of medical care. It helps to involve or participate more patients and directly concern with the expertise doctor.

In this chapter, we analyzed the research publications regarding the telemedicine and telemedicine enabling technologies that are used by the medical healthcare providers and presented the finding from the different telemedicine technologies based on the different medical cares like Heart Failure, Tele-ICU. To prov ide a deeper insight, this chapter discussed a wide overview of telemedicine technologies. This overview does not provide in depth analysis regarding the telemedicine technologies challenges like Security, C onnected internet to remote areas. Future research will need to overcome these challenges.

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Part III

ROBOTICS TECHNOLOGIES AND APPLICATIONS FOR HEALTH AND MEDICINE

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (163–284)

CHAPTER 13

CRITICAL POSITION USING ENVIRONMENT MODEL APPLIED ON WALKING ROBOTS

M. Migdalovici[1], L. Vladareanu[1], N. Pop[1], H. Yu[2,3], M. Iliescu[1], V. Vladareanu[1], D. Baran[4], G. Vladeanu[1]

[1] Romanian Academy, Institute of Solid Mechanics of the Romanian Academy, Romanian
[2] School of Computer Science and Network Security, Dongguan University of Technology, China
[3] Faculty of Science and Technology, Bournemouth University, Poole BH125BB, UK
[4] National Institute of Aerospace Research Elie Carafoli, Bucharest, Romanian
Emails: luige.vladareanu@vipro.edu.ro, migdal@imsar.bu.edu.ro, yuh@bournemouth.ac.uk, iliescumihaiela7@gmail.com, victor.vladareanu@vipro.edu.ro, nicpop@gmail.com

Abstract. The chapter presents the walking robots evolution models in correlation with modeling of the environment in order to integration into the concept of virtual reality by applying the virtual projection method. The environment's mathematical model is defined through the models of kinematics or dynamic systems for the general case of systems that depend on parameters. In the first part of the chapter, some mathematical conditions that imply the separation of stable regions from the free parameters domain of the system are formulated. The property of separation between stable and unstable regions from the free parameters domain of the system is deeply approached, being an important property of the dynamic system evolution model that approaches the phenomenon from the environment. In the second part an innovative method is developed on walking robot kinematics and dynamic models with aspects exemplified on walking robot leg. The results lead to an inverse method for identification of possible critical positions of the walking robot leg, applied in the robot control in the virtual reality environment by the virtual projection method.

Keywords: Environment's model, Walking robot, Kinematics/dynamic model, Stability regions.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (165–284)

13.1 Introduction

The first part of the exposure is referred to mathematical modeling of the environment where the walking robots evolution models are assumed.

The models of kinematics or dynamic system in the general case of systems that depend on parameters assure, by its properties, the mathematical characterization of the environment.

Any system is expressed in terms of relevant parameters as geometrical parameters, physical parameters (*in particular mechanical parameters*), possible chemical, biological, economical, etc, [1-8, 13-26].

The important property of the dynamic system evolution models that approach the phenomenon from the environment is property of separation between stable and unstable regions from the free parameters domain of the system. This property is proposed that define the environment's mathematical model. The mathematical conditions on the linear dynamic system matrix components that assure the separation between stable and unstable regions from the free parameters domain of the system are formulated.

In the second part of the exposure is described our walking robot evolution kinematics model and corresponding dynamic model with application on particular case of walking robot leg.

An inverse method for identification of possible critical positions of the walking robot is established. The link between mathematical model of the dynamic system walking robot and corresponding kinematics system mathematical model is emphasized.

The problem analyzed by kinematics walking robot model that can be analyzed as problem in dynamic walking robot model having similar results, is also underlined.

13.2 On the Environment's Mathematical Model

The mathematical property that one can remark on all dynamic systems models from the literature, which approaches the environment phenomena, is separation property between stable and unstable regions on the system free parameters domain [4-7]. We have formulated, for the first time, the sufficient conditions needed for the functions that defined the dynamic system, linear or non linear, which assure the separation between stable and unstable regions on the free parameters domain [6, 7].

The real matrix, which defines the linear dynamic system or "*first approximation*" of the nonlinear dynamic system in general case that depends on parameters, is denoted by *A* and assumed as matrix from $R^{n\times n}, n \in N$. Below is discussed on *QA* algorithm for Hessenberg form of the real matrix *A*.

Let matrix

$$A \in R^{n\times n}$$

be with real elements $a_{ij}, i = 1..n, j = 1..n$. The matrix *A* is considered for beginning that has the distinct eigenvalues, real or complex. The matrix *A* is in Hessenberg form if their elements

$$a_{ij} = 0$$

for

$$2 < i \leq n, j < i - 1$$

. Any real matrix *A* can be substituted by a similar matrix in Hessenberg form, because they have the same eigenvalues, which facilitates studies of the stability.

The QR algorithm is formulated in hypothesis of matrix *A* in Hessenberg form to assure that the complex eigenvalues $\alpha \pm i\beta$, if there exists, to appear in real final Schur form of the matrix *A*, calling the real matrix of two order $\begin{bmatrix} \alpha\beta \\ -\beta\alpha \end{bmatrix}$ situated for each distinct complex conjugate eigenvalues on the diagonal of the Schur form of the matrix and for each distinct real eigenvalue identified also on the diagonal of the Schur form of the matrix *A*, similar with initial matrix. The similar Schur form of the matrix *A* is justified in [7, 11, 12].

The matrices $Q_k, k = 1, 2..$ are orthogonal and the matrices R_k are invertible and upper triangular. The matrices $A_k, A_{k+1}, k = 1, 2...$ are similar and in Hessenberg form.

The *QR* algorithm convergence of matrix *A* to Schur form of the matrix, where real matrix *A* is in Hessenberg form, is analyzed by Parlet [11].

The matrix $A - \lambda I$, where the value λ is real or complex, is a matrix in Hessenberg form if the matrix *A* is in Hessenberg form. The value λ is named "*the shift of origin*" for the matrix. The shift of origin assures the transposition of the matrix with real components that describe the dynamic system in complex domain using suitable complex value λ.

The *QR* algorithm applied to matrix *A* using the shift of origin is defined by the relations [11]:

$$\begin{aligned} &Q_s(A_s - k_s I) = R_s, A_{s+1} = \\ &= R_s Q_s^T + k_s I = Q_s A_s Q_s^T, s = 1, 2, ... \end{aligned} \tag{13.1}$$

The initial matrix *A* of the system is denoted in the *QR* algorithm by A_1 and assumed in Hessenberg form, k_s is "*shift of origin*", Q_s is orthogonal matrix, $A_s, s \geq 2$ is in Hessenberg form, and matrix R_s is in upper triangular form.

The shift of origin, using initial value λ sufficient close to one matrix eigenvalue, real or complex, assures acceleration of the convergence in algorithm to the similar diagonal form of the matrix. This is also an important motivation to use algorithm by shift of origin.

The matrix *A* with distinct eigenvalues is similar with the corresponding matrix in Hessenberg form and algorithm through shift of origin facilitates the convergence of the initial matrix to similar diagonal form of the matrix.

The above analysis is established in hypothesis that all eigenvalues of the real matrix are distinct. For extension of the analysis in the case of real matrix multiple eigenvalues, calling to the results from matrix theory reminded below.

Hirsch, Smale and Devaney have verified on the linear normed space $L(R^n)$ of matrices that the set of matrices with distinct eigenvalues from space $L(R^n)$ is an open and dense set in this space [1].

The above quality creates the possibilities to motivate transmission of some properties, which can arise from the stability analysis on linear or on "*first approximation*" dynamic systems, from the real matrices set with distinct eigenvalues to the real matrices set that include multiple eigenvalues.

Some Liapunov theorems on linear or nonlinear local stability are reminded below.

Theorem 1. Let the linear dynamic system be defined by the differential equation of the form $\frac{dy}{dt} = Ay(t), y(t) = (y_1(t), ..., y_n(t))^T$, $A = (a_{ij}), i = 1..n, j = 1..n$, the symbol *T* signifying transposition of the matrix and where the values a_{ij} are assumed constants. If the real part of all eigenvalues of the matrix *A* is strictly negative then the solution of the differential equation is asymptotic stable in origin. If the real part at least one eigenvalue of the matrix *A* is strictly positive then the solution of the differential equation is unstable in origin. If the real part of the eigenvalues of the matrix *A* is strictly negative with the exception of at least one eigenvalue that has null real part then the stability of the dynamic system in origin is unknown (*possible stable or unstable*).

The function $f(x)$ is assumed dependent of variable $x = (x_1, ..., x_n)^T$ in the following, having value of function in the form . The functions $f(x) = (f_1(x), ..., f_n(x))^T$ are considered that can be developed in series as below:

$$\begin{aligned} f_i(x) = f_i(0) + \textstyle\sum_{j=1}^{n} \left(\partial f_i(x)/\partial x_j\right)\Big|_{\mathrm{x=0}} x_j \\ + \textstyle\sum_{j=1}^{n} \sum_{k=1}^{n} \left(\partial^2 f_i(x)/\partial x_j \partial x_k\right)\Big|_{\mathrm{x=0}} x_j x_k + ..., i = 1, ..., n \end{aligned} \tag{13.2}$$

Without loss of the generality can consider $f_i(0) = 0, i = 1, ..n$ and using the notations $a_{ij} = \partial f_i(x)/\partial x_j|_{x=0}$, $i, j = 1, ..n$ for the first order derivatives we can formulate the differential equation:

$$\frac{dx}{dt} = [a_{ij}]\, x + g(x); i, j = 1, ..., n \tag{13.3}$$

The linear system of "*first approximation*" deduced from (13.3) is of the form:

$$\frac{dx}{dt} = [a_{ij}]\, x; i, j = 1, ..., n \tag{13.4}$$

The following Liapunov theorems are also mentioned:

Theorem 2. The evolution of non linear dynamic system (13.3) is asymptotic stable in origin if the real part of all eigenvalues of the matrix $A = [a_{ij}], i, j = 1..n$ is strictly negative.

Theorem 3. The evolution of the non linear dynamic system (13.3) is unstable in origin if the real part of at least one eigenvalue of the matrix $A = [a_{ij}], i, j = 1..n$ is strictly positive.

The important result performed by Halanay and Rsvan on nonlinear dynamic system is reminded below [2].

Theorem 4. Let the dynamic system be defined by the equation $\frac{dx}{dt} = Ax + g(x)$. The real matrix *A*, of dimension $n \times n$, is assumed that is compounded from constant elements, the variable is $x = (x_1, ..., x_n)^T$ of dimension *n*, the function $x(t) \equiv 0$ is a solution of the equation, the function $g(x)$ is assumed continuous and with the property that for each $\gamma > 0$ there is $\delta(\gamma) > 0$such that if $|x| < \delta(\gamma)$ then $|g(x)| < \gamma\,|x|$. It is also assumed that the matrix *A* has the property that all roots $\lambda_i, i = 1, .., n$ of the characteristic polynomial have the real part strictly negative such that $\mathrm{Real}\lambda_i \le -2\alpha < 0, , i = 1, ..n.$

Then there is $\delta_0 > 0$, $\beta \ge 1$ such that for each is true the inequality:

$$|x(t; t_0, x_0)| \le \beta e^{-\alpha(t-t_0)/2}\,|x_0|\,, t \ge t_0 \tag{13.5}$$

Remark: If the function $g(x)$ and the matrix *A* that intervene in theorem 4 have the imposed properties then we observe that stability in origin implies stability in neighborhood of origin and thus implies stable region separation in origin neighborhood.

The following theorem on the QR algorithm is described because can help us to verify conditions imposed by theorem of separation exposed in the next [7].

Theorem 5. If the components of the matrix *A* are continuous on piecewise and the sequence of Hessenberg form matrices $A_s, s = 1, 2, ...$ from algorithm that started with the matrix is uniform convergent to the Schur form of the matrix *A* then the eigenvalues of the matrix *A* are continuous on piecewise.

The extended conditions on the matrix of functions that define the autonomous linear dynamic system or "*first approximation*" of nonlinear dynamic system that allow the separation of the stable regions on the parameters domain are mentioned below in our theorem on separation. Some results performed in matrix theory are used for deduction of this theorem [9-12].

Theorem on separation: *If the autonomous linear dynamic system, defined by the matrix , has the continuous on piecewise components of the matrix as functions on dynamic system free parameters and is assured that the eigenvalue functions of the matrix are also continuous on piecewise, then these conditions allow the separation between stable and unstable regions of the dynamic system in the parameters domain.*

Remark: For the kinematics models of systems that depend on parameters, the property of separation is formulated on existence and in-existence regions in the domain on free parameters. This case is analyzed through our application on walking robot leg model.

13.3 Physical and Mathematical Models of The Walking Robot Leg

In the following we firstly describe our physical and mathematical model on the walking robot leg kinematics, with physical model of the robot leg defined by a "*pivot point*" attached to the robot body and two components B_tP and *PQ* jointed in point *P* denoted "knee joint" of the leg and the point *Q*, denoted "*base point*" of the leg, which are moved in vertical plane, as shown in Figure 13.1.

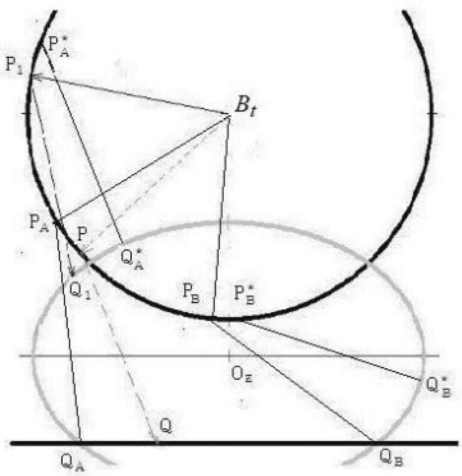

Figure 13.1 Physical model of the walking robot leg; *Bt* and *OE* are center of circle respectively ellipse arc trajectories; P_1, P_A, P, P_B are knee joint positions in leg cyclic evolution; Q_1, Q_A, Q, Q_B are base point positions in leg cyclic evolution; $\mathrm{P}_\mathrm{A}^*, \mathrm{P}_\mathrm{B}^*, \mathrm{Q}_\mathrm{A}^*, \mathrm{Q}_\mathrm{B}^*$ are critical positions

The point *P*, in the case of fixed pivot point, describes a circle arc route in a cycled evolution of the robot leg and the base point *Q* is assumed that describes a close route compounded from the superior ellipse arc Q_BQ_A with semi axes length *a, b* and with point O_E center of the ellipse, and closure of the leg evolution cycle by horizontal segment Q_BQ_A traversed by the base point *Q*.

The orthogonal system of coordinates and parameters signification are identified from the coordinates on the figure points: $B_t(a, h), O_E(a, b_1), P(x_P,\mathrm{y_P}),Q(x_Q,y_Q),, Q_A(x_A, 0),$ $Q_B(x_B, 0)$.

The points P_A^* and P_B^* define the extremities of the maximal domain on circle arc where the knee joint *P* is moving because in these points, geometrical identified by the property that the segments $P_A^*Q_A^*$ and $P_B^*Q_B^*$ are normally on the ellipse arc, the direction of movement is changed. The positions P_A^* and P_B^* of the knee joint, identified by us on the particular case of Figure 13.1, are named by us the critical points from the leg evolution. In other cases of robot leg with fixed pivot point, defined by the values of the geometrical parameters or in cases where the pivot point is moved in the walking robot evolution, is important to search the possible existence of the knee joint critical positions where the direction of movement is changed and where the speed of the knee joint must to be zero for the continuous evolution of the knee joint [8].

The mathematical model deduced from the physical model, suggested by the particular case represented in Figure 13.1, is defined through two formulas described by the equations:

$$\begin{aligned} &(x-a)^2 + (y_P - h)^2 - a^2 = 0.; \\ &(x-a)^2/a^2 + (y_Q - b_1)^2/b^2 = 1. \end{aligned} \tag{13.6}$$

Between the parameters' values, are assumed conditions $a > b > b_1 > 0; 2a > h$ where *a* and *b* are semiaxes of the ellipse.

Explicit functions generated by (12.6), are:

$$\begin{aligned} &y_P = h \mp (2ax - x^2)^{1/2}; \\ &y_Q = \pm b/a(2ax - x^2)^{1/2} + b_1 \end{aligned} \tag{13.7}$$

Let $P(x_P, y_P)$ and $Q(x_Q, y_Q)$ be points on the circle arc respectively on the ellipse arc for one leg position from the evolution.

The condition on the distance PQ for a position of the walking robot leg, namely the relation $(x_\mathrm{P} - x_Q)^2 + (y_P - y_Q)^2 - a^2 = 0$, is imposed.

The uniform linear evolution of the variable *x* between 0 and *2a*, excepting a neighborhood around possible critical points, in the case of fixed pivot point of the leg, is assumed as below, where the constant speed v_0 and initial condition x_0 are selected using compatible values:

$$x(t) = v_0 t + x_0 \tag{13.8}$$

One cycle for the robot leg evolution can start from the position of base point Q_B, traversing the superior ellipse arc up to the point Q_A, using the evolution law (13.8), and returns by the linear uniform displacement on the horizontal axle, in the point Q_B, excepting a selected neighborhood around each position Q_A^*, Q_B^*, where is defined a proper evolution.

The mathematical model of the walking robot leg, near of the critical point P_A^*, which have abscise denoted x_{PA^*}, using physical model from the Figure 13.1 and abscise x_P convergent to abscise x_{PA^*}, imposed by abscise x_Q evolution assumed decreasing convergent to abscise x_{QA^*} with $x_Q \in (x_{QA^*}, \frac{2a}{3})$, is described through below formulas:

$$\begin{aligned} &y_\mathrm{P} = h + (2ax_\mathrm{P} - x_\mathrm{P}^2)^{1/2}; \\ &y_\mathrm{Q} = b/a(2ax_\mathrm{Q} - x_\mathrm{Q}^2)^{1/2} + b_1; \\ &x_\mathrm{Q}(t) = -v_0 t + 2a/3 \\ &(x_\mathrm{P} - x_\mathrm{Q})^2 + (y_\mathrm{P} - y_\mathrm{Q})^2 - a^2 = 0 \end{aligned} \tag{13.9}$$

The value of abscise $x(t)$, in our hypothesis, respect the condition $x_{PA^*} < x(t)$ that implies $x_{PA^*} < -v_0 t + 2a/3$ such that $v_0 < 2a/3 - x_{PA^*}$. The corresponding expression of $y_P(t)$ is as follows:

$$y_{\mathrm{P}}(t) = h + (2ax_{\mathrm{P}}(t) - (x_{\mathrm{P}}(t))^2)^{1/2} \tag{13.10}$$

The value of time parameter, in assumption that $x_Q(t)$ is decreasing convergent to abscise x_{QA^*}, for which is verified the equation $\frac{d(y_p(t))}{dt} = 0$, using admissible value of parameter v_0, is of interest for us because identifies critical position, if it exists, of knee joint *P*.

We remark that the domain of the parameters' values $x, y_{\mathrm{P}}, y_{\mathrm{Q}}, h, v_0, x_0, t$ with fixed values of positive parameters a, b, b_1, in this analyzed case, for which described evolution exists, is an interval for one free parameter. The domain of existence coincides, in these formulated cases, with the domain of stability, such that we can affirm that there is a separation between stable (*existence*) and unstable (*inexistence*) regions of the free parameters values of the robot leg kinematics model.

The intuitive analysis permits to conclude that the separation is true and for robot leg with uniform distributed mass on the leg in the dynamic model. The following judgment on kinematics and dynamic models of walking robot leg, describe their link. The dynamic model is assumed that consists from two pipes of mass decreasing convergent to zero. The contribution of pipe mass for leg dynamic model is negligible in the case of mass sufficient close of zero. One can affirm that our kinematics model of leg is a limit case of dynamic model. Evolution of the leg dynamic model can be described using supplementary our study on Bernoulli Euler beam model with some analytical results described in the next [8]. The problem that arises in kinematics walking robot model can be transferred as problem in dynamic walking robot model with similar solution. The problem of critical positions, analyzed in our two dimensional case of walking robot leg model, having some specific problems in three dimensional case analyzed in follows capitol, is an example.

13.4 On Critical Positions of 3D Walking Robots

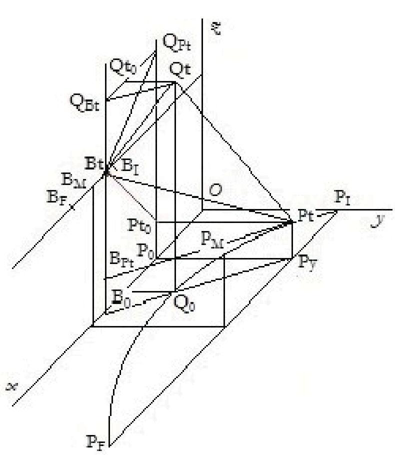

Figure 13.2 Physical model of three dimensional walking robot leg

A three dimensional (3D) leg evolution physical model for one leg from multi-legged walking robot is described in Figure 13.2 using three orthogonal coordinate system denoted *xyz*.

In the critical point is necessary to be assured zero value of the leg base point speed to respect natural continuous evolution of the leg. We remark that the property of walking robot stability (*existence*) position is also maintained in a neighborhood for one such position.

One 3D leg model is compounded from superior component B_tQ_t defined by the extremities points B_t, Q_t jointed in pivot point B_t attached to the body of the robot and inferior component Q_tP_t that consist from "*knee joint*" Q_t and base point P_t.

For the length of components B_tQ_t and Q_tP_t has assumed a constant value.

The base point P_t is moving on the ellipse arc between points P_I and P_F, in vertical plane, orthogonal on axis *Oy*, using uniform accelerated displacement on the horizontal direction up to the median point P_M, on the ellipse arc, and symmetric displacement assured up to the final point P_F. The joint point B_t attached to the body of the robot is moving together with point P_t, having linear route parallel to the axis *Ox*, using uniform displacement between initial point B_I up to median point B_M and symmetric displacement assured between the median point B_M up to final point B_F.

The trajectory of the "*knee joint*" point Q_t, unique identified in the vertical plane, defined by the points B_t, Q_t, P_t in each time *t*, having defined the distance between its, with the length of segment B_tP_t dependent on time *t*, is studied for possible critical points identification, similar as in two dimensional cases described above. The following formulas, using geometric data from Figure 13.2 and corresponding physical data are described. The trajectory of the point Q_t, in three dimensional of system coordinates is orthogonal projected on the plane *xOz* using the projected point Q_{t0} from this plane. The critical position of the knee joint Q_t, in its three-dimensional evolution, if there exists, is identified using critical position on the plane projected trajectory of the point Q_{t0} where the direction of movement must to be changed. The point Q_{t0} is projection of the point Q_t on the side $Q_{Bt}Q_{Pt}$, which is parallel with the axis Ox, and where the triangles $Q_tQ_{Bt}Q_{Pt}$, $Q_0B_0P_0$ have the sides respectively parallel.

The uniform accelerated displacement of the point denoted *P*, on the horizontal line, from the point P_I up to middle of the segment P_IP_F, is described by the relation:

$$x_P(t) = a_P t^2/2 \tag{13.11}$$

The parameter a_P represents constant acceleration in the horizontal direction of the point denoted *P*.

The uniform displacement of the pivot point B_t, on parallel line with axis *Ox*, from the point B_I up to middle of the segment B_IB_F, is described by the relation:

$$x_{Bt}(t) = v_B t \tag{13.12}$$

The parameter v_B is constant speed in displacement, on parallel line with axis *Ox*, of the point B_t.

The parameter *L* is introduced for correlating the data from the three-dimensional walking robot leg mathematical model. The following lengths are defined $\overline{\mathrm{BtQt}}=2L$, $\overline{\mathrm{QtPt}} = 3L$, $\overline{\mathrm{BtB_0}} = 1.5L$, $\overline{\mathrm{PtPt_0}} = 1.5L$.

The walking robot having six legs is assumed, so that to close the cycle of evolution, so that the following relation arises $\overline{\mathrm{P_IP_F}} = 6\overline{\mathrm{B_IB_F}}$. This relation is justified by the hypothesis on the separation and successive displacement of each leg in cycling evolution.

The time for simultaneously arriving in the middle of the trajectories $B_I B_F$, $P_I P_F$, by point B_t respectively P_t, is denoted t_M. The following relations are true:

$$\begin{aligned} &v_B t_M{=}d/12, v_B{=}d/t_M/12; \\ &a_P t_M^2/2 = d/2, a_P = d/t_M^2 \end{aligned} \tag{13.13}$$

The coordinates for the points B_t, P_t are identified in function of the time as below:

$$\begin{aligned} &x_{\mathrm{Bt}} = x_{\mathrm{B_I}} + v_{\mathrm{B}} t, y_{\mathrm{Bt}} = 0., z_{\mathrm{Bt}} = 1.5L \\ &x_{\mathrm{Pt}} = a_{\mathrm{P}} t^2/2, y_{\mathrm{Pt}} = 1.5L, \\ &z_{\mathrm{Pt}} = (b/a)(a^2 - (x_{\mathrm{Pt}} - d/2)^2)^{1/2} - b_1 \end{aligned} \tag{13.14}$$

In the relations described above are considered $0 \leq t < t_M$ and *a, b* that represent ellipse semiaxes where $0 < b_1 < b$. Coordinate *z* is imposed negative for the ellipse centres from the Figure 11.2 so that $z_{\mathrm{Pt}} \in [0, b - b_1)$.

The length of the segment $B_t P_t$ is evaluated from:

$$\overline{\mathrm{BtPt}} = ((x_{\mathrm{Pt}} - x_{\mathrm{Bt}})^2 + (y_{\mathrm{Pt}} - y_{\mathrm{Bt}})^2 + (z_{\mathrm{Pt}} - z_{\mathrm{Bt}})^2)^{\frac{1}{2}} \tag{13.15}$$

The angles in the vertical triangle $B_t Q_t P_t$ are evaluated, using the lengths of the triangle sides, by the relations of type:

$$\cos((\mathrm{QtBtPt})) = \frac{(\overline{\mathrm{BtQt}})^2 + (\overline{\mathrm{BtPt}})^2 - (\overline{\mathrm{QtPt}})^2}{2\overline{\mathrm{BtQt}} \times \overline{\mathrm{BtPt}}} \tag{13.16}$$

The angles values of the vertical triangle $B_t Q_t P_t$, from the physical model shown on Figure 11.2, permits to evaluate all angles or sides of the physical model. The critical point position where is changed the direction of movement referred to projected point Q_{t_0} is searched in the interval $[0, t_{\mathrm{M}})$ of time parameter.

The mathematical model referred to three dimensional legs evolution of multi-legged walking robot, proposed above, permits to identify the critical position, if they exist, for knee joint point, using specialized computer program.

13.5 Mathematical model of beam without damping

Firstly, we analyze the extended Bernoulli - Euler dynamic beam model without damping, necessary for studying the model of beam with damping. This model is suitable for beams with length more large than section, as in our case studied. The following equation of beam is considered:

$$m_L \frac{\partial^2 w_i(x,t)}{\partial t^2} = -k_i w_i(x,t) + T\frac{\partial^2 w_i(x,t)}{\partial x^2} - EI\frac{\partial^4 w_i(x,t)}{\partial x^4} + q(x,t) \tag{13.17}$$

The equation (12.7) describes the behaviour of the beam, excited by the force *q*, applied transversal on the beam, acting in the point of abscissa *x*, at the time *t*.

We denote by m_L the mass unit length of the beam, by *EI* the bending rigidity of the beam, by *T* the tension in the beam, by $w_i(x,t)$ corresponding vertical displacement of the beam for vibration mode of order *i*, by *k* the rigidity of the beam as a coefficient of beam transverse displacement, and by *L* the length of the beam. The case of free vibrations ($q(x,t) = 0$, excepting initial conditions) is needed to be studied.

The stabilized free transverse vibration of the beam without damping is searched in standing wave form:

$$w_r(x,t) = w_r(x)\sin(\omega_r t + \varphi_r), r = 1, 2, ... \tag{13.18}$$

In formula (12.8), the notations signify: $\omega_r = 2\pi f_r$ is the circular frequency, f_r is the resonance frequency of the beam in free vibrations without damping, and φ_r is the phase angle between the initial impulse and displacement. Below appear the following dimensionless notations (Nowacki, 1961):

$$\begin{aligned} \alpha^2 &= \tfrac{TL^2}{EI}, \delta_r = \left[\alpha^2/2 + \left(\alpha^4/4 + \beta_r^4\right)^{1/2}\right]^{1/2}, \\ \varepsilon_r &= \left[-\alpha^2/2 + \left(\alpha^4/4 + \beta_r^4\right)^{1/2}\right]^{1/2} \end{aligned} \tag{13.19}$$

In the above expressions, we use the notation $\beta_r^4 = m_L(\omega_r^2 - k_r)L^4/EI$ and assume the condition $\omega_r^2 - k_r \geq 0$. For all $r = 1, 2, ...$ in case of rigidity k_r not negligible. The equation of free vibrations for undamped beam is described by (12.6) where $q(x,) = 0$, excepting needed initial conditions.

The following equation is deduced from equation of free vibrations, using formula (12.7):

$$(m_L\omega_i^2 - k_i)w_i(x) = -T\frac{\mathrm{d}^2 w_i(x)}{\mathrm{d}x^2} + EI\frac{\mathrm{d}^4 w_i(x)}{\mathrm{d}x^4}, i = 1, 2, ... \tag{13.20}$$

The solutions of equation (11.20), which respect some boundary conditions by identify its coefficients, are searched in the form described below.

$$w_i(x) = c_{1i}\sin(\varepsilon_i\frac{x}{L}) + c_{2i}\cos(\varepsilon_i\frac{x}{L}) + c_{3i}\mathrm{sh}(\delta_i\frac{x}{L}) + c_{4i}\mathrm{ch}(\delta_i\frac{x}{L}), i = 1, 2, ... \tag{13.21}$$

The particular case analyzed here is the simple supported undamped beam. That means simple supported extremity at both extremities of the beam.

The coefficients $c_{1i}, ..., c_{4i}$ are searched so that the following analytical conditions to be respected:

$$\begin{aligned} w_i(0) = 0, \ \frac{\mathrm{d}^2 w_i(x)}{\mathrm{d}x^2}\Big|_{x=0} = 0, \\ w_i(L) = 0, \ \frac{\mathrm{d}^2 w_i(x)}{\mathrm{d}x^2}\Big|_{x=L} = 0. \end{aligned} \tag{13.22}$$

The equation of natural frequencies for undamped beam, in the particular case analyzed, is simply described by:

$$\sin\varepsilon_i = 0 \tag{13.23}$$

The vibration mode of undamped beam, using the particular case of beam boundary conditions, is as follows:

$$w_i(x) = c_{1i}\sin(\varepsilon_i\frac{x}{L}) \tag{13.24}$$

The coefficient c_{1i} is independent of *x*.

The transcendental equation (12.13), for any resonant frequency of undamped oscillated system (*identified by theoretical and experimental way*) can be used to obtain the bending rigidity *EI* of the beam, in specified boundary conditions.

13.6 Mathematical Model of Beam with Viscous Damping

The equilibrium equation in this case of free vibrations is:

$$m_L \frac{\partial^2 w_i}{\partial t^2} = -k_i w_i - c_i^V \frac{\partial w_i}{\partial t} + T\frac{\partial^2 w_i}{\partial x^2} - EI\frac{\partial^4 w_i}{\partial x^4}; i = 1, 2, ..., \tag{13.25}$$

One searches, in the equation (12.15), the solution as:

$$w_i(x,t) = X_i(x)T_i(t) \tag{13.26}$$

The $X_i(x)$, which verifies (12.10), defines a vibrating mode of the beam undamped free vibration of order *i*.

The equation deduced from (12.15) for $T_i(t)$ is as below:

$$\begin{aligned} &\tfrac{d^2T_i(t)}{dt^2} + 2c_i^{VL}\tfrac{dT_i(t)}{dt} + \omega_i^2 T_i(t) = 0., \\ &c_i^{VL} = c_i^V/m_L/2, i = 1, 2, ..., \end{aligned} \tag{13.27}$$

The free vibrations of the beam, having denoted values of initial conditions ($w_i(x_o, 0) = D_{oi}$, $\dot{w}_i(x_o, 0) = 0.$) are deduced as:

$$\begin{aligned} &w_i(x,t) = X_i(x)\tfrac{D_{oi}}{X_i(x_o)}e^{-c_i^{VL}t}\left\{\tfrac{c_i^{VL}}{\omega_i^V}\sin\omega_i^{V_t} + \cos\omega_i^{V_t}\right\}, i = 1, 2, ...; \\ &c_i^{VL} = c_i^V/m_L/2, \\ &\left(\omega_i^V\right)^2 = \omega_i^2 - \left(c_i^{VL}\right)^2 > 0. \end{aligned} \tag{13.28}$$

In this case, the objective function for identification of one parameter, by selection of other suitable parameters values, is of the type below:

$$f = \sum_{i,x,t} w_i^{cof}\left\{{w_i}^c(x,t) - {w_i}^{\exp}(x,t)\right\}^2 \tag{13.29}$$

The theoretical value ${w_i}^c(x,t)$ and experimental value ${w_i}^{\exp}(x,t)$ of the displacements are used in (12.18), theoretically calculated or experimentally measured, in some points of abscissa denoted *x*, for some moments of time and some frequencies, in the domain of interest. The weights $w_i^{cof} = \frac{1}{({w_i}^{\exp}(x,t))^2}$ assure the dimensionless objective function.

13.7 Conclusion

The property of separation in the free parameters domain on the dynamic systems that approach the phenomena on the environment permits us to characterize the environment mathematical model. This notion includes dynamic and kinematics models. The link between dynamic and kinematics walking robot model applied on walking robot leg model and our considerations on environment's mathematical modeling, on stability theory of the dynamic systems or on kinematics systems existence regions that depend on parameters is not exhausted by our analysis but is opened a promising and attractive way of research.

Acknowledgment

This work was developed with the support by Romanian Academy, European Commission Marie Sklodowska-Curie SMOOTH project (H2020-MSCA-RISE-2016-734875/2016-2020 and "*Joint Laboratory of Intelligent Rehabilitation Robot*" collaborative research agreement between Romanian Academy by IMSAR, RO and Yanshan University, CN,

Project KY201501009/2016.

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CHAPTER 14

THE WALKING ROBOT EQUILIBRIUM RECOVERY APPLIED ON THE NAO ROBOT

N. Pop[1], L. Vladareanu[1], H. Wang[2], M. Ungureanu[3], M. Migdalovici[1], V. Vladareanu[1], Y. Feng[2], M. Lin[2], E. P. Mastan[4] and I. El Emary[5]

[1] Romanian Academy, Institute of Solid Mechanics, Bucharest, Romanian
[2] Yanshan University, Qinhuangdao, 066004, China
[3] Technical University of Cluj-Napoca - North University Centre of Baia Mare
[4] High School Nemeth Laszlo Baia Mare, Romania
[5] King Abdulaziz Universitry Jeddah, Computer Science and Systems, Saudi Arabia
Emails: luige.vladareanu@vipro.edu.ro , luigiv2007@yahoo.com.sg, nicpop@gmail.com, hongbo_w@ysu.edu.cn, omary57@hotmail.com, yf_feng@126.com

Abstract. The chapter equilibrium recovery of the walking robot applied on the NAO robot using strategies for balancing in the sagittal plane, in the presence of external disturbances is analyzed, by comparing the feedback time to the equilibrium position for the same disturbance the case of lower control effort. The case of the high values chosen for *R*, in the case of higher control effort, together with the case of the low values chosen of the *R* are presented. Equilibrium and maintaining the balance of the biped walking robots play an important role in robot's operation. The model of a double linear pendulum inverted under-actuated, with one passive and one active joint are studied in modeling the robot's balance. The proposed strategy of balance has a goal to move the disturbed system to the desired equilibrium state. The results lead to a biped walking model equipped with actuator that provides a torque at the hip. or/and at the ankle. The case studies by these strategies is validated by Webots and is applied on NAO robot.

Keywords: Walking robots; Balance; Under-Actuated System; Control law.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (179–284)

14.1 Introduction

The support area of the robot, is either the foot surface in case of one supporting leg or the minimum convex area containing both foot surfaces in case both feet are on the ground. These are referred to as single and double support phases, respectively.

The most used models and strategies for balancing of the biped walking robots are:

- CoG (or CoM) balancing which has goal to maintain the projection of the center of gravity (*or center of mass*) on the ground, inside of the foot support area. This strategy is used for static walk or only for slow walking speeds;
- ZMP (zero momentum point) balancing which has goal to maintain the point inside the surface defined by BoS (*boundary of support, this is the polygon described by the robot's foots*). This strategy is used for dynamic walking. ZMP is a point where the horizontal moments are zero. In conclusion, if point P is inside the surface defined by BoS, all moments and forces exerted by the body on the ankle are compensated, which necessarily leads to a dynamic balance [1, 2, 10-12].

Combined strategy applies to both ankle and hip strategy to protect the system against external disturbances.

We specify that for the dynamic walking robots CoG (or CoM) can be outside of the BoS, but the ZMP, cannot. This chapter uses a two-link inverted pendulum model in the sagittal plane, with actuator at the hip joint - see Figure 14.1.

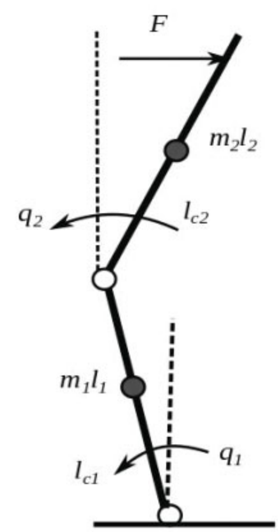

Figure 14.1 Two-link inverted pendulum model in the sagittal plane

14.2 The Choice of the Model

For analyzing the balance control for a biped walking model, can be expressed as one or multi-dimensional inverted pendulum chain. Thus the walking biped can be modeled with one-dimensional inverted pendulum [3-5], in this case the system will be described only by-one variable: the angle of the ankle joint.

This model is not sufficient to completely explain balance properties, even for standing balance. In many studies is used the double inverted pendulum model [3-5, 13-15]. This model is not sufficient to completely explain balance properties, even for standing balance. In many studies is used the double inverted pendulum model [6, 7]. For best approximation of the human body, the biped walking robot can be modeled with multi-dimensional inverted pendulum chain that allows the study of the responses for complex perturbations [16, 17].

We chose a simple model which can give as much information as possible to the balance recovery strategy of a biped walking robot. The two rigid links of the model are: one established by both legs and the other including the head, arms and torso. We chose to study, the model of a double inverted pendulum under-actuated, with one passive and one active joint, who can approach balance in the case of a single phase, i.e. in case of one supporting leg [8-9, 18-20]. This model also assumes that both legs move together at all times, there-fore are modeled as a single link.

14.3 Mathematical Modeling of Two-Link Biped Walking Robot

The equations of motion for a two-link inverted pendulum were derived using the Newton-Euler equation and linearized by employing Taylor series expansion, evaluated around the equilibrium point $x = [1.57, 0, 0, 0]$, which is vertical position and zero angular speeds, as follows:

$$M \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix} = -F \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} - G \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} + B_N \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix} \tag{14.1}$$

Where the matrices can be written as follows,

$$M = \begin{bmatrix} J_1 + m_1 l_{c1}^2 + m_2 l_1^2 + 2m_2 l_1 l_{c2} + J_2 + m_2 l_{c2}^2 & J_2 + m_2 l_1 l_{c2} + m_2 l_{c2}^2 \\ J_2 + m_2 l_1 l_{c2} + m_2 l_{c2}^2 & J_2 + m_2 l_{c2}^2 \end{bmatrix} \tag{14.2}$$

$$F = \begin{bmatrix} f_1 & 0 \\ 0 & f_2 \end{bmatrix} \tag{14.3}$$

with a linearized friction model:

$$f_1 = c_1 \frac{\alpha}{2} + v_1 \; and \; f_2 = c_2 \frac{\alpha}{2} + v_2 \tag{14.4}$$

obtained from the following nonlinear model:

$$F_i = c_i \mathrm{sgn}(\dot{q}_i) + v_i \dot{q}_i \approx c_i th(\alpha \dot{q}_i) + v_i \dot{q}_i \tag{14.5}$$

where c_i and v_i are Coulomb and viscous friction coefficients at the ankle joint ($i = 1$) and at the hip joint ($i = 2$), respectively. The function *sgn(.)* is approximate with the hyperbolic tangent function $th(\alpha.)$, $\alpha = 50$. Also,

$$G = \begin{bmatrix} m_1 g l_{c1} + m_2 g l_{c2} + m_2 l_1 g & m_2 g l_{c2} \\ m_2 g l_{c2} & m_2 g l_{c2} \end{bmatrix} \tag{14.6}$$

$$B_N = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \tag{14.7}$$

resulting in only one actuator at the hip joint. Where m_1, m_2, l_1 and l_2 are the equivalent mass and length of each link, leg and torso, respectively, l_{c1} and l_{c2} are mass centers relative to the lower joint, J_1 and J_2 are the moments of inertia about the CoM of the corresponding link (around pitch axis), q_1 and q_2 are the ankle and hip joint angles and τ_1 and τ_2 are the ankle joint torque and hip joint torque, respectively (in our case $\tau_1 = 0$).

After linearization, it is known that coriolis and centrifugal terms obtained in the original non linear equations have been eliminated and do not contribute to the simplified model.

14.4 Linear Control Design

For formulating the feedback control model, we defined the state vector, *x*, of joint kinematics referenced as, where $x = [q_1\ q_2\ \dot{q}_1\ \dot{q}_2]^T$ are the ankle and hip joint angles, and $\dot{q}_1$ and $\dot{q}_2$ represent angular velocities, respectively. The state model is determined by,

$$\dot{x} = Ax + Bu \tag{14.8}$$

where matrix *A* encapsulates the dynamic properties of the system that exist due to the particular chosen state and *B* determines the input function. The variable *u* is the control input and the system output, or response function,

$$y(t) = Cx(t) = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} x(t) \tag{14.9}$$

The system (12.1), representing two ordinary differential equations of the second order, is equivalet with system (12.8), which represents four ordinary equations of the first order. This equations are linearized around the equilibrium state, resulting in a simplified model which is only valid within a close vicinity to this point. This assumptions, for this control technique, implies instability for large deviations from the desired position.

After we defined the state space model, it is important to determine appropriate control input, which will guarantee stability and convergence of the system to the desired position. For this purpose, state feedback is employed, which requires gain tuning to get convergence at the desired position under constraints imposed by actuator and joint limitations.

If we note the matrices:

$$M^{-1} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \tag{14.10}$$

$$M^{-1}G = \begin{bmatrix} mg_{11} & mg_{12} \\ mg_{21} & mg_{22} \end{bmatrix}, \tag{14.11}$$

$$M^{-1}F = \begin{bmatrix} mf_1 & 0 \\ 0 & mf_2 \end{bmatrix} \tag{14.12}$$

and

$$M^{-1}B_N = \begin{bmatrix} 0 & m_{12} \\ 0 & m_{22} \end{bmatrix} \tag{14.13}$$

from (14.1), the matrix *A* and *B*, from the system (12.8), gets:

$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -mg_{11} & -mg_{12} & -mf_1 & 0 \\ -mg_{21} & -mg_{22} & 0 & -mf_2 \end{bmatrix} \tag{14.14}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & m_{12} \\ 0 & m_{22} \end{bmatrix}, \tag{14.15}$$

$$Bu = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & m_{12} \\ 0 & m_{22} \end{bmatrix} \begin{bmatrix} \tau_1 & 0 & 0 & 0 \\ \tau_2 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ m_{12}\tau_2 & 0 & 0 & 0 \\ m_{22}\tau_2 & 0 & 0 & 0 \end{bmatrix} \tag{14.16}$$

and vector $\dot{x} = [\dot{q}_1 \ \dot{q}_2 \ \ddot{q}_1 \ \ddot{q}_2]^T$.

In the case studied, the ankle joint being stabilized, the hip joint is required to maintain its desired position $q_{2d} = 0$. Optimality in this situation is determined by employing the linear quadratic regulator, described in the next section.

14.4.1 Linear Quadratic Regulator

To determine the optimal trajectory in regaining the equilibrium position an optimal feedback controller needs to be designed. Optimality [4] has been defined in terms of a quadratic cost function as follows

$$J_{lqr} = \frac{1}{2} \int_0^\infty [x(t)^T Q x(t) + u(t)^T R u(t)] dt \tag{14.17}$$

where $x^T Q x$ is the state cost with weight $Q = Q^T > 0$, and $u^T R u$ is called the *control cost* with weight $R = R^T > 0$. The value of *Q* and *R* are randomly chosen until the output of the system does not get the desired value.

The linear feedback matrix u, is defined as:

$$u(t) = -K_{lqr} x(t) \tag{14.18}$$

The K_{lqr} matrix is responsible for defining optimality in the linear quadratic regulator and is obtained by solving the Riccati equation, given below:

$$A^T P + PA + Q - PBR^{-1}B^T P = 0 \tag{14.19}$$

The solution of this equation is P, called the optimal matrix, used in determining the gain matrix:

$$K_{lqr} = R^{-1}B^{T}P \tag{14.20}$$

The feedback control input *u*, the joint torque, was assumed to be generated by full-state feed-back in the following form:

$$u = [\tau_1 \ \tau_2]^T = -K_{lqr}x(t) \tag{14.21}$$

and,

$$K_{lqr} = \begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ k_{21} & k_{22} & k_{23} & k_{24} \end{bmatrix} \tag{14.22}$$

By varying the gain matrix *Q* and *R*, the penalty error of the state *x* and the control effort *u* is controlled. The gain matrix used in experimentation are,

$$Q = I_{4x4}, \quad R = (10e - 12)I_{2x2} \tag{14.23}$$

where a higher penalty is applied on the control effort as compared to the state.

These gains can be determined by keeping in mind joint motor limitations in providing the control effort in terms of torque.

This approach is proven to be much faster compared to traditional pole placement technique, while the desired balance of priorities between the state and control effort can be regulated much easily. The system (12.8) will be equivalent with system:

$$\dot{x} = (A - BK_{lqr})x(t). \tag{14.24}$$

14.4.2 Numerical Results using MATLAB

In order to verify the correctness of the proposed model, the simulations are obtained with the parameters given in Table 14.1 for the NAO robot.

Table 14.1 Parameters of the NAO robot

Model Parameter	Units	Label	Value
Mass	Kg	m_1	2.228
		m_2	2.118
Length	m	l_1	0.27
		l_2	0.27
Center of the mass	m	l_{c1}	0.135
		l_{c2}	0.135
Inertia	Kg m^2	J_1	0.000192
		J_2	0.00000833
Coulomb friction	N_m	c_1	0.1
		c_2	0.2
Viscous friction	N_s	v1	-2.78
		v2	-23.5

The numerical results justify the mathematical model, when the model is under disturbance.

The LQR controller can be tuned in MATLAB when the values for Q and R matrices for state space model are specified, and the state-feedback gain matrix is obtained as follows:

$$K_{lqr} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ -344.14 & -84.68 & -40.52 & 24.99 \end{bmatrix} \tag{14.25}$$

For an initial disturbance of approximately 1.2 degrees (0.02 radians) to the ankle and 1.7 degrees (0.03 radians) to the hip, results are shown in Figure 14.2, Figure 14.3, Figure 14.4, and Figure 14.5.

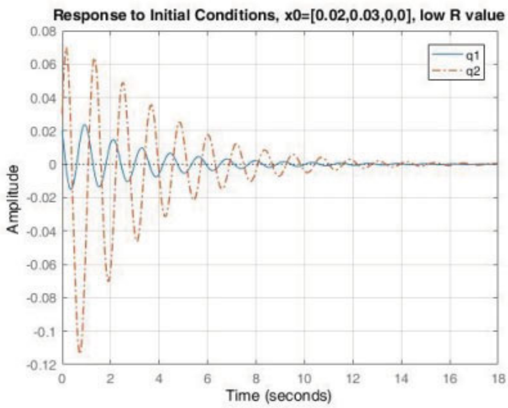

Figure 14.2 Stabilization is done in 18 seconds, with a disturbance to the ankle and the hip of $x_0 = [0.02, 0.03, 0, 0]$ and a low R value

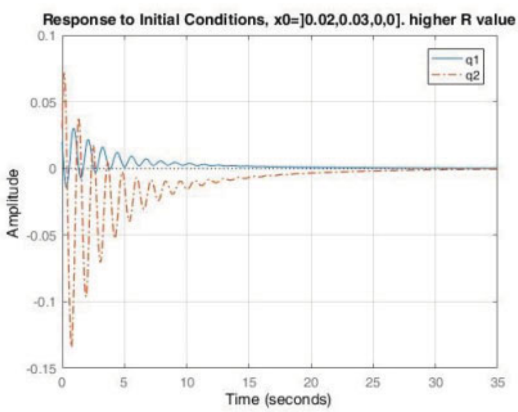

Figure 14.3 Stabilization is done in 35 seconds, with a disturbance to the ankle and the hip of $x_0 = [0.02, 0.03, 0, 0]$ and a high R value

Although, for small values of R, ($r_{ii} = 10^{-12}$), a rapid return to the equilibrium position was obtained, it was through a very high effort for the actuator, as shown in Figure 14.2 and Figure 14.4.

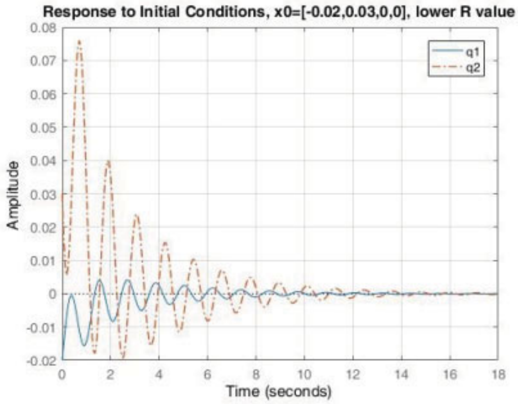

Figure 14.4 Stabilization is done in 18 seconds, with a disturbance to the ankle and the hip of $x_0 = [-0.02, 0.03, 0, 0]$ and a low R value

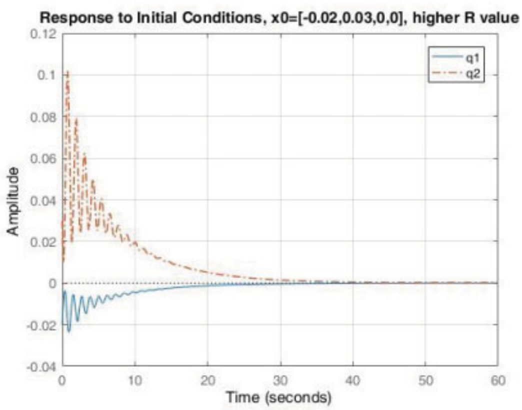

Figure 14.5 Stabilization is done in 60 seconds, with a disturbance to the ankle and the hip of $x_0 = [-0.02, 0.03, 0, 0]$ and a high *R* value

In case of high values for the elements of the matrix *R*, ($r_{ii} = 1.$), the actuator control effort is lower, but the stabilization is reached in a longer time and after several oscillations, as seen in Figure 14.3 and Figure 14.5.

Also, in the case of a disturbance only at the level of the hip, in Figure 14.6 and Figure 14.7, it can be noticed that the stabilization time is twice as high, with lower control effort, meaning higher *R* values chosen.

In this paper, we compared the return times to the equilibrium position for the same disturbance, when the NAO robot has the mass centers in the middle of the links or when the robot has the mass centers placed in the ratio $(l_i - l_{ci})/l_{ci} = 1.618,\ i = 1, 2,$ (*i.e. the golden section*). It has been found that, for the NAO robot case, a low height robot, the stabilization time is approximately equal.

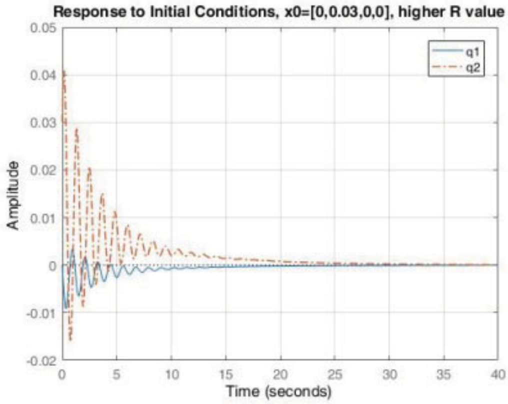

Figure 14.6 Results for disturbance only to the hip $x_0 = [0, 0.03, 0, 0]$ with high R values, stabilization is done in 40 seconds.

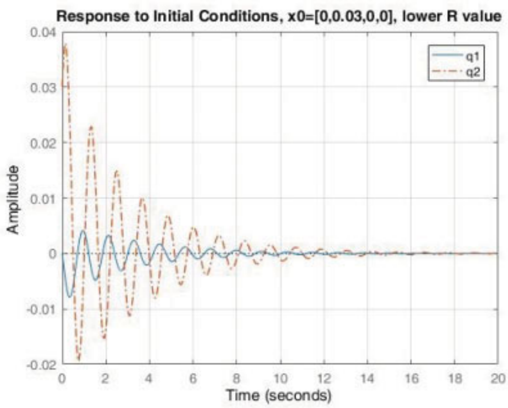

Figure 14.7 Results for disturbance only to the hip $x_0 = [0, 0.03, 0, 0]$ with lower R values, stabilization is done in 20 seconds.

The possible justification is that in the case when the mass centers are placed in the middle of the links and in the case when the robot has the mass centers placed in the golden section ($l_{c1} = 0.135$, $l_{c1} = 0.103$), are approximately equal, and that the spectral radius of the matrices of the two dynamic systems are almost equal (0.16 or 0.1).

14.5 Results and Discussion

The linear quadratic regulator is used as a faster means of convergence when the hip joint is close to the desired state. The control strategy formulated defines torque for the hip joint, this can be accompanied with a simple PD controller at the ankle, $\tau_1 = K_{P1}(1.57 - q_1) - K_{D1}\dot{q}_1$.

This algorithm completely removes any torque provided to the ankle and evaluates performance of various controllers under such conditions.

14.6 Conclusions

The analyzed state space model has been tested in several cases, under the same disturbance applied to the system, and the return times to the equilibrium position have been compared. The numerical result, established in the case of lower control effort, implies a higher *R* value and in the case of higher control effort, a low *R* value will be used. If the *R* gain value is increased to make a lower control effort, the stabilization is achieved after a few oscillations.

The obtained results were quantified by decreasing the spectral radius of the matrix, which means increasing stability of the biped walking robot.

Acknowledgment

This work was developed with the support by Romanian Academy, European Commission Marie Sklodowska-Curie SMOOTH project (H2020-MSCA-RISE-2016-734875/2016-2020) and "*Joint Laboratory of Intelligent Rehabilitation Robot*" collaborative research agreement between Romanian Academy by IMSAR, RO and Yanshan University, CN. Project KY201501009/2016.

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CHAPTER 15

DEVELOPMENT OF A ROBOTIC TEACHING AID FOR DISABLED CHILDREN IN MALAYSIA

N.Zamin[1], N.I. Arshad[2], N. Rafiey[2] and A.S. Hashim[2]

[1] University Malaysia of Computer Science and Engineering, Putrajaya, Malaysia
[2] Universiti Teknologi PETRONAS, Seri Iskandar, Perak, Malaysia
Emails:

Abstract

Many special needs children suffer from a common characteristics impairment which appear as disability to interpret social cues, fail to use joint-attention tasks as well as a failure in social gaze when communicating. This what makes them different than the normal children. The results of this difficulty are the special needs children often get frustrated when they are unable to expressively share their feeling and socially interact with the community. This research is investigating the problems faced by autistic, down syndrome and slow learner children to respond and communicate appropriately with the people around them and to propose an efficient approach to improve their social interaction. Malaysian education policy is to integrate students with learning difficulties or special educational needs. Thus, the development of a robotic approach using LEGO Mindstorms EV3 to aid the teaching and learning of special needs children especially autism in in Malaysia in introduced in this paper. Robotic approach in special education provides changes, inclusive and sustainable development of the disabled community towards supporting Industrial Revolution 4.0.

Keywords: Robotic, Special Education, Social Interactions, Developmental Disabilities, Autism, Down Syndrome, Slow Learner

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (191–284)

15.1 Introduction

Creating the abilities of the special needs children's day by day life is truly a test as each of them has diverse symptoms and is remarkable in their own particular ways. To help improve their life's quality, there are few real zones of education that must be thought to. Those ranges are communication, social and independence. Special needs children have an alternate route in learning and tolerating data that is different from normal children. The primary goal of this research is to enhance the teaching and learning experience of the special needs children from the fundamental methodologies and therapies. Many studies have previously proposed robotic approach as alternative therapy tool to improve social interaction skills and as well as reducing the emotional problem among the special needs children [2-4]. This is because robot has no feeling and can perform repetitive actions without getting bored or stressed. The proposed solution is to develop an LEGO robot to assist teachers, therapists as well as parents to improve social interaction skills among special needs children. This tool is not intended to replace the teachers and therapist but rather as an assistive tool.

15.2 Case Study - Autism

Autism is a complex neurobehavioral disorder that includes impairments in social interaction and developmental language and communication skills combined with rigid and repetitive behaviours [5]. Autism Spectrum Disorder (ASD) refers to the wide range of symptoms, skills and level of impairment or disability which include Asperger's and Kanner's Syndrome [6]. Among early signs of ASD is persistent deficit in social communication and interaction, repetitive patterns of behaviour, interests or activities and low ability in understanding multiple instructions. Typically, symptoms are presence in the first two years of a child's life [7]. Until today, the medical society is unable to confirm that the genetic factor is the main cause of ASD [8]. There is no specific medical treatment to cure autism, but many strategies and treatment options are available for autistic children [9]. Early diagnosis and correct therapy would help young children with autism to develop their full potential. Most current therapy methods aimed to improve the overall ability of the autistic children. As the number of children with autism has risen dramatically over the past couple of decades, experts have discovered that the earlier specialized therapy can be initiated; the outcome can be significantly improved [10]. The proposed approach is tested on autistic children at selected special schools and centers in Malaysia [11].

15.3 Movitations

Inspired by the difficulties of the observed current therapy methods and from the literature studies, a new and sustainable approach using robotic technology is proposed. The robotic intervention in nurturing autistic children has been very helpful in enhancing reading skills and generalizing knowledge for young pupils with autism. The sequence, progressive development is well defined and simple for therapists and parents to amend and keep track of the child's improvement. A rising comprehension of the robotic learning practice of autistic children is getting more attention from academic society. Autistic children go through their day by day activities by their weak senses that can be further enhanced with the aid of robotics [4]. It reduces the tension for them to rekindle what happens later, give a concise and clear path between actions, and aid them to be independent. The nonverbal signs shown by the robots to them can last a long time since they have a habit of repeating on every action they learnt [12].

Thus, robotic engagement has causes the evolution of education practices amongst autistic children. LEGO therapy is one of the current treatments for learning among disabled group of children including the autistic children. The LEGO therapy can improve cognitive development, creativity and hand-eye coordination while improving social skills when played together in a team [13, 14]. In this traditional LEGO therapy, children are normally supervised by assigned therapists. Our proposed method is to automate the LEGO therapy by using the LEGO Mindstorms, a programmable LEGO toolkit as a teaching and learning aid for the autism therapist. Our method is referred as the RoboTherapist that will adapt the ability to teach the basic foundation of knowledge through observation and hand-eye coordination with the supportive function from their attracted repetitive behaviors.

15.4 Proposed Approach

As the fourth industrial revolution (IR 4.0) and its embedded technology diffusion progress is expected to grow exponentially in terms of technical change and socioeconomic impact, we introduce a holistic approach that encompasses innovative and sustainable system solutions for special needs children [15]. In this article, a robot known as RoboTherapist using LEGO Mindstorms EV3 to teach autistic kids to differentiate shapes and encourage the kids to draw basic shapes correctly. It is a new approach and never been applied in special educations in Malaysia.

The RoboTherapist will be placed on a flat whiteboard and detect color by using color sensor that has been programmed in the LEGO Mindstorms EV3 Software. When the RoboTherapist detects the color on the whiteboard, it will start to draw shapes as preprogrammed. It will keep on looping until the user click end program. The association of colors and shapes are programmed as follows:

Figure 15.1 The shapes and colors

The mechanism used by the RoboTherapist is the fixed rotation of the motor steering to draw each shape shown in Figure 15.1. The following figures illustrate the movement of RoboTherapist:

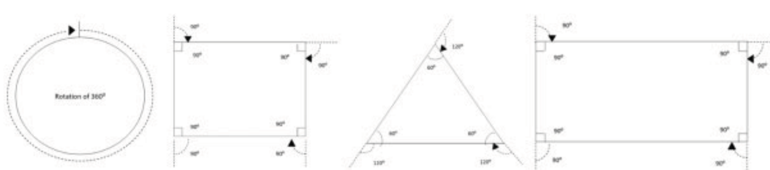

Figure 15.2 The fixed motor directions

The flow chart in Figure 15.2 shows the flow of the overall program. RoboTherapist initiates by detecting the color read by the color sensor and draw the shapes as pre-programmed in Figure 15.2.

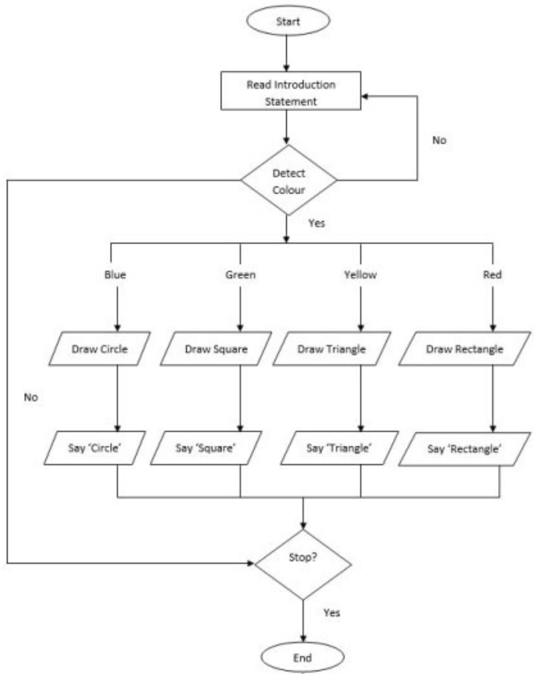

Figure 15.3 RoboTherapist flowchart

Figure 15.4 RoboTherapist

Then, it will keep on looping until the stop button is pressed. The special needs children will observe the teaching from the RoboTherapist guided by the teachers. Their understanding is tested by a manual test designed to evaluate the effectiveness of the robotic approach.

15.5 Results and Discussions

Initially, before the test was carried out, a pre-selection test was done to make sure whether the test candidates are fit for the test or otherwise. In the pre-selection, the potential candidates are asked to tinker with the RoboTherapist and their responses are recorded. If they can handle the robots well, then they are selected. This effort is highly crucial to avoid unnecessary damage on the robot by highly uncontrolled kids (*a normal behaviour for some autistic children*). Once selected, they will seat for the actual test where the therapist will assist the children to RoboTherapist. The comparative results between the traditional learning method and the robotic approach are presented. From the survey conducted we can see that most of the children with autism will get easily distracted, need to repeat several times in making them understand. It is very challenging in attracting and retaining the autistic children attention, especially in learning.

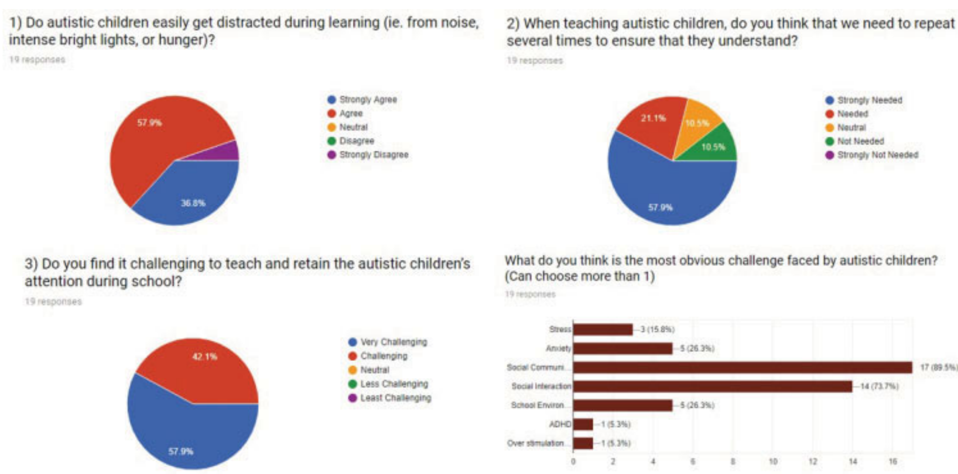

Figure 15.5 Survey on students' attentiveness

We can also conclude that most of the major challenge in teaching the autistic children falls under "*Social Communication*" where the children find it hard in letting people to control their emotion and also behavior. This happens because for them it is difficult to understand and follow the instructions given by the teachers. Then, the survey continues with the benefits of implementing or introducing the learning method with robot as a medium in teaching the autistic children. As we can see and observe from the results below, most of the respondents agree with the implementation of Robot in teaching basic shapes to the autistic children.

Most of the respondents agreed that the teaching approach using robot is the best assistive tool for teaching the autistic children. In addition, below are the opinions shared by the adult respondents (*teachers, parents and caretakers*) throughout the survey. As the autistic

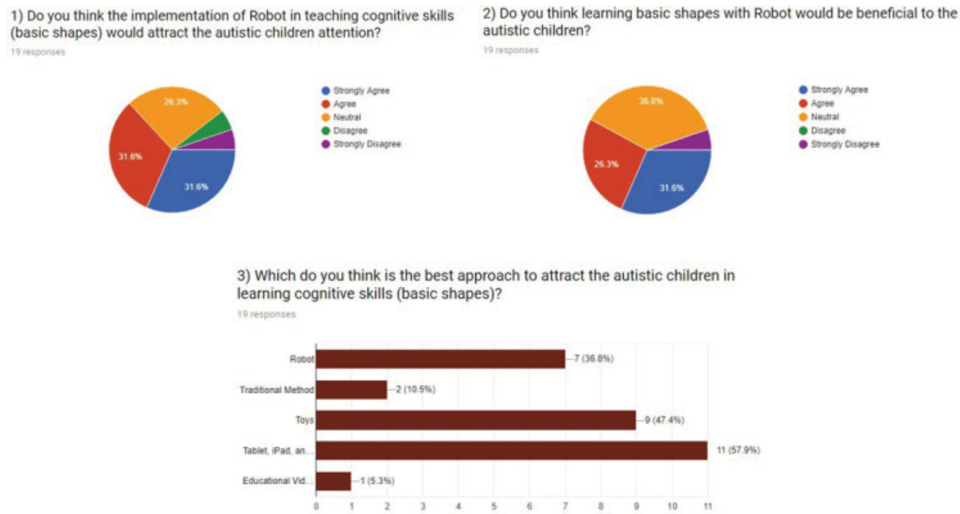

Figure 15.6 Survey on the effectiveness of robotic approach

children can easily get distracted therefore more attention are needed when teaching them. Thus, with the new teaching and therapy method by introducing the robot to the autistic children, attracts the children's attention and making learning basic shapes fun and easy.

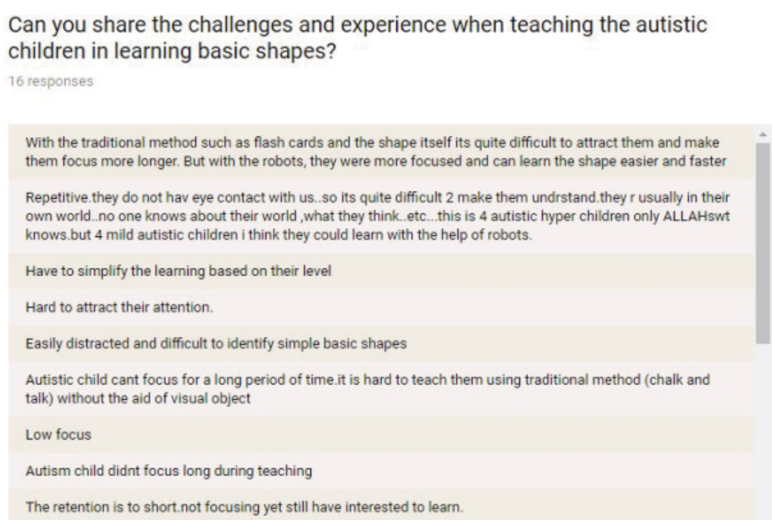

Figure 15.7 Opinions on robotic approach

Following this, observation and assessment was conducted in a selected school. Five selected respondents participated voluntarily (refer to Table 15.1) with the assistance of a well-trained teacher. The results gathered from the observation and assessment were then analyzed and discuss in the following paragraphs.

Table 15.1 Participants Details

Participants	Background	Age
RN	An autistic student	10
DH	An autistic student	11
KMH	An autistic student	10
CWG	An autistic student	14
CSN	A trained teacher teaching autistic students	N/A

15.6 Robotic Intervention Enhance Autistic Students' Engagement, Interaction and Focus

It was observed that the traditional method that have been used in teaching the autistic children in learning basic shapes, which is by using shape cards and whiteboard creates a monotonous and mundane learning environment. All students have to sit and listen to the teacher and focus on the drawn shapes on whiteboard or the shapes being shown on the cards. Students were quiet and seems not interested after 5 minutes, as shown in Figure 15.8.

Figure 15.8 Traditional method in teaching basic shapes using cardboard and whiteboard

Throughout the observation, the traditional learning could only sustain the concentration of autistic children in learning within 10 minutes. After that, the autistic children start to lose their interest in learning. This is due to the fact that, the autistic children have the tendency to engage in repetitive behavior and attention (Autism Speacks Inc., 2017). As shown in Figure 15.9, the children tend to lost interest when they did not get attention from the teacher.

Contrary to the traditional learning, learning using Roboshapes creates a different and more positive atmosphere. From the observation throughout the learning process, the autistic children seem more attracted to learn with the robot as all of them can maintain to learn basic shapes with the robot for more than 20 minutes. From the Figure 15.10, we can see that all the autistic children are excited and attracted to learn with the Robot.

Moreover, by implementing robot in assisting the teacher in teaching, the learning process held in the classroom seems more active. The students were pro-active in asking questions, suggesting new things and idea. This is because they are adopting a different style of learning basic shapes by learning-by-doing thus, the children are the one who are really eager to learn and want to see the action done by the robot. The teacher as well as

Figure 15.9 After 10 minutes learning autistic children started to lose their interest

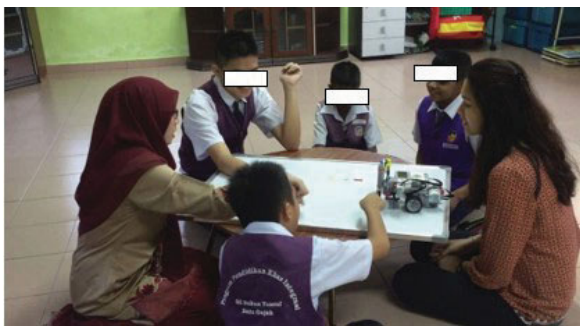

Figure 15.10 Autistic children still attracted to learn even after 20 minutes

some parents did gave a positive feedback from the robotic intervention. It was highlighted that the implementation of EV3 Robot in teaching basic shapes to the autistic children is much more beneficial and gives such positive feedback from the children themselves. For example, from the Figure 15.11 it was shown that the autistic children took a pro-active step to command the robot to draw shapes by putting the color sensor of the robot at the starting point without being asked to. This shows that students were more engaged in learning.

Figure 15.11 Hands-on learning

After both learning process (i.e. traditional and robotic intervention) were completed, the students were given two assessment tests to see the impact of learning basic shapes, as shown in Figure 15.12. The first test is relating to the content of the traditional module, while the second test is relating to the robotic intervention learning content. The results were then collected and analyzed to see the differences and impact of both methods. The results were presented and discussed in the next paragraphs.

Figure 15.12 Test after learning process with Robot

Table 15.2 shows the results of assessment conducted after the students completed both the traditional learning and with the assistance of Roboshapes. The '*traditional method*' column presents the results of the assessment (i.e. Test 1) that was conducted based on the modules taught by the teacher using cards and whiteboard. Following this, the column '*robot method*' presents two assessment results (i.e. Test 2 & Test 3) based on the modules taught by the Roboshapes. Referring to Table 15.2, the average score for Test 1 (i.e. traditional learning) was 90%, while the average score for Test 2 and Test 3 (i.e. learning with the assistance of Roboshapes) were 100%. This shows that students learn better when the teaching and learning was assisted by the Robot.

Table 15.2 Test Assessment Results (traditional vs robotic intervention)

STUDENT	TRADISIONAL METHOD		ROBOT METHOD			
	TEST PAPER 1	REMARK	TEST PAPER 2	REMARK	TEST PAPER 3	REMARK
S1 KMH 10 y/o	5/5*100% =**100%**	Recognize all shapes. However, S3 did not understand and follow the instruction of the question. Colour shapes that he wants to colour.	5/5*100% =**100%**	The autistics children recognize all the basic shapes. However, S3 and S4 did not understand and follow the instruction of the question. They colour all the shapes given.	4/4*100% =**100%**	The autistics children recognize all the basic shapes. They match all the shapes with the picture correctly.
S2 R 10 y/o	5/5*100% =**100%**		5/5*100% =**100%**		4/4*100% =**100%**	
S3 D 11 y/o	3/5*100% =**60%**		5/5*100% =**100%** (colour other shapes)		4/4*100% =**100%**	
S4 CWG 14 y/o	5/5*100% =**100%**		5/5*100% =**100%** (colour other shapes)		4/4*100% =**100%**	
Total average	18/20*100% = **90%**		20/20*100% = **100%**		16/16*100% = **100%**	

As mentioned by the teacher, the autistic students learn better by learning through robotic intervention. This is due to the fact that they find it interesting were attracted to the learning approach. For example, to make the autistic children more attracted in learning, it is found that they like to receive compliments. Those compliments will make them feel more excited and motivated to learn. Since Roboshapes never fail to give them compliments such as ”*Well done!*”, ”*Good!*” and ”*Congratulations*!”, the students feel engaged and attracted to learn more. However, it is noted that it is important to ensure that the learning process of the autistic children to be conducted in a conducive environment (*e.g. not hot or noisy, morning time etc.*). This is to ensure that learning process could be run smoothly.

15.7 Conclusion

There are numerous approaches to teach autistic children in a more engaging manner and this study has shown that robotic intervention seems to be very promising. From the observation and results of the test assessments, it shows that the implementation of robot in assisting the teacher in teaching leads to more effective learning experience. This could be seen from students' behavior whom are more engaged, interested and focused. Further, the sustenance in learning and focus-learning time span is longer with robotic intervention.

On the other note, having robots as a teaching and learning tool opens up many other opportunities. This include skills to build and construct robots based on creativity to teachers and the interested autistic children. They could also use it for playing and distressing themselves. This definitely creates a better teaching and learning in class experiences for the special needs children.

In conclusion, an extension to the current way of teaching and learning for the special needs students should not be left unexplored. Although the schools and parents had to take risks in exploring the best support for this group of children, it is important to note that this group of students deserve relevant and quality experience in the endeavor of learning. Therefore, it is hoped that more future studies will be conducted towards exploring better opportunities in improving this group of students in learning so that they could also embrace the wave of IR 4.0.

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CHAPTER 16

TRAINING SYSTEM DESIGN OF LOWER LIMB REHABILITATION ROBOT BASED ON VIRTUAL REALITY

H. Wang[1], M. Lin[1], Z. Jin[1], X. Wang[1], J. Niu[1], H. Yu[1], L. Zhang[1], L. Vladareanu[2]

[1] Parallel Robot and Mechatronic System Laboratory of Hebei Province and Key Laboratory of Advanced Forging & Stamping Technology and Science of Ministry of Education, Yanshan University, Qinhuangdao, 066004, China

[2] Romanian Academy, Institute of Solid Mechanics, Bucharest, Romanian

Emails: uige.vladareanu@vipro.edu.ro; luigiv2007@yahoo.com.sg

Abstract

This chapter introduces a training system for the lower limb rehabilitation robot based on virtual reality (VR), mainly including trajectory planning and VR control strategy. It can simulate the bike riding and encourage patients to join in the recovery training through the built-in competitive game. The robot could achieve the linear trajectory, circle trajectory and arbitrary trajectory based on speed control, the training velocity and acceleration in the planning trajectory have been simulated. The human-machine dynamics equation was built which is used for judge the patient's movement intention. The VR training mode is a variable speed active training under the constraint trajectory, and it has adapting training posture function which can provide individual riding training track according to the legs length of patients. The movement synchronization between the robot and virtual model is achieved by interaction control strategy, and robot can change the training velocity based on the signal from feedback terrains in game. A serious game about bike match in forest was designed, and the user can select the training level as well as change perspective through the user interface.

Keywords: Rehabilitation Robot; Trajectory Planning; Virtual Reality; Interact Strategy; Serious Game.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (203–284)

16.1 Introduction

As aging society comes to many counties in the world, the health of elderly has become a focus problem [1-2]. Stroke is a common disease in the elderly which has a high morbidity and disability [3], and the rehabilitation training based on neural plasticity is regarded as an effective method to stroke sequel [4-6]. Traditional rehabilitation need a long term one-on-one treatment which costs too much human resources, and it cannot maintain a stable intensive. Since the training process is too boring and simple, it is hard to attract patients and receive active cooperation. However, the combination of robotics and VR could properly solve these problems.

Serious game is a kind of application designed for a primary purpose other than pure entertainment, and it is generally referred to video games based on VR technology which are commonly used in defense, education, and scientific exploration, health care. As the positive effects of VR games in rehabilitation are shown by various scientific studies [7-11], the VR applications in rehabilitation robots have been the focus of researchers in various countries [13-15]. MIT-Manus is the first widely known limb rehabilitation robot with simple VR system, and a robot named GENTLE/s with virtual interaction scenes was designed by University of Reading [16-17]. A 6-DOF (Degree Of Freedom) rehabilitation robot with VR function was developed by Osaka University [18]. A VR-based rehabilitation robot was developed by Tianjin University of Technology, which could make the training process visual and interactive [19].

This chapter presents a VR training system based on a lower limb rehabilitation robot, and it is shown as follow: section 16.2 is the introduction of the rehabilitation robot and the sensors. In section 16.3, the design of training trajectory and simulation are presented. In section 16.4, the design of VR training system is presented. Section 16.5 is the build process of VR game scenes and game functions. The experiment data of VR training is shown in the last section 16.6.

16.2 Application Device

16.2.1 Lower Limb Rehabilitation Robot

Figure 16.1 Lower limb rehabilitation robot

The LLRR (*Lower Limb Rehabilitation Robot*), presented in Figure 16.1, was designed as a modular structure, and it consist of the left mechanical leg, the right mechanical leg, the separable chair and the electric box. User could control the robot through the touch-screen equipped on the right mechanical leg.

Each mechanical leg owns 3-DOF and contains hip joint, knee joint and ankle joint which are same as human joints shown in Figure 16.2. The mechanical leg could be divided into the thigh part and the shank part, and the length of each part could be changed electronically to meet the various legs length of patients from 1.5m to 1.9m.

Figure 16.2 Left mechanical leg

To satisfy the different shapes of patients, the width between two legs could be adjusted automatically. A separable chair with four universal wheels used for sitting/lying training and patients transfer was designed.

16.2.2 Necessary Sensor Element

The torque and pressure sensors equipped on LLRR are shown in Figure 16.3. Four torque sensors are installed in hip and knee joints which could receive torque data constantly from the joints. The joint torque data is the necessary judgment of the active training and the VR training.

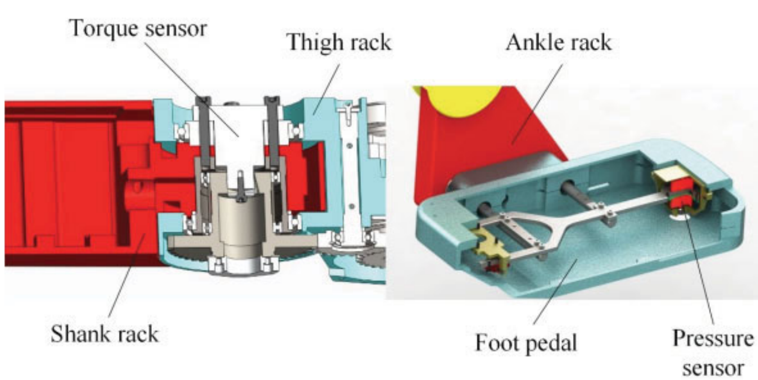

Figure 16.3 Necessary sensor element

Foot pressure data, which is collected by sensors equipped in the foot pedal, could transformed into the acceleration factor used for controlling training velocity of mechanical legs terminal.

16.3 Trajectory Planning and Smooth Motion

In order to obtain LLRR training trajectories smooth and flexibility, the velocity and the acceleration of the endpoint of the mechanical leg should be continuous. However, the realization of the endpoint motion is through the control of the LLRR mechanism leg joints. It is necessary to map movement of the end point in the Cartesian coordinate into joints space to get each joint angular velocity, angular position and angular acceleration. The linkage model of LLR-Ro mechanism leg is built as shown in Figure 16.4.

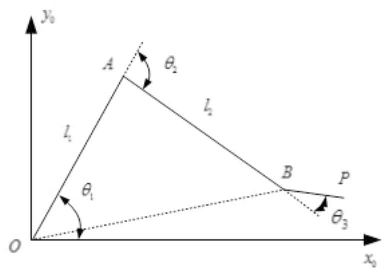

Figure 16.4 Linkage model of LLRR mechanical leg

Hip joint axis, knee joint axis and ankle joint axis are placed at point *O*, *A* and *B*, respectively. Besides, *P* represents end point of mechanical leg; $l_i\ (i = 1, 2, 3)$ expresses length of thigh, calf and foot; $\theta_i\ (i = 1, 2, 3)$ represents the angular position of three joints; the joint axis of hip joint is located at the base coordinate system. x_0 represents the horizontal direction. y_0 represents the vertical direction. In the below trajectory planning, as the coordinate of the end point *P* is almost same with the point *B*. So, the movement of ankle will be planned separately. Then target path is the position of the point B and the coordinate of point *B* can be calculated easily as below:

$$\begin{cases} x_B = l_2 \cos(\theta_1 + \theta_2) + l_1 \cos\theta_1 \\ y_B = l_2 \sin(\theta_1 + \theta_2) + l_1 \sin\theta_1 \end{cases} \tag{16.1}$$

16.3.1 Design of Training Velocity and Acceleration with Linear Path

The displacement of the end point in the direction of the line path is designed to meet a quintic polynomial. It describes the relationship between the displacement in the direction of the line and the time in the equation 16.2.

$$l(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 \tag{16.2}$$

Also, constrains are given: When the time is zero, the displacement of the end point is zero. When the time is t_{end}, the displacement of the end point is $l(t_{end})$. To make the motion smooth, the velocity of origin and end points must be zero. To meet the continuous acceleration, the acceleration of origin and end points must be zero.

$$\begin{cases} l(0) = 0 \\ l(t_{end}) = l_{end} \\ \dot{l}(0) = 0 \\ \dot{l}(t_{end}) = 0 \\ \ddot{l}(0) = 0 \\ \ddot{l}(t_{end}) = 0 \end{cases} \tag{16.3}$$

The polynomials of the displacement, velocity, acceleration in *X* axis and *Y* axis are obtained,

$$\begin{cases} x(t) = l \cdot cos(\theta_l) + x_0 \\ y(t) = l \sin(\theta_l) + y_q \\ \dot{x}(t) = \dot{l} \cdot cos(\theta_l) \\ \dot{y}(t) = \dot{l} \sin(\theta_l) \\ \ddot{x}(t) = \ddot{l} \cdot cos(\theta_l) \\ \ddot{y}(t) = \ddot{l} \sin(\theta_l) \end{cases} \tag{16.4}$$

where, θ_l represents angular position between line-trajectory and X-axis. From the forward kinematics equations (16.1), we could obtain,

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = J(q) \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} \tag{16.5}$$

where,

$$J(q) = \begin{bmatrix} -l_2 \sin(\theta_1 + \theta_2) - l_1 \sin\theta_1 & -l_2 \sin(\theta_1 + \theta_2) \\ l_2 cos(\theta_1 + \theta_2) + l_1 \cos\theta_1 & l_2 \cos(\theta_1 + \theta_2) \end{bmatrix}$$

The velocity of joints can be calculated,

$$\begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} = J^{-1}(q) \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} \tag{16.6}$$

The acceleration of the joint is calculated:

$$\begin{bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} = J^{-1}(q) \left(\begin{bmatrix} \ddot{x} \\ \ddot{y} \end{bmatrix} - \dot{J}(q) \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} \right) \tag{16.7}$$

where,

$$\dot{J}(q) = \begin{bmatrix} -l_1\dot{\theta}_1 \cos\theta_1 - l_2(\dot{\theta}_1 + \dot{\theta}_2) cos(\theta_1 + \theta_2) & -l_2(\dot{\theta}_1 + \dot{\theta}_2) cos(\theta_1 + \theta_2) \\ -l_1\dot{\theta}_1 \sin\theta_1 - l_2(\dot{\theta}_1 + \dot{\theta}_2) sin(\theta_1 + \theta_2) & -l_2(\dot{\theta}_1 + \dot{\theta}_2) \sin(\theta_1 + \theta_2) \end{bmatrix} \tag{16.8}$$

The angle of the ankle joint is changed according to the position in the training track. It is defined by the equation below.

$$\theta_3 = \frac{l_{BO}(t) - l_{BO\min}}{l_{BO\max} - l_{BO\min}} \times (\theta_{3\max} - \theta_{3\min}) + \theta_{3\min} \tag{16.9}$$

where, θ_3 represents the ankle angle and initial position is at where the footboard is perpendicular to the calf. Anticlockwise is the ankle joint motion as positive direction. l_{BO} represents the distance between ankle joint center (same with point *B*) and the original point (the point *O*).

Then displacement of the ankle joint could be designed as below:

$$\theta_3 = \frac{\sqrt{l^2 + 2lx_0cos(\theta_l) + 2ly_0sin(\theta_l) + x_0^2 + y_0^2} - l_{BO\,\min}}{l_{BO\,\max} - l_{BO\,\min}} \times (\theta_{3\,\max} - \theta_{3\,\min}) + \theta_{3\,\min} \tag{16.10}$$

The expression of the ankle velocity can be obtained by taking differential of equation (16.10) above, and the ankle joint acceleration can be obtained by taking the derivative of velocity equation.

16.3.2 Design of Training Velocity and Acceleration with Circle Path

The displacement of the end point in circle path is also designed to meet a quantic polynomial.

$$\alpha(t) = a_0 + a_1t + a_2t^2 + a_3t^3 + a_4t^4 + a_5t^5 \tag{16.11}$$

The end point need to satisfy with the constrains,

$$\begin{cases} \alpha(0) = 2\pi \\ \alpha(t_{end}) = \alpha_{end} \\ \dot{\alpha}(0) = 0 \\ \dot{\alpha}(t_{end}) = 0 \\ \ddot{\alpha}(0) = 0 \\ \ddot{\alpha}(t_{end}) = 0 \end{cases} \tag{16.12}$$

The polynomials of the displacement, velocity, acceleration following the *X* axis and *Y* axis are obtained,

$$\begin{cases} x(t) = rcos(\alpha(t)) + x_0 \\ \dot{x}(t) = -r\dot{\alpha}(t)\sin(\alpha(t)) \\ \ddot{x}(t) = -r\dot{\alpha}(t)\dot{\alpha}(t)\cos(\alpha(t)) - r\ddot{\alpha}(t)sin(\alpha(t)) \\ y(t) = r\sin(\alpha(t)) + y_0 \\ \dot{y}(t) = r\dot{\alpha}(t)cos(\alpha(t)) \\ \ddot{y}(t) = -r\dot{\alpha}(t)\dot{\alpha}(t)sin(\alpha(t)) + r\ddot{\alpha}(t)cos(\alpha(t)) \end{cases} \tag{16.13}$$

The joints angular position, angular velocity and angular acceleration of the knee and hip could be solved by inverse kinematics relationship which is same with the solution method at straight-line trajectory. The ankle joint will be defined as below:

$$\theta_3 = \theta_{3\,\max} - \frac{\sqrt{r^2 + x_0^2 + y_0^2 + 2rx_0cos(\alpha(t)) + 2ry_0sin(\alpha(t))} - l_{BO\,\min}}{l_{BO\,\max} - l_{BO\,\min}} (\theta_{3\,\max} - \theta_{3\,\min}) \tag{16.14}$$

16.3.3 Design of Training Velocity and Acceleration with Arbitrary Trajectory

The arbitrary trajectory is made by connecting the points with lines. The time is defined between the two adjacent points in the arbitrary path,

$$t_n = \frac{l_n}{\sum\limits_{k=1}^{m} l_k} T \tag{16.15}$$

where, l_n represents the distance of the two adjacent points; t_n represents the motion time between the two adjacent points; *T* represents the whole motion time of the arbitrary trajectory.

The displacement, velocity and acceleration are defined at *X* axis and *Y* axis, and that curve will be divided into many small curves by the intermediate points. Taking the *X* axis as an example, the points' displacement x_n in the direction of *X* axis is combined with its corresponding time t_n,

$$(x_1, t_1), (x_2, t_2), ..., (x_n, t_n), ..., (x_{\mathrm{m}-1}, t_{m-1}), (x_m, t_m)$$

Displacement function between two adjacent points is a polynomial. The polynomials of first small curve and the last small curve are quartic polynomial, and the rest polynomials are defined cubic polynomial. To make the velocities are smooth and continuous, the velocities at the beginning point and end point are required to be zero, and the velocity of the intermediate adjacent points is required to be equal to its previous adjacent point. Also, in order to make the acceleration smooth and continuous, the acceleration at the beginning point and end point are required to be zero and the acceleration of the intermediate adjacent points is required to be equal to its previous adjacent point. These constraints can be used to obtain the expressions of the small curves.

The expression of ankle joints displacement could be obtained separately as below,

$$\theta_3 = \frac{\sqrt{x^2(t) + y^2(t)} - l_{BO\,\min}}{l_{BO\,\max} - l_{BO\,\min}} \times (\theta_{3\,\max} - \theta_{3\,\min}) + \theta_{3\,\min} \tag{16.16}$$

16.3.4 The Analysis of Ambiguous Points

The motion range of knee joint's angle is from -120^0 to 0^0. When the θ_2 approaches to 0^0, the robot is close to its singularity, as the velocity calculated by $J^{-1}(q)$ of knee joint is infinite. Thus, the constrain $\theta_2 \leq -10^0$ is added in the path planning, considering the actual position of calf will become collinear with the thigh when θ_2 is close to 0^0.

When θ_2 is under the value -10^0, the knee's velocity is calculated by $J^{-1}(q)$. When θ_2 is $-10^0 \leq \theta_2 \leq 0^0$, we can plan the displacement, velocity and acceleration of the knee joint directly, instead of $J^{-1}(q)$, to train the calf. However, it is not necessary for knee joint in the motion of the circle path.

16.3.5 The Simulation of Training Velocity and Acceleration in the Planning Trajectory

As paper space is limited, this paper displaced the simulations of the linear trajectory and the arbitrary trajectory. l_1 equals 390mm, l_2 equals 295mm and the whole time cost 5s.

1) The planning of the arbitrary trajectory: The initial point, the intermediate points and the end point is shown in Figure 16.5.

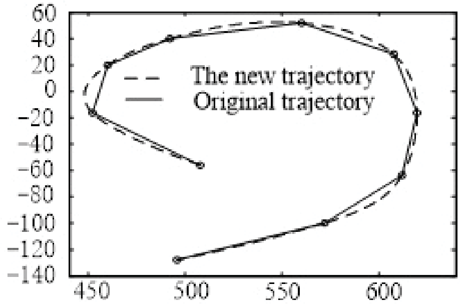

Figure 16.5 Comparison between the original path and the new path planned

Applying the design of training velocity and acceleration with arbitrary trajectory, the displacement, velocity and acceleration of the new path in the direction of *X* axis and *Y* axis are displayed in the Figure 16.6, Figure 16.7 and Figure 16.8. Obviously, we can find that the displacement, velocity and acceleration are continuous.

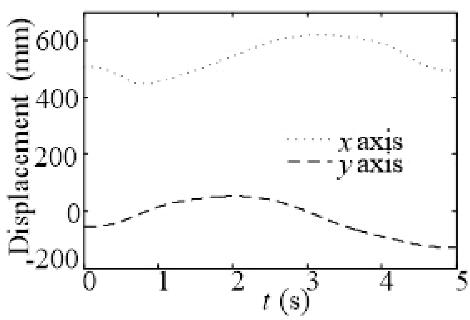

Figure 16.6 The angular position of the end point at X axis and Y axis

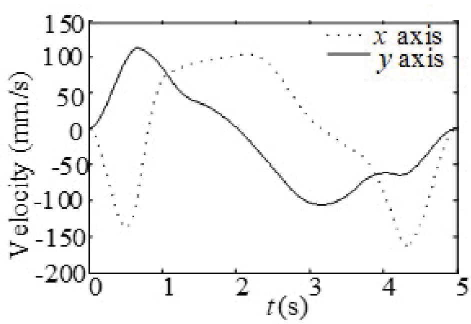

Figure 16.7 The velocity in the direction of X axis and Y axis

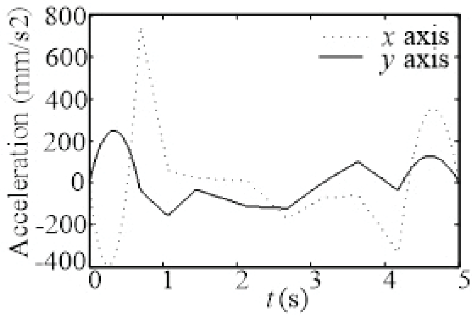

Figure 16.8 The acceleration in the direction of X axis and Y axis

The displacement, velocity and acceleration of each joint are calculated as shown in Figure 16.9, Figure 16.10 and Figure 16.11. The results show that the angular position and velocity of joints can be smooth and the acceleration is continuous after interpolation for arbitrary trajectory.

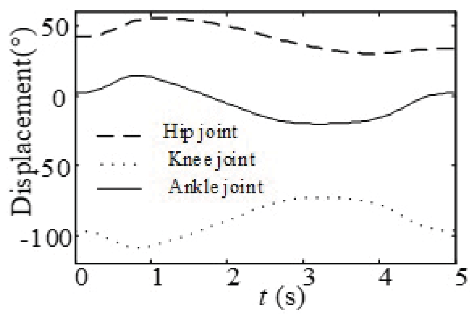

Figure 16.9 The angular position of three joints

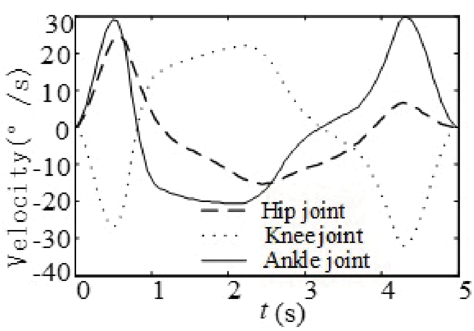

Figure 16.10 The angular velocity of three joints

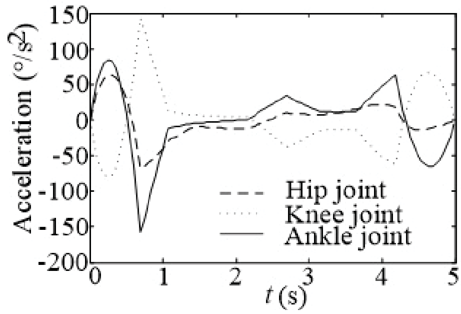

Figure 16.11 The acceleration of three joints

2) The planning of the linear trajectory: Through workspace analysis of the linkage model, a linear trajectory is designed from coordinate (362.16, 131.36) to coordinate (758.69, -30.66). Applying the design of training velocity and acceleration with linear trajectory, the displacement, velocity and acceleration of the new path in X axis and Y axis are displayed in Figure 16.12, Figure 16.13 and Figure 16.14. Obviously, we can find that the displacement, velocity and acceleration are continuous.

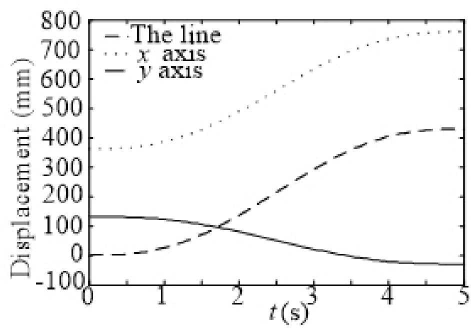

Figure 16.12 The angular position curves at X axis and Y axis

Displacement, velocity and acceleration of each joint are obtained as shown in Figure 16.15, Figure 16.16 and Figure 16.17. Based on analysis of the above results, angular position and velocity of each joint are smooth and the acceleration is continuous after interpolation for arbitrary trajectory.

16.4 Virtual Reality Training System

To cooperate with the VR software and simulate the riding body feeling, a VR training system was designed. VR training is an improved kind of active training, it includes intention judgment, adapting training posture and interaction control strategy. The intention judgment is similar to the normal active training, and more details are shown in paper [20].

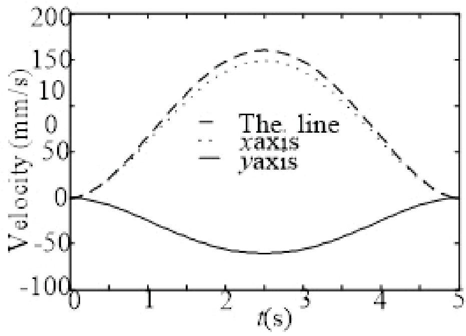

Figure 16.13 Angular velocity curves at the line, X axis and Y axis

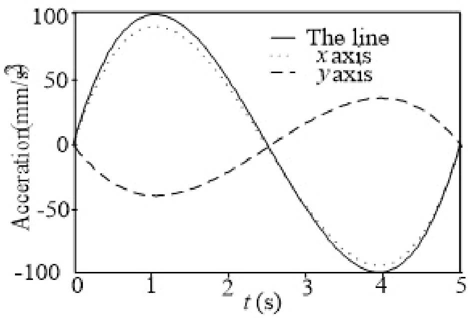

Figure 16.14 The acceleration in the direction of the line, X axis and Y axis

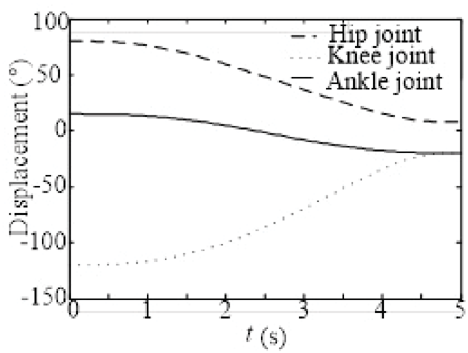

Figure 16.15 The displacement of three joints

16.4.1 Design of Intention Judgment of Patients

Lagrange dynamics method was used to solve the inverse problem of the mechanical leg, and the joint torque was obtained in real time to judge the patient's movement intention.

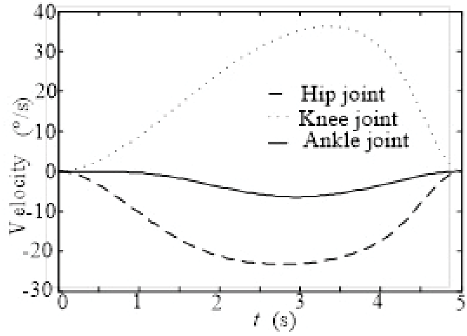

Figure 16.16 The velocity of three joints

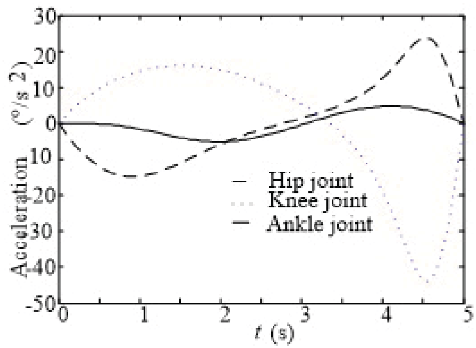

Figure 16.17 The acceleration of three joints

The general equation of dynamics was obtained,

$$\mathbf{H}(\theta)\ddot{\theta} + \mathbf{C}(\theta, \dot{\theta})\dot{\theta} + \mathbf{G}(\theta) = \tau \tag{16.17}$$

θ represents the angular position of the joints; τ represents the joint torque; $\mathbf{H}(\theta)$ represents the inertia matrix; $\mathbf{C}(\theta, \dot{\theta})$ represents the centrifugal force and Coriolis force related term matrix; $\mathbf{G}(\theta)$ represents the gravity terms matrix.

To achieve active rehabilitation training for patients, it must be considered that the impact of lower limb gravity on the mechanical leg joint torque. In this chapter, referring to the study of robotic statics, the patient's lower limb is reduced to a two-bar linkage model. The gravity of foots is concentrated at the ankle joint, and the direction of force is vertical. Refer to linkage model of the mechanical legs in Figure 16.4, the equation could be obtained according to the principle of leverage,

$$m_1 g R_1 \cos\theta_1 + m_2 g \left[l_1 \cos\theta_1 + R_2 \cos(\theta_1 + \theta_2)\right] = (F_0 - m_3 g)\left[l_1 \cos\theta_1 + l_2 \cos(\theta_1 + \theta_2)\right] \tag{16.18}$$

m_i represents the quality of the patient's leg; l_i represents the length of the patient's leg; θ_i represents the angular position of the joints; R_i represents the distance from the center of the patient's leg to the joint; F_0 represents the end force when the patient relaxes.

And the force vector F of lower limb to the leg end could be obtained:

$$\mathbf{F} = \begin{bmatrix} 0 \\ m_3 g + \frac{m_1 g R_1 \cos\theta_1 + m_2 g [l_1 \cos\theta_1 + R_2 \cos(\theta_1+\theta_2)]}{[l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2)]} \end{bmatrix} \tag{16.19}$$

The joint torque τ_0 from terminal force be calculated easily as below,

$$\tau_{\mathbf{0}} = \mathbf{J}^T(\theta)\mathbf{F} \tag{16.20}$$

$\mathbf{J}^T(\theta)$ is the force Jacobian matrix of the mechanical leg model.

Finally, the human-machine dynamics equation, when patient's lower limb freely placed on LLRR, are obtained,

$$\mathbf{H}(\theta)\ddot{\theta} + \mathbf{C}(\theta, \dot{\theta})\dot{\theta} + \mathbf{G}(\theta) = \tau - \mathbf{J}^T(\theta)\mathbf{F} \tag{16.21}$$

According to the equation above, the real-time torque of the mechanical leg and the patient's lower acting on each joint can be determined while the patient does not have an active exercise intention. The real-time torque of the joint and the measured data of the torque sensor can be used to complete the active training control.

16.4.2 Design of Adapting Training Posture Function

Based on the research of bike mechanism and riding body posture, as shown in Figure 16.18, adapting posture function was built.

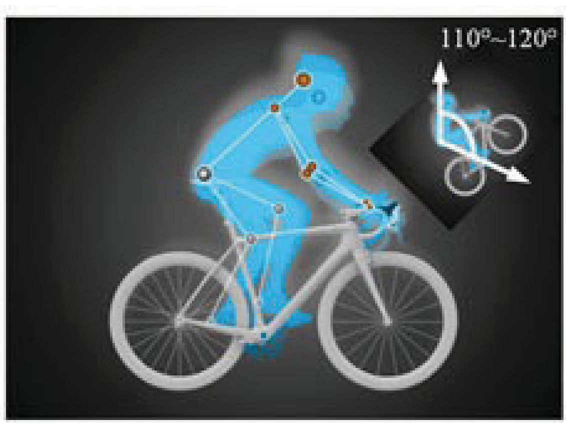

Figure 16.18 Riding body posture

The function can provide individual terminal trajectory according to the different legs length of patients. Based on alternative tracks in workspace, it could select suitable track for patients which could make training closer to real bike riding (Figure 16.19).

16.4.3 Interaction Control Strategy

Interaction control strategy is a necessary link between the robot and the VR software, and it mainly contains the model synchronization and feedback terrains. The strategy block diagram of interaction control is shown in Figure 16.20.

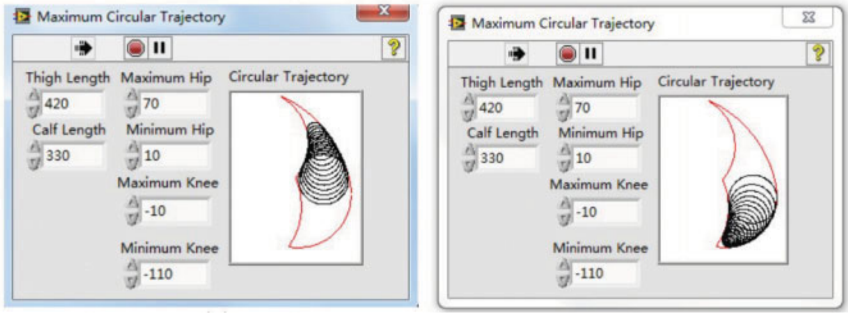

Figure 16.19 Calculated circular trajectory

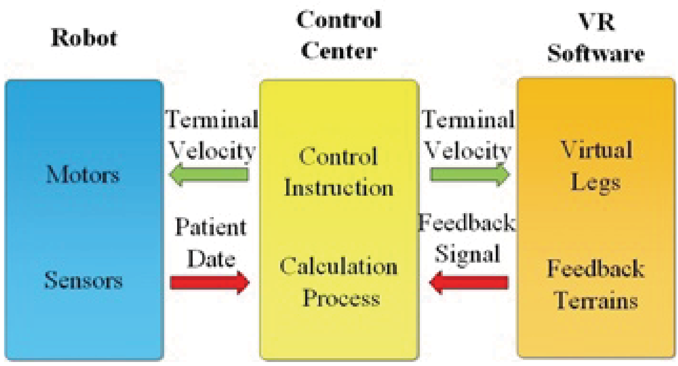

Figure 16.20 Interaction control strategy

Comparing the sensors data with calculated data, the patient movement intention data could be determined. The torque intention is defined as the judge factor, and the robot will begin to run with default terminal velocity when judge factor exceeds the preset threshold. The pressure intention works as an acceleration factor when it exceeds the threshold, and there is a linear relationship between the factor and the value added on default velocity.

Final terminal velocity is used for LLRR control, and it is sent to VR software for model action synchronization. Meanwhile, there are some different feedback terrains set up in the VR riding game, such as hill and obstacle road. When the virtual character model in those terrains upon, the robot will receive the feedback signal from the VR software and then change the mechanical legs running speed depending on different conditions.

16.5 Virtual Reality Software Design

16.5.1 Virtual Scene Build

Based on the game development engine Unity3D, the VR riding game was built. The planning of the virtual scene not only meets the requirements of exercise intensity for rehabilitation training, but also could stimulate the nervous system of the patients and has a good influence on psychological of patients. This scene properly meets the outdoors walking desire of the patient with walking problems.

An outdoor riding match scene with green background tone and plenty sunlight is shown in Figure 16.21, and it could provide a relaxing virtual environment for patients.

Figure 16.21 Match scene in game

Riding game has 4 character models, except one controlled by the patient, 3 models are NPC (Non-Player Character) with different actions controlled by the computer. Multi-characters could avoid loneliness, while match training has properly entertainment and competitiveness.

The whole road is about 600 meters, a single match will take 2 or 3 minutes. There are 2 obstacle areas and a hill on the road, and the stimulus strength of training could be changed when the model goes through these areas.

16.5.2 Game Function Design

VR game software cannot run without scripts, and each component or model in the game need a relative script at least. The main scripts are shown as follows.

1. User Interface: Used for game start, level select, software close and other buttons.
2. Model synchronization: Control the virtual legs move same as the real legs based on robot terminal velocity.
3. Model movement: According to terminal velocity, calculate speed and control model move forward along straight road.
4. NPC action: Control models run in preset parameters when game start, and NPC could run in 4 levels speed based on the difficulty choice in the title screen.
5. Feedback trigger: Constantly monitor positions of 4 models, if a model enter the feedback areas it will send signal to robot until the model leave areas.
6. Signal I/O: Build temp files used for writing and loading signal by robot and software.
7. Pause and timer: Game and robot could be paused at any time when training start, it could also record the time since the game start.

Figure 16.22 First-person perspective

8. Camera: Game screen could be switched between the first-person perspective and the third-person perspective when the game start (Figure 16.22).

The connections between scripts and models were built, and scripts working condition in the simple scene was tested as shown in Figure 16.23. After debugging, all components were imported into the completed scene.

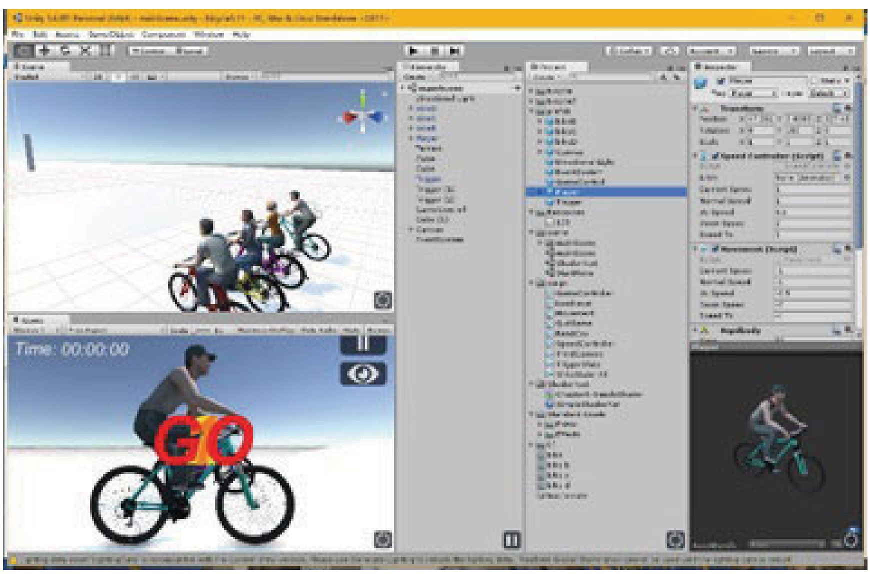

Figure 16.23 Function test

16.6 Virtual Reality Training Experiment

16.6.1 Model Synchronization Test

The movements of mechanical legs and virtual legs were recorded through the video. Due to the deflection between the training posture and the real riding posture, the movements are not exactly same as shown in Figure 16.24. But the time costs of both legs reaching the lowest point in their own circle track are same, the synchronization between the robot and the model is properly achieved.

Figure 16.24 Screenshot of synchronization test

16.6.2 Feedback Terrains Test

The sensors data is set as a fixed value, and the robot terminal velocity is recorded when the model goes through the feedback terrains in the game. The recording data was transformed into a graph shown in Figure 16.25.

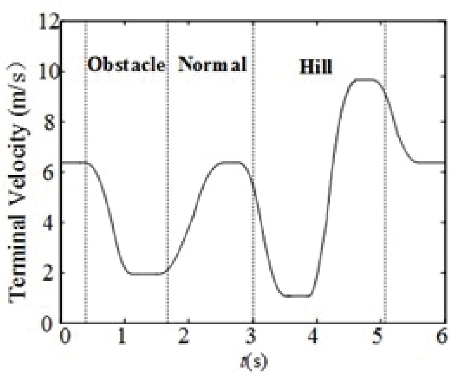

Figure 16.25 Feedback terrains test

The result shows that the patient need to pay more efforts or reduce the training speed when the character model goes into the difficult feedback areas, and the opposite effect will occur in easy areas.

16.7 Conclusion

Based on the lower limb rehabilitation robot, a virtual reality training system with competitive game was designed, which could simulate the bike riding and encourage patients to join in the recovery training. LLRR could achieve three types of trajectories and each one is smooth and continuous. It can realize movement synchronization between the robot legs and the virtual model, and the robot can vary terminal velocity according to the signal of feedback terrains in the game. The system can select the suitable training trajectory based on the legs length of patients before training, and the training can be paused by patients or doctors at any time while training. Doctors could switch VR training difficulty according to the recovery of patients, and the recovery could be reflected through the timer function.

Contributions

Applying virtual reality technology in active training can greatly mobilize the enthusiasm of patient training, and doctors can regard the virtual training situation as a basis to evaluate the rehabilitation situation. This study provides a template for the follow VR technology research in the field of rehabilitation robots. The team may later upgrade the virtual training experience and will introduce VR glasses to enhance the visual experience, and add virtual training scene such as high jumps or pedal boats. It will bring changes in the field of rehabilitation, if the idea above could be achieved, and the study of this article is necessary.

ACKNOWLEDGEMENTS

This work was developed with the support of ”Joint Laboratory of Intelligent Rehabilitation Robot” collaborative research agreement between Yanshan University, China and Romanian Academy by IMSAR, RO by China Science and Technical Assistance Project for Developing Countries (KY201501009).

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Part IV

INTERNET OF THINGS TECHNOLOGIES AND APPLICATIONS FOR HEALTH AND MEDICINE

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (223–284)

CHAPTER 17

AUTOMATION OF APPLIANCES USING ELECTROENCEPHALOGRAPHY

Shivam Kolhe[1], Dhaval Khemani[1], Chintan Bhatt[1], and Nilesh Dubey[1]

[1] Charotar University of Science And Technology, Changa, Gujarat
Emails: 15ce054@charusat.edu.in, 15ce051@charusat.edu.in, chintanbhatt.ce@charusat.ac.in, nilesh-dubey.ce@charusat.ac.in

Abstract
Brain Computer Interface (BCI) is one of the new emerging field in which a direct communication pathway is established between a human or animal brain and any outside or external device. The two way BCI's allow the brain and the external devices to exchange signals in both the directions. But until today we have been successful in establishing one way BCI's. In future, we will be able to use two way BCI's effortlessly. The best is yet to come. In this chapter, an introduction to the BCI technology is given, the different signals generated by the brain are stated, also brain anatomy is explained. In addition, how are brain signals generated by the brain, how does BCI system work, a method to perform Electroencephalogram, how are those brain signals detected is explained and also BCI classes are stated and introduced.

Keywords: Internet of Things (IoT), Brain Computer Interface (BCI), Electroencephalography / Electroencephalogram (EEG)

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17.1 Introduction

There may not be a drastic increase in the population but there is surely massive change in the number of devices people are using. The Internet is also evolving and so is its usage. So with the increase in both electronic devices and the internet, a new field is born and that is "*Internet of Things*". The Internet of Things is a newly emerging and we can say evolving field. Internet of Things is a system of interrelated computing devices and objects which we use in our daily lives and when connected within a network gain the ability to communicate with each other without requiring human to human or human to computer interaction.

Till now we were living in the Information Era, but now we have left it far behind and we are now living in the Technological Era. Computers are becoming smarter, powerful and cheaper in cost. Now the molecular computer is expected to accelerate this trend. One time will come when these computing machines and sensors will move to each and every object we have or use in our daily lives. Even our bodies will also be connected to the internet. Just imagine the world where every object will interact with other and with humans. This time is coming soon. By 2020, we will surely be living in technology. We will have to harness the power of Internet of Things. So we can technically say that the Internet of Things Era has begun. A new massive wave is coming and going towards connected cars, smart houses, health monitors, wearable, smart cities. Basically a connected life. According to the report, by 2025 connected devices count will reach to 1 trillion. In IoT the unstructured machine generated data is being collected by the sensors, it is then properly analyzed and then used for the desired purpose. A thing in the Internet of Things can be anything like it can be an implant in the heart of the person for heart rate monitoring, it can be a be tracker implanted in the belt of a pet or it can be a coffee maker machine which is smart enough to automatically works as human wants without his/her efforts.

Applications of Internet of Things are: Smart Homes, Wearable, Connected Cars, Industrial Internet, Smart Cities, in Agriculture, Smart Retail, Energy Engagement, IoT in Poultry, IoT in HealthCare.

17.2 Background, History and Future Aspects

The Brain Computer Interface is a direct communication between the brain and any external device. The brain signals travel from brain to the computer directly instead of traveling through the neuromuscular system to the body parts. In earlier days the brain computer interface devices or the electrodes were implanted in the brain but nowadays non-invasive techniques are used which are directly placed on the scalp to control the external devices. The Brain Computer Interface devices nowadays require effort but in future, these devices are expected to work effortlessly. This field is the combination of the fields like Electrical engineering, computer engineering, biomedical engineering and neuroscience or neurology.

Hans Berger worked in the human brain research field and its electrical activity and by his innovation Brain Computer Interface was discovered. Hans Berger thus developed the new field called Electroencephalography. Thus he is known as the father of Electroencephalography. His research made it possible to detect brain diseases. He was inspired by Richard Canton's discovery of electrical signals in brains of animals in the year 1875. In the year 1998, Philip Kennedy implanted the first brain computer interface device into the human brain. In 2003, a first BCI game called BrainGate was designed John Donoghue and his team. In June 2004, Matthew Nagle became the first human to be implanted with BCI devices (*BrainGate BCI devices*) to restore functionality he lost because of paralysis. John Wolpaw demonstrated the ability to control a computer using a BCI in December 2004. In his study electrode cap was placed on the scalp to capture EEG signals This field will be greatly developed in the future. Many developments have been taking place in this field nowadays. Future of BCI will be like a man will be able to control and manipulate the outside objects by their mind. Man will be able to control natural as well as complex motions of everyday life. The mobility functions lost during paralysis or any accidents will be restored perfectly. Mental health problems will be instinct.

In this chapter main focus is on a new life changing technology called "*Brain Computer Interface* (BCI)". It is based on a test called "*Electroencephalography*" (EEG) that meters and maps the brain's electrical activity. The electrodes are connected to your scalp and the system is wired to a computer, the signals are analyzed and translated into actions and instructions that are used to drive the computer and this data can be used to perform different tasks. The first EEG was recorded by Hans Berger in 1929 on animals. Instead of using keyboard and mouse as the input methods, by using BCI we will be able to give input using our brain. There are many applications of BCI depending on your thinking. The signals are processed and integrated and then the impulses are given back to actuators. This works just like your body e.g. when we touch anything the fingers work as sensors which send the data to the brain to process it and then brain resends the processed data to fingers.

The BCI was also not only studied on humans but on animals also. A monkey was able to control a robotic hand using this technology. BCI will help us understand how and what animals think and also how their brain performs. A time will come when animals will be able to interact with humans. BCI includes the study of brain wave patterns of various people. When that will be done perfectly humans will be able to communicate with their brains. The BCI can lead to various applications. This technology is still in progress and BCI tools are also limited.

17.3 Brain with Its Main Parts and Their Functions

The brain is the most complex and important organ of the human body. No other thing on this planet can be compared with the human brain. The brain performs the physiological tasks like receiving information from the rest of the body, interpreting the information and then assisting the body to work according to that information. Our body is embedded with natural sensors like eyes, ears, nose, skin, and tongue which give inputs to the brain like light, sounds, odors, pain, and taste. The brain interprets these inputs. The brain also helps perform operations like breathing, releasing hormones, maintaining balance and blood pressure, thoughts, movement of the body (arms and legs), memory and speech. The brain controls all the functions of the body and works like a network that transfers messages to different parts of the body. An average brain weighs approximately 3 pounds. The brain is protected by the bones called a skull. Meninges are the cushion layered membrane which along with the cerebrospinal fluid protects the brain.

The nervous system in the human body is divided into two main parts: Central Nervous System, and

17.3.1 Central Nervous System

The Central Nervous System consists of two main parts that are brain and spinal cord. The human brain is divided into 3 parts:

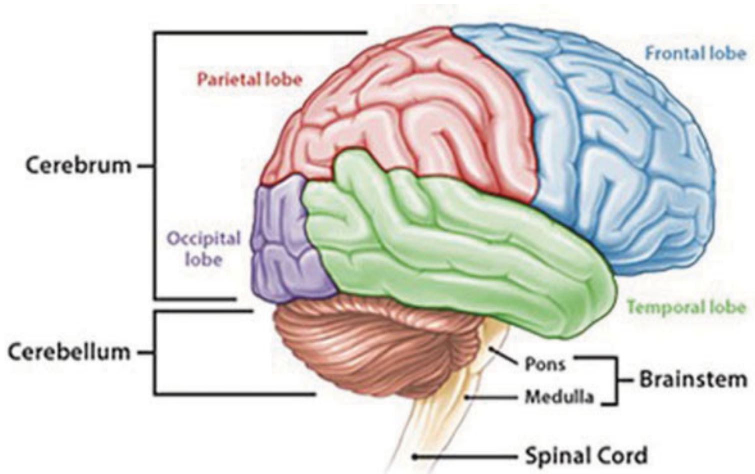

Figure 17.1 Brain Anatomy

Fore Brain: is the largest part of the brain, most of which is made up of Cerebrum also called Telencephalon and Diencephalon. Fore brain contains information related to human intelligence, memory, personality, emotions, speech, ability to feel the mood.

The cerebrum is divided into two parts/hemisphere:

- **Left Hemisphere**: is considered to be logical, analytical and objective. It controls voluntary limb movements on the right side of the body.
- **Right Hemisphere**: is thought to be more intuitive, creative and subjective. It controls limb movements on the left side of the body.

The cerebral hemispheres are hollow from inner side. Walls of cerebral hemisphere have two regions; the outer cortex is the '*Gray Matter*' and the inner White Matter. Gray matter is folded to form the coil like structure and the folds are called gyri and the grooves or canal like structure are called sulci. These sulci and gyri increase the surface area to accommodate more neurons. Thus, it is believed that large number of convolutions in the human brain indicate greater intelligence.

Each hemisphere is divided into 4 lobes which are interconnected:

- *Frontal Lobes*: The frontal lobes are located in the front side of the brain. They control the organizing the memory, movement, processing of speech and mood.
- *Parietal Lobes*: The location of parietal lobes is behind the frontal lobes and above occipital lobes. These lobes handle the sensory information such as taste, pain, temperature, and touch.
- *Temporal Lobes*: The temporal lobes are situated on each side of the brain. They deal with processing of memory, speech, hearing information and also language functions.

- *Occipital Lobes*: Their location is at the rear side of the brain. They deal with processing of visual information.

The Diencephalon is the posterior part of the forebrain. It contains structures such as Thalamus, Hypothalamus, and Epithalamus. Thalamus is located at the base of the hemispheres. It relays sensory impulses such as pain to the cerebrum. Hypothalamus is located below the thalamus and it regulates autonomic functions such as thirst, appetite and body temperature. The function of Epithalamus is to connect the limbic system to other parts of the brain. It also secrets melatonin by the pineal gland and regulates motor pathways and emotions.

Mid Brain: The mid brain acts as the master coordinator of all the messages going in and coming out of the brain to the spinal cord. It is located underneath the middle of the fore brain. It is also known as mesencephalon. It connects the forebrain and hindbrain. Mid brain consists of cranial nerves which control the reflexes involving eyes and ears.

Hind Brain: The hind brain also called rhombencephalon, is a brain stem connecting the brain with the spinal cord. It is composed of the metencephalon and the myelencephalon. The metencephalon contains structures such as the pons and cerebellum while the myelencephalon contains medulla oblongata.

Cerebellum: Cerebellum is located just behind the cerebrum, above the medulla oblongata. It is divided into two hemispheres. Each hemisphere has a central core made up of white matter and an outer region made up of gray matter. The main function of the cerebellum is to maintain the balance of body, coordinate muscular activity, motion, learning new things. Thus we can walk without falling.

Pons: is the broad horse shoe shaped mass of nerve fibers. It is located below the cerebellum and it serves as a bridge between mid-brain and the medulla oblongata. It is also the point of origin or termination for four of the cranial nerves that transfer sensory information and motor impulses to and from the facial region and the brain.

Medulla Oblongata: Myelencephalon or the medulla oblongata is the lowest part of the brain stem and is continuous posteriorly with the spinal cord. It has a central core made up of gray matter. It contains several functional centers that control autonomic nervous activity regulates respiration, heart rate, and digestive processes. Other activities of the medulla include control of movement, relaying of somatic sensory information from internal organs and control of arousal and sleep.

17.3.2 Peripheral Nervous System

This consists of many nerves which are spread throughout the body. There are two types of nerves and they are:

- *Sensory Nerves*: The sensory nerves carry messages from sensors to the brain.
- *Motor Nerves*: The motor nerves carry messages from brain to the body. They carry instructions from the brain to the body and what action to take.

An example for this is when you eat a chilly your sensory organ tongue carries the taste data to the brain and then brain resends the processed data to the body that spit out the chili to avoid any further damage. And this process is very fast.

The nerves are not directly connected to the brain but they are connected to the spinal cord which indirectly connects the nerves with the brain.

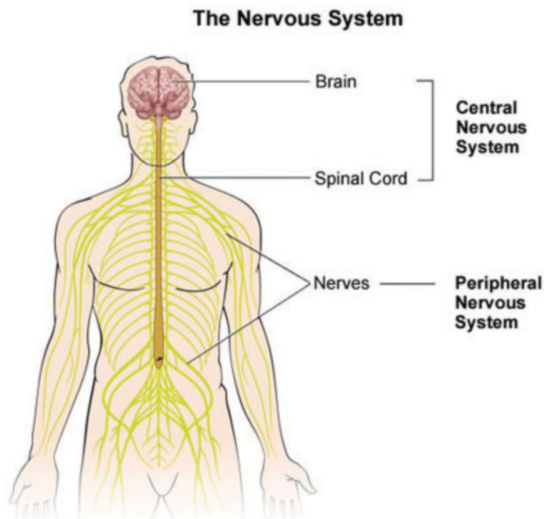

Figure 17.2 Nervous System

17.3.3 How are The Brain Signals Generated

In the term Electroncephalogram; Electro stands for electrical, Encephalon stands for brain and Gram or Graphy stands for a picture. Neuron communicate electrically or using neurotransmitters. EEG measures the summation of electrical activity on the scalp primarily derived from post-synaptic activity round the dendrites of pyramidal neurons in the cerebral cortex. Neurons communicate by passing an electrical signal by the movement of ions flowing in or out of the cell.

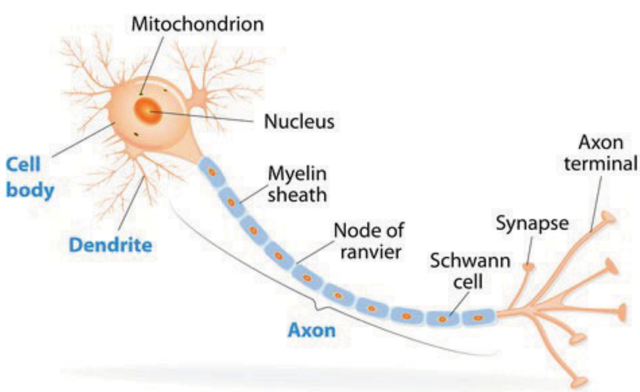

Figure 17.3 Neuron

Parts of Neuron are: Nucleus, Dendrites, Myelin Sheath, Axon, Axon terminals. First, the electrical signals are transmitted from the dendrites to the cell membrane where they meet axon hillock. Axon Hillock is the gate keeper through which the signal can pass to the axon. Here the summation of all the charges is used by axon hillock to decide whether or not the signal should be passed to the axon terminal. The axon hillock is the part where the summation of the excitatory post-synaptic potential and inhibitory post-synaptic potentials meet.

If the summation of these potentials reaches the threshold voltage the signal passes.

A neuron is like a battery with its own separate charges. Outside there are positive sodium ions lingering outside the membrane. And inside there are positive potassium ions, they are also positive but are mingled with the negatively charged protein. So the cell interior has overall negative charge. This state is called Polarized state. This is the resting state of the neuron. A neuron has the resting membrane potential of about -70mV. Cell membrane contains voltage gated channels. They allow either sodium or potassium ions to pass through. When any message arrives a neuron the voltage gated sodium channels open and the sodium ions enter the cell membrane which decreases the negative voltage. Because of this, more voltage gated sodium channels will open causing more sodium ions to enter the cell membrane and the membrane potential becomes more positive or depolarizes and reaches up to +40mV. This occurrence is called Action Potential. A signal electrical event isn't big enough to be detected by EEG and the action potentials can cancel each other out. So the Pyramidal Neurons come in to picture.

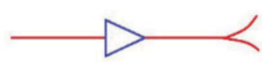

Figure 17.4 Pyramidal Neuron

They are found within the most superficial layers of the brain and they are spatially aligned. Therefore, their activity is synchronous that produces a larger signal which will be measured superficially from the scalp. Axons from neighboring neurons synapse with the pyramidal neurons.

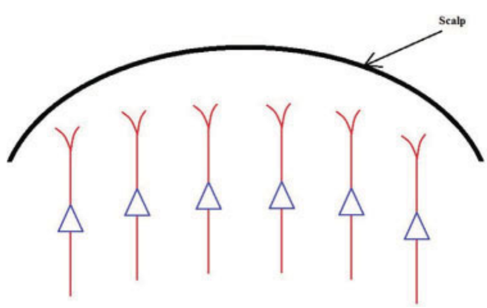

Figure 17.5 Pyramidal Neuron Chain

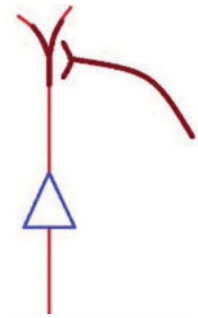

Figure 17.6 Synapse with Pyramidal Neuron

17.3.4 What is Neuron Synapse?

Synapse: Synapse is the meeting point between two neurons. A neuron is of no use if nothing is connected to it. So the communication among neurons is taken care by Synapse. In Greek, Synapse means to join. An action potential transmits an electrical message to the end of an axon. The electrical message then strikes a synapse that then converts it into another type of signal and transfers it to the neighbouring or other neuron.

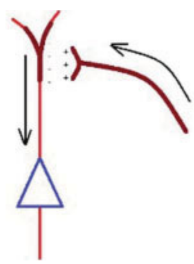

Figure 17.7 Neurotransmitters

Each synapse acts like a minute computer. It is able to change and adapt in response to the neuron firing patterns. Synapses are what allow you to learn and remember. They are the reasons why psychiatric disorders arise like drug addiction. Synapses have two modes of communication, electrical and chemical. Electrical synapse works like broadcasting the signals and one synapse can activate thousands of different other cells such that all cells can act in synchrony. While chemical synapse is slower but more precise and more selective. They use neurotransmitters or chemical signals. Chemical signals can convert electrical to chemical and chemical to an electrical signal which allows different ways to control that impulse. The cell that sends a signal is called pre-synaptic neuron. The pre-synaptic terminal is filled with thousands of neurotransmitters. Receiving cell is called post-synaptic neuron. They are present on the body of the cell. Its function is to accept neurotransmitters. Chemically gated ions on the post-synaptic membrane open in response to increasing of neurotransmitters that bind to the proteins.

When the depolarization begins at one end of the neuron the other end repolarises back to -70mV thus creating a dipole of the neuron and conducting a current.

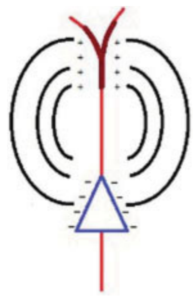

Figure 17.8 Neuron Dipole

Dipole: A dipole is a part of equal and oppositely charged or magnetized poles separated by a distance.

In Neurology: EEG signals are derived from the net effect of ionic currents flowing in the dendrites of the neurons during synaptic transmitters. Any electric field produces a magnetic field which can be measured. The net current can be thought as current dipole i.e. currents with a position, orientation, and magnitude. All post-synaptic potential will contribute to the EEG signals. Every post-synaptic potential causes the charge inside the neuron to change and the charge outside the neuron to change in opposition. Electrical dipole from a single cell is undetectable because of thick skull and brain protective layers. Thus, the summation of the dipoles created by hundreds to thousands of neurons is what is detected by the EEG.

17.4 Working of BCI

1) Signal Acquisition and Pre-processing: First of all the EEG electrodes are implanted in the brain either by invasive or by non-invasive techniques. The brain waves electrical impulses are detected by the electrodes. The signals that we get have actually low signal strength so they need to be amplified to be of use. The computer understands digital information so they need to be digitized. In pre-processing the electrical signals are recorded and filtering is used so that the signals are properly and clearly detected.

2) Signature Extraction: Whenever the electrical signals are recorded they are not alone but noise is also detected. Our aim is to extract some specific brain signals which can be useful. So we need to remove that unwanted noise or signals. Because of these unwanted signals, we may get incorrect results. So the signals are separated through the signature extraction process. This process is also called Feature Extraction.

3) Signal Amplification: The signals that we get have the low signal strength and signals with that much low signal strength cannot be useful. So these extracted signals are then amplified. And then these amplified signals are used for specific purposes.

4) Signal Translation and Signal Classification: The extracted signals are then translated into their corresponding frequencies so that the user can use them directly for their specific purposes. These waves are then classified according to their frequencies like Alpha waves, Beta waves, Gamma waves, Delta waves and theta waves. After these processes, the output is then shown on computer screen.

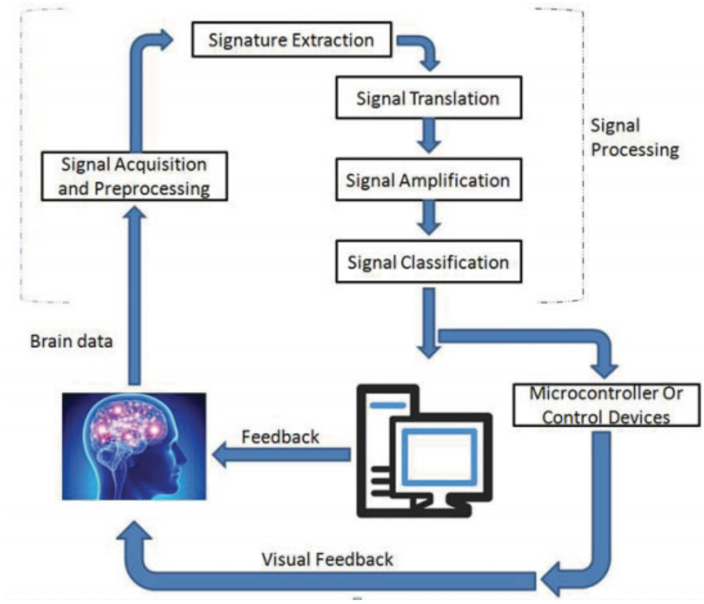

Figure 17.9 Working of BCI

17.4.1 Types of Waves Generated and Detected by Brain

There are four types of brain wave namely Delta, Alpha, Beta, and Theta. For example, when we sleep a vast number of neurons activate and all together work in synchrony and produce Delta waves high amplitude. The brain transmits the waves in the form of electrical signals. These signals are generated when the neurons fire messages to one another. Frequency and amplitude of the waves are directly proportional to the rate of neurons working in synchrony and transmitting the signals all together at same time. The different types of waves are classified according to their specific frequencies and their specific activities. These waves are listed below with their corresponding frequencies:

1. Delta Waves: 0 Hz to 4 Hz
2. Theta Waves: 4 Hz to 8 Hz
3. Alpha Waves: 8 Hz to 12 Hz
4. Beta Waves: 12 Hz to 40 Hz
5. Gamma Waves: 40 Hz to 100 Hz

Delta Waves: Delta waves are the waves having the least frequency among the five waves and also they are the slowest recorded brain waves. These waves are mainly detected from young kids or infants. These waves are related with the deep sleep and relaxation. When we grow up these waves tend to decrease. People having learning disabilities and those who cannot control their consciousness have less delta wave brain activity. Abnormal delta wave activity is generated during brain injuries, severe ADHD, poor sleep, problems in thinking and learning problems.

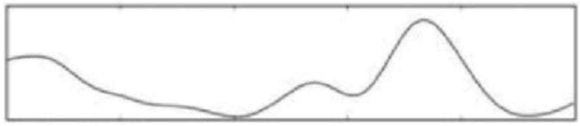

Figure 17.10 Delta Waves

Increased amount of delta waves is found during deep sleep.

Theta Waves: Theta waves are generally connected with sleep, daydreaming and with deep emotions. They help in improving creativity and helps us feel natural. The number of theta waves decrease during ADHD, depression, stress, poor emotional awareness, inattentiveness, etc. Theta waves are not produced an excess in waking state. Theta waves are related to the subconscious brain state.

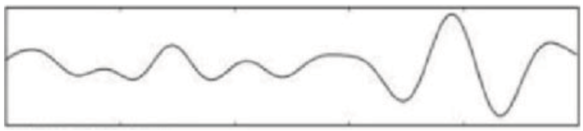

Figure 17.11 Theta Waves

Alpha Waves: Alpha waves lie between the conscious and subconscious state of mind. These waves are related to deep relaxation and calm state of the brain. If we are experiencing any stress then the alpha waves are blocked. Alpha waves generation can be increased by alcohol, drugs, antidepressants.

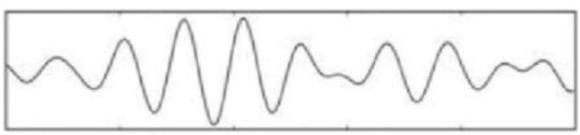

Figure 17.12 Alpha Waves

Beta Waves: Beta waves are commonly detected when awake. They are the high-frequency waves. These waves are associated with consciousness. They are observed when focussed on something or during logical thinking. These waves are associated with daily common tasks like reading, writing, focusing, critical thinking, etc. Energy drinks, coffee, etc. can increase a number of beta waves.

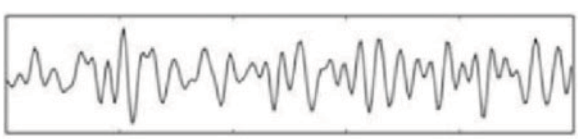

Figure 17.13 Beta Waves

Gamma Waves: Whenever brain performs tasks that have higher processing then these waves are generated. These waves are important during learning and memory functions. During learning of new things, gamma waves are involved. People having low memory power, or if they are mentally challenged have low gamma wave brain activity. During high anxiety, stress, depression a number of gamma waves generated are less. These waves are known for higher alertness.

Increased amount of gamma waves are found during meditation.

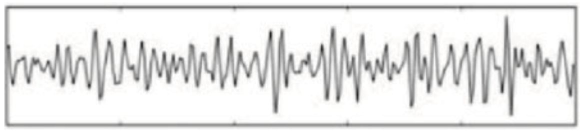

Figure 17.14 Gamma Waves

17.4.2 How to Perform Electroencephalogram

Using EEG is not that simple just put on the device and read the data. Some steps are needed to get the accurate EEG data.

Let's talk about how to collect EEG data:

- **Phase A**: Prepare the solution
  - Step 1: Fill the vessel or a bucket with some distilled water.
  - Step 2: Mix in Potassium Chloride to increase the electrical conductance. One can also mix shampoo to soften the scalp and to decrease the electrical impedance. Now mix it well.
- **Phase B**: Measure the head
  - Step 1: Measure the diameter and then the circumference of the head of the user to correctly determine the EEG cap size which the user will be wearing.
  - Step 2: Once the measurement is taken, select the right EEG cap and soak the cap in the solution that is already prepared. Soak it for approximately 10 minutes.
  - Step 3: Now other measurements are needed to be taken to find the exact center of the user's head. First measure from jawline to jawline. We may need to ask the user to open and close the mouth to get the correct measurements. Once the correct center is found take a note of it.
  - Step 4: Now measure from Nasion (*the point between the eyebrows of the user*) to the Inion. Inion is the bony projection on the back of the skull which you can feel it with your fingers. Now once the measurement is obtained, divide it by 2 to get the center and note that center point. The two points that are noted as above should form an 'X' on the user's scalp.
- **Phase C**: Lowering the impedance
  - Step 1: Connect the cap with the electrical recording equipment. Make sure that the user is comfortable.

– Step 2: Last step is to place the EEG cap on the participant's head. To do so spread your fingers on either side of the inside of the cap. There is a reference electrode present on the center of the cap which is called 'CZ. Place this directly on the 'X' mark that was obtained from the measurements. As you bring the cap around the user's head, bring down the straps onto the chin.
– Step 3: Adjust the cap so that it is properly fit using the openings that are present at the end of the cap. More tightly the cap fits, more will be the conductance for the electrodes and more accurate will be the results.
– Step 4: Still there can be impedance seen in the software we are using for capturing EEG signals. So, for that wiggle the electrodes. This will bring the electrode closer to the scalp. And if there are still some electrodes that are causing impedance, then add some saline solution and then again wiggle the electrodes. Now you are ready to ask the user to start the test and thus we can measure the EEG data.

17.4.3 How to Take Measurements of the Head

First of all, measurement is taken from Nasion to Inion. And then this measurement is then divided into 10 or 20% parts and this way this system gets its name. Now marks are placed. Now measurements are taken from one pre auricular point to the other. Again this is divided into 10-20% parts and additional marks are made. Further marks are made around the circumference of the head and separated by 10% distance. Then para-sagittal measurements are made separated by 25%. And then transverse measurements are made and then at the intersection of these two lines marks are made.

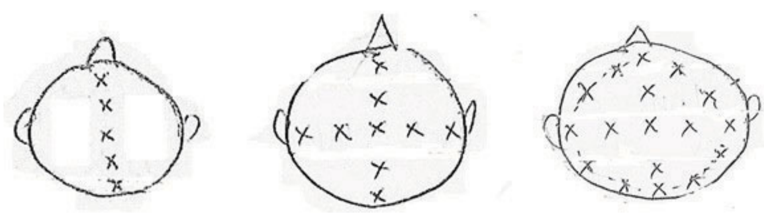

Figure 17.15 Steps

When all electrodes position is marked, they are named with letters and numbers.

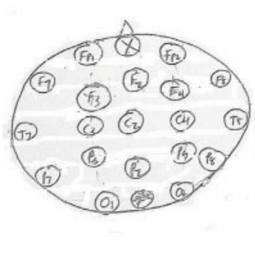

Figure 17.16 Electrode position

Side of the scalp (*head portion*) is represented by the numbers. Odd numbers represent left side and even numbers represent the right side. As the numbers get closer it mean that the electrodes are closer to the midline. E.g. here C_4 is closer to midline as compared to T_8. ”z” i.e. Zero represents the midline. Positions on the scalp are indicated by letters. In the middle chain of electrodes, it can be seen that F means Frontal, C means Central and P means Parietal.

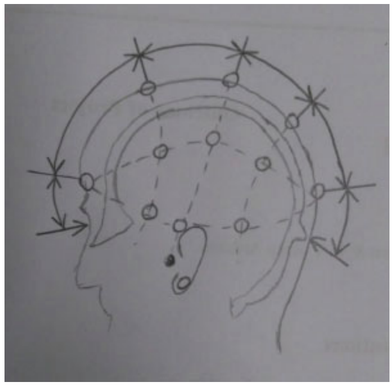

Figure 17.17 Electrode Cap side view

17.4.4 How are EEG Signals Recorded

EEG is recorded using the technology called Differential Amplifier.

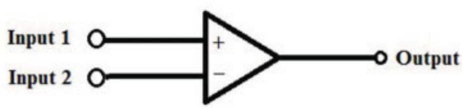

Figure 17.18 Differential Amplifier

It accepts two inputs and we get the output in the form of difference between the two inputs. This is particularly useful for recording and showing very little amount of electrical signals like of EEG. For example, consider two signals as input to Differential Amplifier. So the output is the difference between the inputs and the remaining common portion (*part*) is ignored.

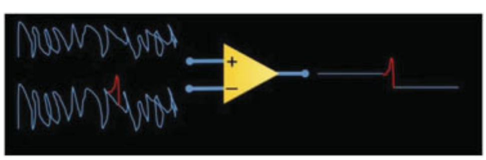

Figure 17.19 Differential Amplifier Working

So, it can be said that EEG is always relative.

17.4.5 Methods to Display EEG on Screen

EEG can be displayed in different ways which are called Montages. Different types of Montages are:

1. Bipolar Montage
2. Common Electrode reference
3. Average reference
4. Weighted average reference
5. Laplacian Montage

But in this document, most commonly used montage i.e. Bipolar Montage will be explained. Consider a picture of the head from the top down.

If we display the difference between Fp2 and F8 as a single tracing, it would look like:

Figure 17.20 Fp2-F8 Single Tracing

And we call this single tracing a Channel or Derivation. Next, we move downwards and take the difference between F8 and T8 and we can display this as a different channel. Similarly, as we move downwards we get a string of recording from the front of the head to the back.

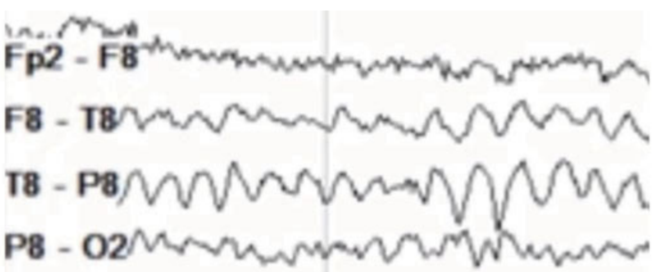

Figure 17.21 Chain

This string of recordings is called a "*Chain*"

The above chain is Right Temporal Chain.

Several chains can be put on a display together as shown below:

These above recordings are displayed as if our head position is pointing towards the right side. So in above figure, we first see the Left Temporal Chain, then the left Para-Sagittal chain, then the Midline, then the Right Para-Sagittal Chain and at last the Right Temporal Chain.

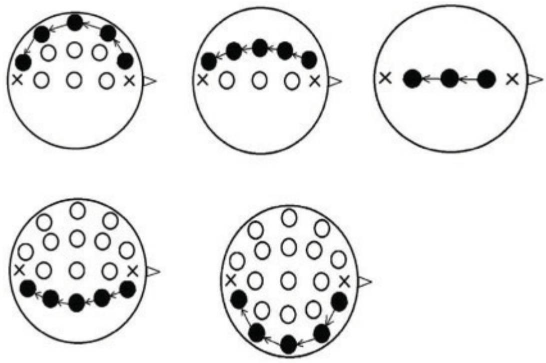

Figure 17.22 Bipolar Montage Electrodes

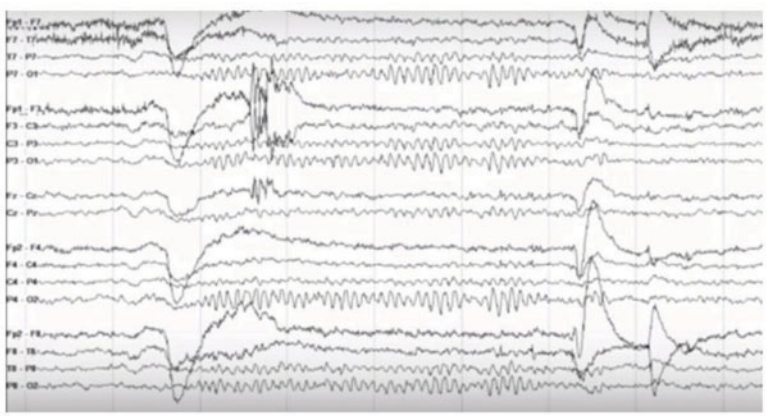

Figure 17.23 Anterior-Posterior Montage

17.4.6 Eye Blink EEG Patterns

One of the important parts of EEG signal recordings is the Eye blink patterns. EEG also detects eye patterns. Each EEG has special types of electrodes to detect eye muscle movements and this is called '*Electrooculogram*'(EOG). So to understand this, think about an eye as a dipole with polarity. Our eye has a Retina and Cornea. The Retina is negatively charged and the Cornea is positively charged. Whenever user blinks an eye the eyeball moves upward into the head. This phenomenon is known as Bell's Phenomenon. If we think about the EEG electrode that is closest to the eye, the upward movement of an eye will cause large positive signals at the frontal electrodes Fp1 and Fp2. On EEG this results in a very large deflection on the Frontal electrodes on both sides as indicated in the snap below:

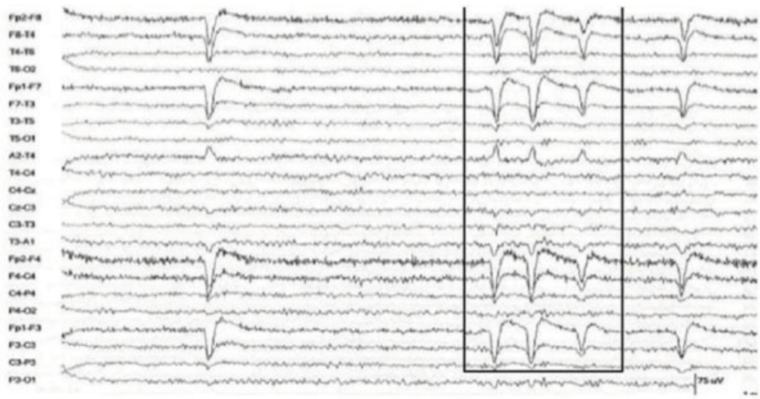

Figure 17.24 Eye Deflection Readings

17.5 BCI Classes

There are three classes of BCI:

1) Invasive Brain Computer Interface: In the Invasive BCI technique, electrodes or Brain Computer Interface devices are implanted onto the brain directly by performing some surgical operations. They are meant to provide highest quality brain signals. The predominant platform used here is Cortical multi-electrode array.

Invasive BCI is again divided into two parts: Single Unit Invasive BCI and Multi unit Invasive BCI. When signals from a single side of the brain are to be detected then these devices are called Single Unit Invasive BCI devices. If signal detection from multiple areas of the brain is needed, then it is called multi-unit Invasive BCI. Invasive BCI's can be used to restore hearing by implanting the hearing device directly onto the brain and connected with the ear. Also, eye vision can be restored and limb movement can be restored by brain controlled robotic arms and legs. It directly records the cortical neuron potential.

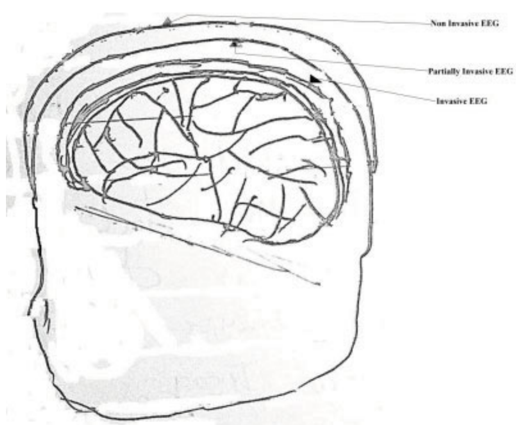

Figure 17.25 BCI methods Implantation

Invasive BCI can cause neuronal damage. Neurosurgical implantation is required which is risky if not handled with proper care. As the electrodes and BCI devices are directly in contact with the brain, they can form scar tissue on the brain which can weaken the signals.

2) Partially Invasive Brain Computer Interface: The predominant platform used in partially invasive BCI is ECoG (ElectroCorticoGram). Here electrodes are implanted inside the skull, above the brain and beneath the Dura Mater rather than within cerebral cortex or within gray matter. Signals obtained from partially invasive BCI are weaker than Invasive BCI. The advantage of [partially invasive BCI over Invasive BCI is that it has less risk of forming scar tissue. It causes no cortical damage but surgery should be performed with proper care. In this technique, the electrodes are covered within the thin plastic pad.

3) Non Invasive Brain Computer Interface: Among the three BCI classes, the non-invasive class gives the least quality of signals. The electrical impulses or signals coming out from the neurons are scattered and distorted by the skull. The advantage of non-invasive BCI over other two classes is that it is the safest option to use non-invasive BCI methods. In this technique, the sensors or the electrodes are placed on the cap and then placed on the head such that the electrodes touch the scalp completely to read the brain signals. The most popular method under this category is Electroencephalography (EEG) and is cheap, easy to use and portable. Other than EEG, other noninvasive methods Magneto-Resonance Imaging, Single Photon Emission Computed Tomography, magnetoencephalography and Positron Electron Tomography. Many consumer EEG BCI interfaces are available for sale. Some of the leading hardware companies manufacturing these EEG BCI interface devices are NeuroScan, Brain Products, BioSemi, EGI, EMOTIV, NeuroSky, Advance Brain Monitoring, AntNeuro, Neuroelectrics, MUSE, OpenBCI, Cognionics, g tec, mBrainTrain.

17.5.1 Applications of BCI

There are various applications of BCI. Some of them are as below:

1. Games and Entertainment
2. Rehabilitation and Movement Control
3. Neuroprosthetics
4. Medical Field.
5. Neuromarketing and Neuroadvertisement.
6. Communication.
7. Neuroergonomics and Smart Environment control
8. Security
9. Education
10. Self-regulation

17.5.2 Challenges BCI is facing

The major challenges that BCI is facing are:

1. Data Transmission Rate.

2. Lower Signal Strength.
3. High Error Rate.
4. Inaccuracy in Signal Classification.
5. Understanding the functions of brain areas.
6. Robust machine learning algorithms.
7. Effect of feedback.
8. Interaction of the electrode and cortical tissue or scalp.

17.6 Conclusion

With the discovery of Electroencephalography, the newly developed branch Brain Computer Interface captures the brain signals from different positions of the brain. These received signals are then translated and this processed data can be used to control anything. In fact, the computer itself can be controlled using brain waves. BCI is the future. It will become the new mode of communication and by this people will be able to control almost everything. Different methods are used to detect the EEG signals from the brain but each of these methods has their own pros and cons. This technology almost seemed impossible before it was developed. And still, also it seems impossible to researchers because Brain Computer Interface is capable of solving verities of issues that seem impossible. Still, researchers are working on development in this field.

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CHAPTER 18

DESIGNING A BEAUTIFUL LIFE FOR INDIAN BLIND PEOPLES: A SMART STICK

Aatrey Vyas, Dhaval Bhimani, Smit Patel, Hardik Mandora, Chintan Bhatt

U & P U. Patel Department of Computer Engineering, CSPIT, CHARUSAT, India
Emails: aatrey.vyas61@gmail.com, dhavalbhimani206@gmail.com, smitnakrani60@gmail.com, hardikmandora.ce@charusat.ac.in, chintanbhatt.ce@charusat.ac.in

Abstract

The target of the proposed chapter is to fill in as a concise groundwork to make daze individuals life more intelligent and more solid utilizing the shrewd sensors. The section begins with an outline of the IoT and unavoidable frameworks and proceeds in talking about the nuts and bolts of what are genuine issues looked by daze people groups to the what are diverse arrangements. The part explains the issues looked by a white visually impaired stick and how a smart stick can tackle that issues. Lastly, the section closes with how brilliant sensors can make life of visually impaired individuals more agreeable and how a visually impaired individual can live with no help by lying on the savvy frameworks.

Keywords: IoT, Unavoidable Frameworks, Blindness, Smart system, Shrewd sensors, Visually impaired stick, Savvy frameworks

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (245–284)

18.1 Introduction

Internet of Things (IoT) is the buzz word now a day roaming here and there. But what does it actually mean? Let's Imagine that things around you begin to talk to you and start providing information in a smatter way. What if your alarm clock, knows your college location and path, knows traffic conditions, weather conditions and is learned enough to create an estimation of your arrival time and wake you up accordingly. Wouldn't it be great that your coffee machine does know your arrival time and when you enter to your home sweet home and you will be amazed by the warm smell of coffee. Yes, you are nearer to what is Internet of things (IoT). The formal definition of Internet of Things can be: Embedded System + Cloud. Internet of Things has a broader area of its definition. One can notice that main aim of the Internet of Things is towards how to make human life better and easier. As one can notice that it is being applied to all parts of life. Hospitality to Medical. Manufacturing to Logistics. Now a day health is main sector where more and more researches are going on. And when one talk about making life better of a human first thing come in the mind will be What about disabled peoples? What kind of problems they are facing? How to make their life more beautiful? How Internet of Things will be helpful?

Yes, you are thinking right. The whole chapter will talk about what is Internet of things and how one can make the life of disabled people (*Blind people*) more beautiful with the help of Internet of Things. And one simple example will be given as a small implemented project. That is our small contribution to the field of IoT: "*Smart stick for Blind people*".

18.2 Internet of Things

Definition: Devices with sensors and that all sensors are connected with each other and shares the information to archive certain result. If one explores the definition then connecting sensors and sharing the information doesn't mean that it should be connected using internet only it can be connected via any transmission media. Here the device can be any device that you will observe from waking up to sleeping down.

The IoT (*Internet of Things*) is growing at a pace as consumer, businesses, and governments are noticing the benefits of connecting impotent devices to the internet. Since there are already billions of IoT devices existing athwart industries, Integration of Artificial Intelligence is that what will bring about the real revolution, which won't just gather the information for investigation and improvement, yet in addition prepare those IoT gadget to know the conduct of their client and alter itself in like manner to best sit the reason and needs, consequently influencing them to brilliant.

Smart Refrigerator System: Smart refrigerator at your home connected to the internet. Now imagine that your child has opened the refrigerator door and he forgets to close the door. And you at your office get a notification that the refrigerator door is opened please close it. By following few simple steps in mobile application you are able to close the refrigerator by sitting at your office miles away from the home sweet home!

Face Recognition System: Face recognition system installed at your door step which it connected to the internet. Now imagine that you are busy with your work at office and your parents come to your home. And keys are with you but there will be no problem as you are having the Face Recognition System. When someone will be at your door step it will capture small video and send it to your mobile application. If you want to open the door then you can open it while seating at the office.

Smart Home: Wouldn't you revere if you could switch on cooling before accomplishing home or kill lights even after you have left home? Or then again open the approaches to sidekicks for passing access despite when you are not at home. Do whatever it takes not to be astounded with IoT happening as intended associations are building things to make your life less demanding and supportive. Savvy Home has transformed into the dynamic venturing stool of accomplishment in the private spaces and it is foreseen Smart homes will push toward getting to be as typical as phones.

Nest-Thermostat [10]: One of the principal IoT based gadgets, Nest appeared as a savvy indoor regulator that projects itself as per your timetable and necessities utilizing its imaginative temperature, mugginess, climate and action sensors. Other than preserving vitality and diminishing bills, Nest has now developed into a thorough home computerization gadget with 'works with Nest' designer program.

Activity Tracker [9]: Jawbone Up is an entire wellness following unit moved into a wristband. Stacked with a wide range of sensors, it causes you measure steps, separate, calories, rest, heart wellbeing, and sustenance and drink logging. It accompanies 'savvy mentor' aide to help survey execution. To top everything, it hosts unending availability with third get-together applications and furthermore gives group-based information sharing.

Body Analyzer [8]: You can without much of a stretch confuse this gadget for a consistent advanced measuring scale, yet it does substantially more than that. It quantifies weight, body structure (*fat mass and BMI*), heart rate, and air quality. It likewise does program individual profiling for up to 8 people and offers information (as diagrams, charts and so forth.) finished applications and cloud. The innovation takes a shot at 4 weight sensors and a body-situating locator.

MakerBot Replicator Mini [11]: 3D printing is ostensibly the greatest assembling upheaval holding up to happen. Makerbot has not just contracted the size to make it home amicable, the forward-looking group has additionally coordinated Internet of things at the center of this model. You can cooperate with the printer from different gadgets and make and offer outlines autonomously or utilizing Markebot's Printshop application.

18.3 Background

Smart Cane (Developed by IIT Delhi) [1]: For almost 60 outwardly disabled undergrads in Mumbai, identifying hindrances before them will never again require physical contact. '*Smart canes*' created by a group from Indian Institute of Technology Delhi (IIT-D) group will empower the understudies to recognize open windows, electric posts, hanging branches and projecting AC units, open auto entryway at a separation of three meters utilizing ultrasonic running sensors appended to their standard sticks.

The device gets vibrated with three different frequencies when hindrances is one, two or three meters away. There is also one special alarm (*buzzer*) facility provided for fast moving objects like car, truck etc. The product is tested live with 150 blind peoples in India. The device is made to find hindrances from knee to head height up to 3 meters. Device will get recharged using USB port. Device is made in such a way that it can also identify the low occurring objects such as potholes.

Oh, it is just beginning! If we talk about the non-technical part and user experience then the stick(cane) is facilitated by: Elegant Design, Ergonomic grip. As per IIT Delhi site 20000+ smart cane devices are distributed, 40+ channel partners are there and in more than 12+ countries have facility to order this.

Smart stick for Blind (Developed by Shruti Dambhare and Prof. A.Sakhare) [2]: This framework works by utilizing GPS, simulated form framework, impediment location and voice circuit. This framework works by fitting a camera on the people head, the camera will be use and algorithm to distinguish the highs and obstructions in front the visually impaired individual. This framework likewise contains ultra-sonic sensors to distinguish the obstructions, Furthermore, this framework incorporates GPS framework is to achieve the required goal. The precision of the fake vision unit gives a high exactness yield to the client. Be that as it may, the planning multifaceted nature of the framework makes it hard to outline and get it.

Ultrasound running from a long stick (Directed by Professor Robert X. Gao) [3]: Another examination in similar field to help dazzle individuals utilizes the beat resound system keeping in mind the end goal to give notice sound when recognizing the obstructions. This method is utilized by the United States military for finding the submarines. They utilized beat of ultrasound run from 21KHz to 50KHz which hit the hard surface to produce reverberate beats. By figuring the distinction between signals transmit time and flag getting time we can foresee the separation between the client and the obstructions. This framework is extremely delicate as far as recognizing the impediments. It has a location extend up to 3 meters and a discovery point 0 to 45 degrees. Nonetheless, this framework should be re-intended to work with less control utilization.

18.4 Purpose Approach

This system purposes the stick which uses the ultrasonic sensors for detection of obstacles, NodeMCU that controls the system, mobile phone GPS sensor for sensing the live location, buzzer for alert, cloud for storing the buzzer data and location. Mobile phone GPS sensor is used because of the cost factor.

18.4.1 Ultrasonic Sensor

Ultrasonic sensors [7] are regularly utilized as a part of robotization assignments to gauge remove, position changes, level estimation, for example, nearness finders or in exceptional applications, for instance, when estimating the immaculateness of straightforward material. They depend on the standard of estimating the spread time of ultrasonic waves. This guideline guarantees dependable discovery is free of the shading rendering of the question or to the plan and the sort of its surface. It is conceivable to dependably distinguish even such materials as fluids, mass materials, straightforward articles, glass and so on. Another contention for their utilization is them utilizing as a part of forceful situations, not exceptionally extraordinary affect-ability to earth and furthermore the likelihood of estimating a separation. Ultrasonic sensors are made in numerous mechanical outlines. For research facility utilize, the basic lodging utilized for transmitter and beneficiary independently or in a solitary lodging, for modern utilize are frequently built vigorous metal lodging. A few sorts enable you to alter the affect ability utilizing a potentiometer or carefully. Additionally, the yield might be in the bound together form or the simple flag straightforwardly in advanced shape. On account of sensors that can be associated by means of the correspondence interface to the PC, it is conceivable to set itemized parameters of all the sensor's working extent and estimated separations.

Figure 18.1 Ultrasonic Sensor Working

18.4.2 NodeMCU

Advancement sheets, for example, Arduino and Raspberry Pi, are regular decisions while prototyping new IoT gadgets. Those advancement sheets are basically smaller than normal PCs that can interface with and be modified by a standard PC or Mac. After it has been modified, the improvement sheets would then be able to associate with and control sensors in the field. Since the ”*I*” in IoT remains for web, the advancement sheets require an approach to interface with the web. In the field, the most ideal approach to associate with the web is by utilizing remote systems. Engineers should include a Wi-Fi or cell module to the board and compose code to get to the remote module. The NodeMCU (*Node Micro-controller Unit*) is an open source programming and equipment advancement condition that is worked around an exceptionally cheap System-on-a-Chip (SoC) called the ESP8266. The ESP8266, planned and fabricated by Espressif Systems, contains every vital component of the cutting-edge PC: CPU, RAM, organizing (Wi-Fi), and even an advanced working framework and SDK. At the point when obtained at mass, the ESP8266 chip costs just $2 USD a piece. That settles on it an amazing decision for IoT undertakings of numerous types.

Figure 18.2 NodeMCU Board [4]

18.4.3 Global positioning system (GPS)

An ordinary GPS recipient tunes in to a specific recurrence for radio signs. Satellites send time coded messages at this recurrence. Each satellite has a nuclear clock, and sends the current correct time also. The GPS collector makes sense of which satellites it can hear, and afterward begins assembling those messages. The messages incorporate time, current satellite positions, and a couple of different bits of data. The message stream is moderate - this is to spare power, and furthermore in light of the fact that every one of the satellites

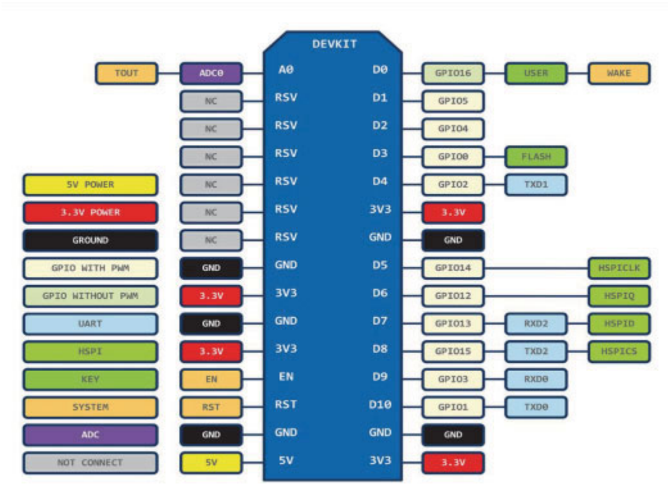

Figure 18.3 NodeMCU pin diagram [5]

transmit on a similar recurrence and they're simpler to choose in the event that they go moderate. Along these lines, and the measure of data expected to work well, it can take 30-60 seconds to get an area on a general GPS. When it knows the position and time code of no less than 3 satellites, a GPS beneficiary can accept it's on the world's surface and get a decent perusing. 4 satellites are required in the event that you aren't on the ground and you need elevation also.

18.4.4 Buzzer

A buzzer is a contraption which makes a murmuring or beeping tumult. There are a couple of sorts; the most central is a piezoelectric buzzer, which is just a level piece of piezoelectric material with two anodes. This kind of buzzer requires a type of oscillator (*or something more jumbled like a micro-controller*) to drive itif you apply a DC voltage you will just get a tick. They are used as a piece of spots where you require something that transmits a fit for being heard tone, however couldn't think less about high-steadiness sound multiplication, like microwave grills, smoke alarms, and electronic toys. They are decrepit and can be rambunctious without using particularly control. They are moreover thin, so they can be used as a piece of level things like "*singing*" welcome cards [6].

Figure 18.4 Simple Buzzer

18.4.5 Flow Diagram

Actors in the system: Care taker of blind people, Blind people who will use the stick. Device is composed of an ultrasonic sensor and buzzer. Mobile is taken as an external peripheral because if one attaches the mobile on the stick it will be an overhead. Mobile GPS sensor is used because of the project cost problem. One can also use GPS module rather than mobile sensor. When ever an obstacle is caught by the ultrasonic sensor the buzzer will automatically cause a beep sound. And this will cause an event trigger in the mobile application. And application will send current location and buzzer count to the cloud. Cloud will store the data for the future use. Another use of the mobile application is it provides the route direction to the user by using Google Map API. When ever buzzer counter is above 5 that means there is a permanent obstacle and mobile application will show another path to reach the destination. Care taker can track the location of blind people. Power Bank is used for the power supply which easily rechargeable.

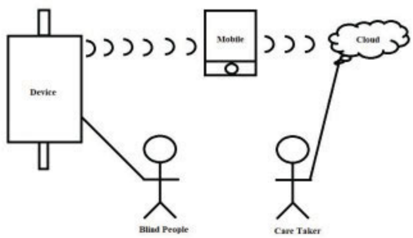

Figure 18.5 Basic Flow Diagram

18.5 Implementation

In this section one will get to know about how to interface ultrasonic sensors and buzzer with NodeMCU. For that 1 NodeMCU, 3 Ultrasonic sensors and one buzzer are needed. Other things which are implemented are using programming not by hardware devices. Power bank is used for power supply purpose. One 9V battery is used to supply power to the Ultrasonic sensors. One IC is used to convert 9V to 5V and that IC is 7805.

Figure 18.6 7805 IC

Let's begin with the implementation steps with good description: Firstly, one need to get a 9V battery to supply power to the 3 ultrasonic sensors. But as we know one ultrasonic sensor works on the 5V power supply. Now to solve this problem we need to take one IC named as 7805 IC. This IC is used to convert power supply to a constant 5V. Now our one problem is solved. Now our ultrasonic sensors will work properly using 5V power supply to each.

Now take one breadboard. Which are a solder-less board. Used to make temporary circuits and prototypes. And the magic is we don't have to do any soldering. And as we are using breadboard this will not make a permanent device but for learning purpose one can use breadboard because it is easy and effortless.

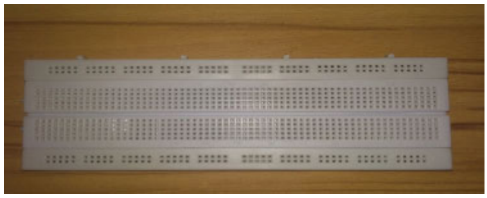

Figure 18.7 Breadboard

Now take one NodeMCU. And connect it to your laptop or desktop using USB cable. We are using NodeMCU here because it has inbuilt Wi-Fi and Bluetooth facility. And another reason is if in future if we want to send data directly from the device only then it is. Other some benefits we get by using NodeMCU are:

- Low cost (*No Budget Problem*).
- Integrated support for Wi-Fi (*No external device needed*).
- Small Size (*It can fit anywhere*).
- Work on low power supply .

We have to associate 9V battery to the breadboard. To connect 9V battery to the breadboard we need SNAP connector. Look something like this

Figure 18.8 SNAP Connector

We need now three kinds of connecting wires named as Female to Female wire, Male to Male wire, Male to Female wire.

(a) Female-Female wire (b) Male-Male wire (c) Male-Female wire

Figure 18.9 Female to Female wire, Male to Male wire, Male to Female wire

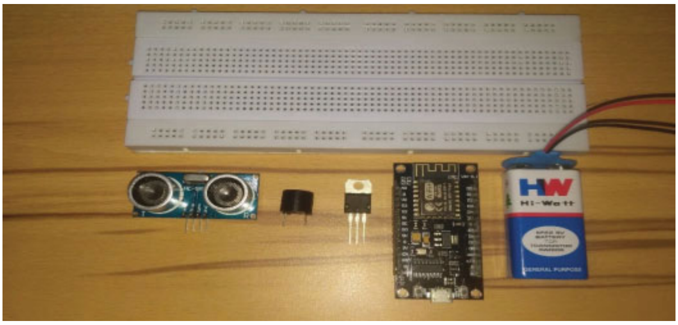

Figure 18.10 All Components

Now we almost have all the required devices to do actual implementation.
Let's look at the circuit diagram so one will get more idea.

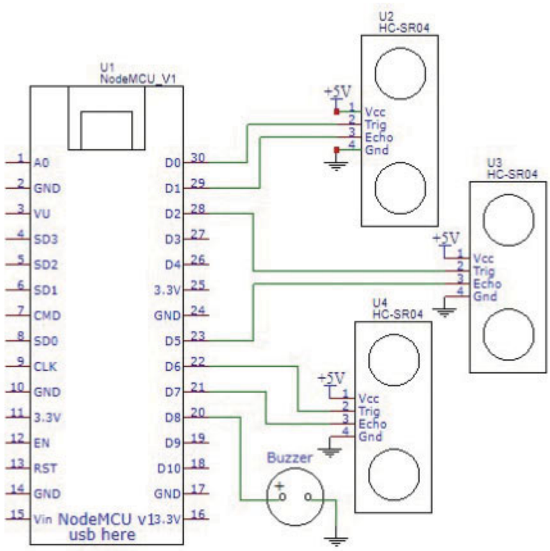

Figure 18.11 Circuit Diagram

Note: Circuit diagram is showing interfacing of three ultrasonic sensors but as per convenience and to make it easier here we will implement only one ultrasonic sensor.

Battery and conversion from the 9V to 5V is done by performing a simple breadboard connection so we will not talk it in more detail.

As mentioned above that 7805 will convert 9V to 5V now we have powers supply of 5V. Now take 5V power supply from the output of 7805 and give it as a VCC in HC-SR04 (*This is the device number of ultrasonic sensor which is shown in the circuit diagram*).

Then take ground from the battery and give that to the ground of HC-SR04.

To trigger HC-SR04. Connect Trigger pin to the D_0 pin of NodeMCU.

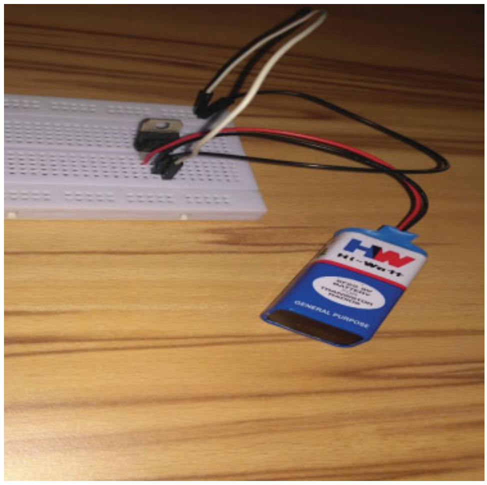

Figure 18.12 Connection of 7805 IC and Battery with Bread board

Trigger pin is responsible for sending the signal in form of high frequency pulse of 10μs. It will send 40KHz ultrasound in 8 cycles and make its echo line high at that time period.

Connect echo pin to the D_1 of NodeMCU.

When signal finds any object, the transmitted signal will be reflected and echo pin will take the input as a reflected signal.

Echo pin takes the input in form of pulse timing.

Object found by the trigger pin and reflected signal came to echo pin now what?

We have to measure the distance between the object and device. For that we use one equation: `PULSE_TIME*0`.034/2.

Output of this equation will be in centimeters.

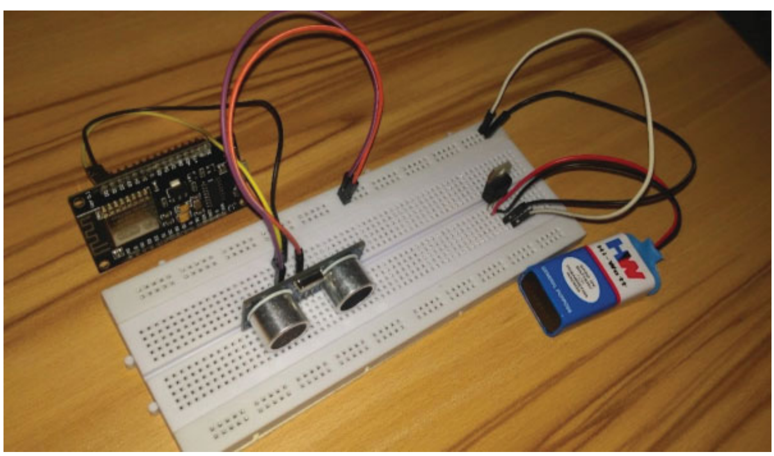

Figure 18.13 NodeMCU connections

If one want to implement three ultrasonic he/she can do it by following same procedure of connecting trigger and echo pins as shown in above circuit diagram.

Sample code to measure the distance:

```
void cal_distance(int tri, int echo)
{
   digitalWrite(tri, LOW);
   delayMicroseconds(2);
   digitalWrite(tri, HIGH);
   delayMicroseconds(10);
   digitalWrite(trigger, LOW);

   time_taken = pulseIn(echo, HIGH);
   dist= time_taken*0.034/2;
   if (dist>300)
      dist=300;
}
```

Now we got the distance. Now we have to find whether the object is at 3, 2, or 1 meter far. That is again programming stuff.

First, let us talk about Piezo buzzer. Because based on the output we have to trigger Piezo buzzer. So that it can play a tone when object is certain nearer.

Integration of buzzer with NodeMCU is very easy. We have to connect negative pin of buzzer to the ground and positive pin of buzzer to the D_8 pin of the NodeMCU.

Just for information piezo buzzer is used in cars/trucks as a reverse indicator so that driver can assume some obstacle is there.

Piezo buffer works at DC power supply. Buzzer is encapsulated by a coating of plastic in a rounded fashion. At the top of the buzzer there is one hole to propagate sound from it.

If we talk inside structure then there is metallic disc that is used for producing buzz sound through top hole.

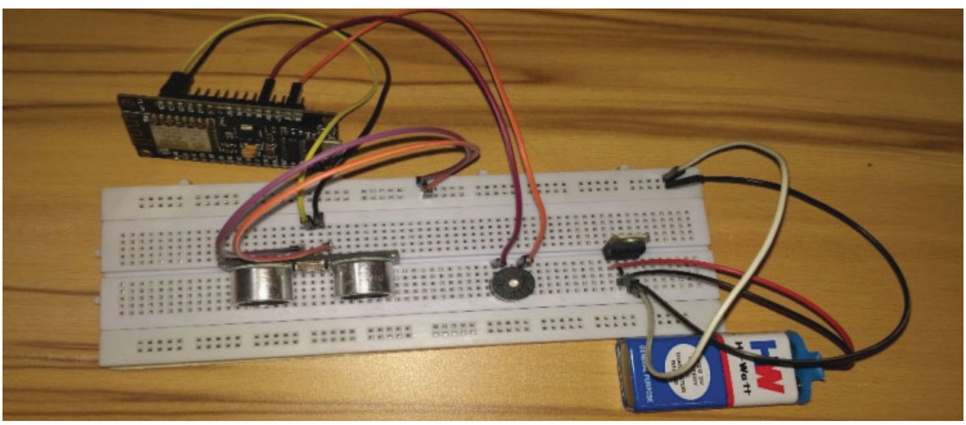

Figure 18.14 Buzzer Implementation

Let's see the sample code by which buzzer will buzz.

```
void loop()
{
   calculate_distance(trigger,echo);

   similar_count=0;
```

```

    //if (dist<70)
    {
          Serial.println("Object detected at :");
          Serial.print(dist);
//dist<70 means IF distance is less than 70 cm at that time buzzer will start

          if (distanceLenght<70)
          {
             digitalWrite(Buzz,HIGH);
             digitalWrite(LED, HIGH);
             for (int increment=distanceLenght; increment>0; increment--)
                delay(10);

             digitalWrite(Buzz,LOW);
          digitalWrite(LED, LOW);
          for (int i=distanceLenght; i>0; i--)
          delay(10);
          }
       }
}
```

By doing this, when ultrasonic finds any object it will make D_8 pin high. Buzzer will produce sound. Such that blind people will get notified when an obstacle is there.

Now main part comes mobile GPS sensor interfacing. For that we have to make one mobile application which implements the Google Map API.

Google map API provides different functionalities like [12]:

- Google Maps Direction.
- Google Maps Distance Matrix.
- Google Maps Elevation.
- Google Maps Geocoding.
- Google Maps Roads.
- Google Maps Time Zone.
- Google Places.

By using this API, one can easily find the Location. It also provides functionality of Direction.

When buzzer rings the Mobile Application will store the location of blind people and the Buzzer count at that location to the cloud.

Here cloud can be any one for an example Google Fire base, IBM Cloud etc.

By programming it is set when ever buzzer count at same location is more then 10. It assumes that obstacle is permanent. And it will direct blind people to another path.

18.6 Advantages and Disadvantages

Advantages

- Cost Saver as we are using mobile device as a one of the sensor. And mostly all are having mobile devices with them.

- Cloud is used so care taker can watch blind people live location whenever and anywhere he/she wants.
- Blind people will be directed to the destination with voice assistance provided by Google API.
- As we are using Ultrasonic sensors which are also called as a basic sensor so implantation is also easy.
- The adjustment of Ultrasonic is in such a way that it can detect up to 45 degrees for the obstacle.
- As all the free and open sources are used there is no much cost of handling of the system. Because all the security and privacy functions are provided at the cloud level only.
- If there is any permanent obstacle then the system it self choose another path to reach the destination.
- As power bank is used to supply power to NodeMCU it is rechargeable. It may run 1-2 days without recharging based on the mAh that power bank provides.

Disadvantages

- As mobile device is used for cost saving purpose but it is an extra overhead to the system.
- System is still in developing state so testing is not applied.
- It cannot detect running obstacles.
- It cannot still detect holes.
- No speech recognition facility is available.
- Care taker can not call or send message to the blind people in emergency.
- System is depended on the external systems.

18.7 Conclusion

Mostly all are trying to make human life better by using IoT. And we can't forget physically disabled peoples. They are also a living being and they also need some facility to live there life easily. By thinking and noticing some live example like Blind people are crossing road and because they can't see car is coming and they loss their life because they can't see. Some times because they can't see dog is sleeping and they walk over dog. Dog bites them and they injured. Because they can't see holes and open gutters they fall into that. By seeing such problems, we got inspired to make a smart stick by which there all problems get solved. For that we tried to use our little knowledge of IoT to provide solution.

Let's talk about the future expansion of the system. We already have discussed what is the system how it works, how to implement it and what are disadvantages of the system. Now the future plan is to solve that all disadvantages. And add some new features like Voice Assistance through Artificial Intelligence.

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CHAPTER 19

SMART HOME: PERSONAL ASSISTANT AND BABY MONITORING SYSTEM

Shivam Kolhe, Sonia Nagpal, Priya Makwana, Chintan Bhatt

Charotar Institute Of Science And Technology, Changa, Gujarat, India
Emails: 15ce054@charusat.edu.in, sonia.sn13@yahoo.com, 15ce058@charusat.edu.in, chintanbhatt.ce@charusat.ac.in

Abstract

In this era of internet and technology, we want every device to be connected with each other. Meaning of Internet of Things is that each and every device should talk to each other. The proposed system exemplifies a new class of home automation and Baby Monitoring platforms that provide intuitive, cloud-based speech interfaces. This system is a combination of 3 systems; Smart Home Personal Assistant, Online Energy Meter and Advanced Baby Monitoring System. Main feature is that all these three systems talk to each other. In this chapter a general introduction about Internet of Things is given and description about these three systems is provided, detailed information about sensors used in this system is given. Technologies used in this system like Raspberry pi 3, Arduino, sensors, Firebase real time database cloud platform, data analytics, Android, speech recognition (STT, TTS), Image and Video Processing are also made familiar in this chapter.

Keywords: Baby Monitor, Internet of Things (IoT), Speech To Text (STT), Text to Speech (TTS), Data Analytics, Online Energy Meter, Smart Home Personal Assistant.

Dac-Nhuong Le et al. (eds.), Emerging Technologies for Health and Medicine, (259–284)

19.1 Introduction

The smart voice assistant has every information about the whole module. The given module listens to you, translating your voice into commands so it can work as an entertainment suite, Baby training guide as well as a caretaker, automates your home, or orders stuff online from the module. The device uses speech recognition to perform an ever-growing range of tasks on given command. The device connects to the voice-controlled intelligent personal assistant module service which responds to the name ”*ABC*”.

The device is capable of voice interaction, music playback, turns off home appliances which are not in use, playing audiobooks, login, and logout from popular shopping sites and also social media sites on your voice commands, suggests you the bestseller items, news, providing weather information, real-time energy meter value, current status of baby, and much more you can’t imagine. It can also control various smart devices by itself as a smart home automation hub. Smart Personal Assistant device that is present in the user’s home is triggered using voice commands. Based on the request made, a response will be returned to the user. This module works as an intelligent and digital personal assistant. It analyses electric current used by the appliances and learns the usage pattern. It alerts the user about the appliances which are using more/less power. And it also helps user minimize the electricity bill. The device uses speech recognition to perform an ever-growing range of tasks on given command. It can also recognize the ABC name: when you say the word ”*ABC*”, it recognizes the module calls or the wake word and starts recording your voice. When you have finished speaking, the speech is converted to text and then according to given command, it will perform tasks. This module converts the recording into commands that it interprets. It is more than a simple voice-to-text service. It is a fully programmable service that can work with various online services to do a surprising range of things. This module utilizes speech recognition and language processing to facilitate interactions with devices. Although voice-enabled interfaces are still in nascent, they have been used to interact with televisions, air-conditioners, speakers, smartphones and other electronic devices. We focus on how to build a cost-effective module that can be widely used. We use this module to develop an application that will communicate with our raspberry pi to control our devices. After smartphones, the voice-controlled module is the next big step for voice assistants. This product or module built-in voice-activated assistants arrived on the scene in the last few years, but the difference between the existing devices and our device is that our device ignores the unnecessary words or not related to the task (*active noise cancellation concept*), it will cancel out the normal communications and focus on to the specific given command. It consumes very less time to implement our task after the wakeup word ”*ABC*”. With the aim of making people’s lives easier They allow us to access the perfect tune with ease and change our music selection without leaving our place. Some kind of devices also come equipped with cameras that can be operated remotely, while others allow you to order goods online using your voice. The user can trigger a skill by saying keywords like open, ask, buy, get, launch, tell, play or start, on, off followed by the name of the module. The range of activities that can be carried out by this kind of module. According to given data, it analyses and performs the task. For this data, analytics is used. It has voice control over the home. This module consists of a voice recognition module that the user can interact with. This module has also smart environmental control in the smart automation system. This Internet of Things application module is created with a combination of many technologies like Raspberry pi 3, sensors, Firebase real-time database cloud platform, data analytics, Android, speech recognition (STT, TTS), Image and Video Processing. It will work as a caretaker for baby as:

1. Moisture sensing, cry detection, movement detection
2. Alerts the parents whenever the module detects the baby cry, moisture and if any changes in vital parameters of health.
3. Works as a health monitor. (*Pulse rate, respiration rate, and temperature monitoring*)
4. If a baby is crying then it sings a lullaby.
5. Face recognition system (*Only limited authorized persons*).

This complete module is a combination of fields like health care, energy conservation, and measurement, environment control, home automation, Education etc.

19.2 Background

There is an abrupt increase in the number of devices and mainly IoT devices. Nowadays we have IoT devices for teens, adults and old people. But there is a need for such healthcare modules for infants too. Adults or mature people can express whatever they are feeling, whatever pain they are suffering through but infants can't express their pain or their feelings. There is a different way of treating adults and babies. If a baby is having a fever or any respiratory problem, then he can express it by just crying but parents can't understand sometimes what is happening to their baby. So, understanding their vital parameters like pulse rate, respiration, body temperature and also other parameters like body movement, moisture detection, cry detection. In this module, pulse rate sensor (*Infrared transmitter and receiver*) detects the pulse rate of the baby. A temperature sensor (*LM35 or IR Temperature sensor*) detects the temperature of the body. Thus, the module is designed in such a way that each and every information about the baby is available to the parents. The parents are made aware of the condition and present status of the baby. The author has used not only SMS service but also Email alerts and Push Notifications from the android app that is developed for this module. SMS service is provided using GSM module connected with a micro-controller. For all of this many research papers are studied as well as articles about healthcare are also studied.

The author has achieved success in connecting this baby monitoring module with the smart home personal assistant module. Parents can know the details about their baby by asking the smart assistant about the status of their baby. And if the baby is in any problem than sensor notify the user, then the smart assistant will immediately alert the parents by speaking it aloud. So, parents can quickly reach to their babies. The technology used here is speech recognition and Text To Speech (TTS). If in any emergency, the smart assistant will alert the trusted or family doctor about the condition of the baby so that the doctor can quickly reach there. The doctor will get each and every detail about vital parameters like heart/pulse rate, respiration, and temperature of the baby. So, while on the way a doctor can look at those readings and when the doctor reaches the baby, the doctor is aware of the problem baby is suffering through. Thus, the doctor can take proper steps for treating the baby.

19.3 Proposed Design and Implementation

This chapter will cover the following three regions:

1. Smart Home Personal Assistant
2. Baby Monitoring System
3. Energy Measurement and Energy Conservation

19.3.1 Smart Home Personal Assistant

Features of Smart Home Personal Assistant:

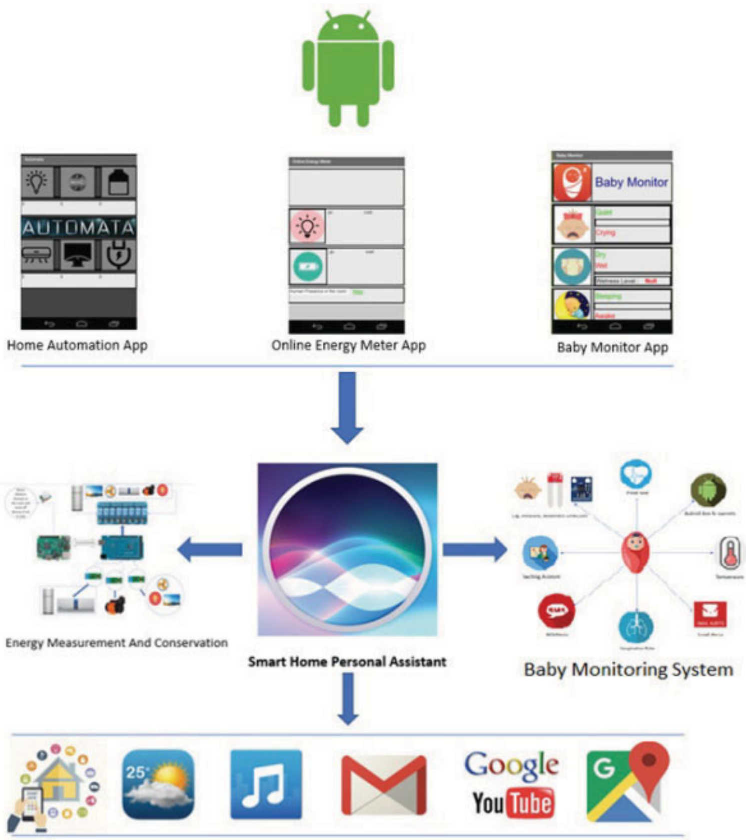

Figure 19.1 Overview of system

1. Home Automation: Different modules of home are controlled by android app and data will be stored on firebase cloud. The medium between the appliance and the application will be wireless and it will use the internet.
   - Smart Auto Home Control (*Turns Off Appliances not in use*).
   - Voice Control Over Home Appliances.
   - Remotely Control Appliances using Android app and Voice Control.
2. Weather Guide:

- It will show the current location weather data, and weather data of any region, Humidity, and UV Index.
- The module acts as a personal caretaker. It alerts the user about UV index and tells the user to take precautions according to UV range.

3. Music Player:
   - The module plays music in the user's playlist.
   - The music player can be controlled using voice commands.
   - The Main feature of the module is that although the music is playing, the module will ignore the music and will listen to your voice only.
4. Send an Email:
   - The module will send an email to anyone using just voice commands.

Similarly other features of Smart home personal assistant are:

1. The module will provide information about the current condition of the baby to the parents.
2. You can surf the web (*Google, YouTube*) using voice commands.
3. You can find any location on Google maps using voice commands.
4. The module will provide the user update about the date, time and day.
5. You can change the name of an assistant. You can call it with whatever name you want.
6. Main Feature of this module is Active Noise Cancellation.
7. This module is also connected with Online Energy Meter module. So, whenever any appliance crosses the threshold then the smart personal assistant alerts the user using TTS service and
8. The system will also keep the user updated about the power consumption and cost of the appliances. This module will also alert the module if any appliance is running uselessly.

The effective feature of this module is Noise-Cancellation. This intelligent module will not only take care of our babies but will also take care of us. It is a kind of module that is fully voice-enabled that gets queries from the user and it gives output accordingly. We have various components in this module and it has one effective feature that is noise cancellation which works when one or two voices merged it and identify automatically which is a proper command for given module and it is fully customized module according to given commands it serves properly, we named our module ”*ABC*”. Whenever we want to turn on or turn off our appliances, the module will automatically turn the appliance on or off accordingly. The core of this project is Raspberry Pi 3. Home automation here is achieved by connecting the relay with Arduino which is connected with Raspberry Pi. Appliances are connected with both relay and ACS712 current Sensor. The user can control appliances in the home using either android app, web portal or using voice commands.

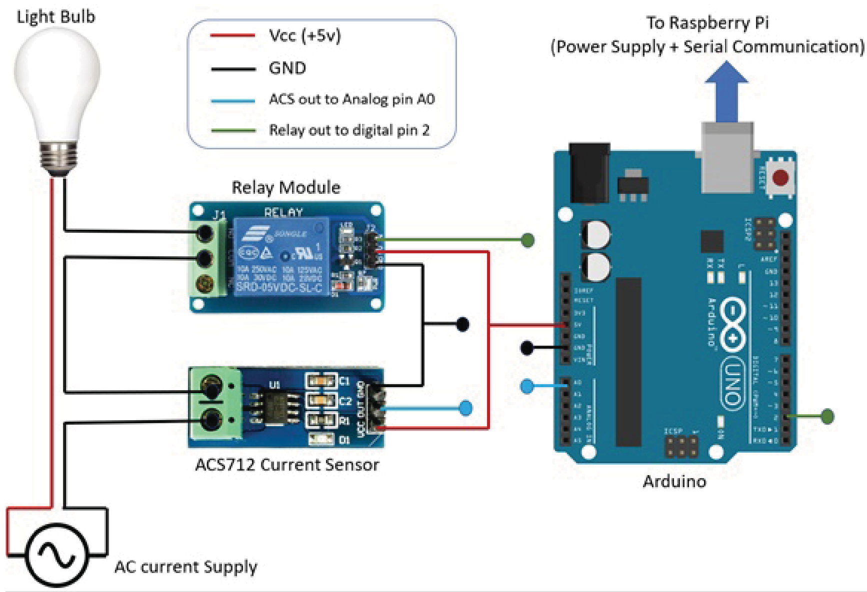

Figure 19.2 Connection of Arduino with ACS712 sensor and Relay

Any of the appliances can be controlled. Here in using this app user can control lights, fans, water motor, Air Conditioners, Televisions and Smart Plug. But this module can be programmed to control any appliance and hardware connections are to be changed accordingly. The serial data of Arduino is fetched by Raspberry Pi. For programming purpose, python and Arduino language are used here. For speech recognition, python library used is Speech Recognition and for face recognition library used is OpenCV. Some of the libraries used in this module are shown in Table 19.1 below:

Table 19.1 Few libraries used in this system

Feature	Library For Python
Speech Recognition	Speech Recognition
Face Recognition	OpenCV
Text To Speech (TTS)	gtts
Email Notifications	Smtplib
Music Playback	Pygame, piglet
Serial Communication with Arduino	Pyserial
Cloud	Firebase

Android App for Everything:

- Home Automation
- Energy conservation Online Energy Meter
- Baby Monitoring

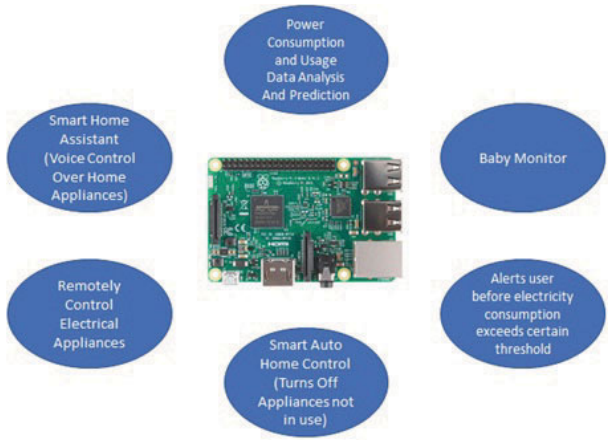

Figure 19.3 Raspberry Pi and connected different modules

19.3.2 Baby Monitoring System

Nowadays, the workload is increasing and people are getting very busy. Here the main problem arises when they are parents and they have to take care of their child or infant as well as their work. Mother is always worried about her child. So, during office hours she can't focus on her work. Thus, this module is developed in such a way that the parents can get each and every vital information as well as current status of their baby. Parents are notified using either SMS, Email alerts or push up notifications from the application that is developed with this module.

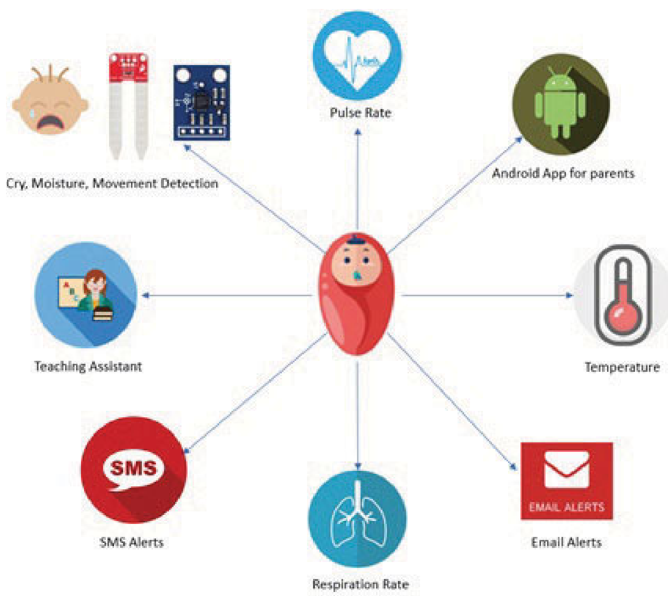

Figure 19.4 Baby Monitoring System and connected sub modules

Here the main feature is that the database used here is Firebase real-time database by Google. This is one of the fastest and free databases available today. The status of the baby is updated in the app at the same time the sensor senses the condition. So, without delay, the parents can get up to date information about their baby. The data includes pulse rate data, movement data, temperature data, diaper moisture data. The Baby Monitoring System also consists of Baby Training or Teaching Module which will teach baby as per his/her age group. This module also sings a lullaby. In baby monitoring system we can get a notification or current status of the baby. In this we have a various parameter in which it will show the values, all data collected from Arduino and from Arduino to python then python to firebase cloud and finally from cloud to the application. The application gets data from firebase cloud. It does not allow any unauthorized persons in baby's room with the help of face recognition system. Parents will be able to monitor their babies (*live feed, moisture detection, sleep detection, movement tracking*). Assistant will act as a caretaker as well as a teacher. So, parents will be tension free.

The graphical presentation of temperature and pulse rate is shown below. Whenever the reading crosses a certain limit, an alert is sent to parents and the doctor immediately.

Figure 19.5 Graph of Body Temperature of a baby

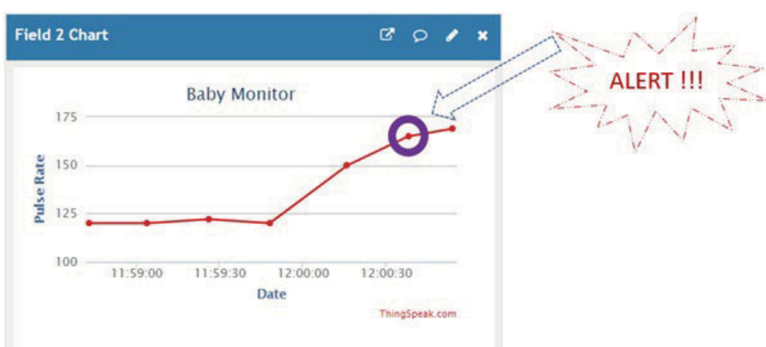

Figure 19.6 Graph of Pulse-Rate of a baby

Face Recognition: A face recognition is a system which is used to identify/detect or verify a person from a digital image or a video frame from a source. There are various methods by which face recognition systems work, generally, it works by comparing applied facial features from given image with faces within an original database. It recognizes and detects faces with the help of Python or by the command line.

Use of face recognition in this system:

- For security purpose.
- Tracks movement of baby's body,
- Facial movement tracking,
- Parents tracking,
- Security for newborn babies in the hospital.
- Intruder and owner detection,
- Notify the user about who is at on the door,
- It will provide protection from criminals and it will alert the user about this situation.

In facial recognition system, the module will find the nodal points on the obtained sample face like facial area, chin, eyes, jawline, the width of nose, cheekbones, length of the face, the width of the face, the area covered by mouth. The first step is the face detection it will look at the person and find a face in it. The second step is the data collecting, in this, it will extract unique characteristics of the person. After that data comparison, despite of variations in light or expression, it will compare those unique features to all the features of the database. In face recognition, it will determine that, that is the authenticated person.

In Face Recognition System, the module will recognize an analog image and extract it. The module will find nodal points on the obtained sample face like eyes, etc. Then it will compare it with the database of images that is already present in the system. In this module, OpenCV module is used and Python used for face detection, face identification, and face recognition. Python module is also used to read systems database, training directories, and file names. This system converts Python lists to numpy arrays as OpenCV face recognizer needs them for the face recognition and identification.

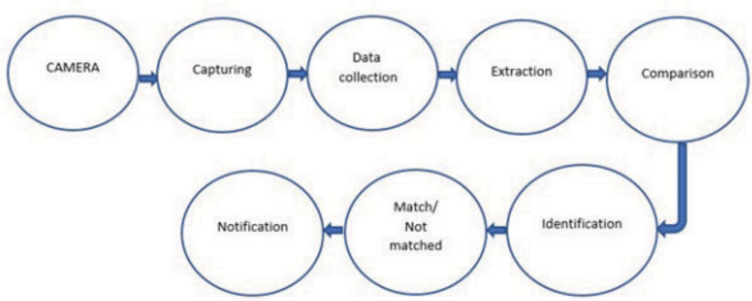

Figure 19.7 Steps of face detection and Recognition

This block diagram shows the flow of the face recognition process, in this module scans and captures an analog or a digital image of a person. The second interface of a module collects the data and extracts the data of the captured image. Another block of the module compares the image with the database. If that image is matched with the database then it will allow the person to enter the room otherwise it will notify the user. In baby monitoring system it will allow an only specific person to come, it is specifically used for baby's security, it will check whether it is an authentic person or not if that image is getting matched with a database then it will allow the person otherwise it will notify the user about incorrect identification.

19.4 Online Energy Meter

Energy Measurement and Conservation Module:

1. The user will know the power consumption of each appliance.
2. If the appliance crosses the threshold then it alerts the user.
3. If the appliances are running uselessly or if no one is in the room then the module will. automatically detect that and will turn off appliances running in that room.
4. The user will be able to control the appliances using the android app as well as by just issuing voice commands.

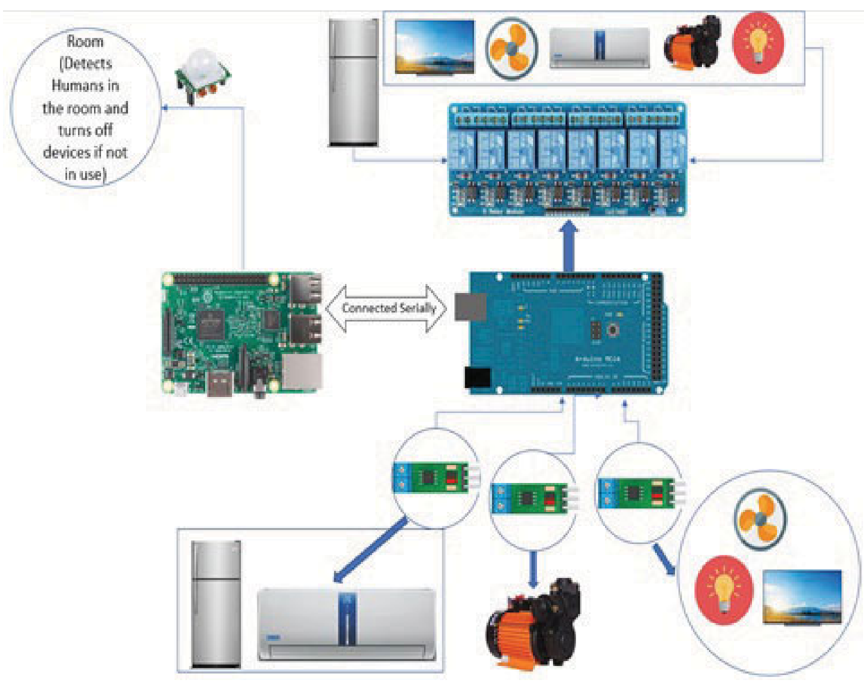

Figure 19.8 Energy Measurement and Conservation Module

The Energy measurement module measures the power consumption of each appliance and displays it to the user. The Energy conservation module tries to minimize the electricity bill of the user by various methods. ACS712 current sensor is also known as Hall Effect sensor by which AC current of any appliance that is present in our home can be measured, in home automation we can get data from this sensor and the data will be stored in the cloud service. It gives analog voltage out proportional to the amount of current which flows through the circuit and it basically works on the principles of magnetism or the relationship between magnetism and electricity. In this module cloud used is Firebase. Firebase provides real-time database functionality. It is one of the fastest and the best cloud platform which provides faster results and faster updating.

The flow diagram represents the connection of appliances with ACS712, PIR motion sensor, relay module, Arduino and raspberry pi. The first current measured by the ACS712 current sensor and after that, it will goes into Arduino and then in relay module and the electrical appliance is already connected with the relay board. This module gets the three-phase RMS voltage and current data from the database. PIR motion sensor is also connected by the module to check human presence. This module is named as energy meter. It shows how much power is consumed by any appliances. The module is able to notify the user about power consumption before power usage exceeds a certain limit. It will also notify the user about the power usage and cost for each and every appliance in the house. This module is fully voice-enabled which executes commands for switching on/off the appliances.

In energy conservation we can measure the power consumption by any appliances and total cost according to the used power consumed by electrical appliances and the energy meter will show energy conservation parameters and alert about the energy consumed by electrical appliances from that we can save our power and lessen the cost or electricity bill. From this module, the user will be able to monitor the usage of each appliance in his home. This module is designed in such a way that it will try to minimize the electricity bill and will alert the module about electricity usage, It shows Energy Efficiency Ratio (EER) of any appliance or any circuit which is present in our home. The app will display used amount of electricity and the units per hour and will notify the user about energy conservation in which it will minimize the electricity bill.

19.5 Sensors used and Their Working

The detailed information about all the components used in this module is shown below:

19.5.1 Temperature Sensor

Two types of temperature sensors can be used in this module:

1. **Semiconductor Sensors**: LM35 is a semiconductor sensor that is used in this project. They are available in the form of IC's. They are known as IC Temperature Sensor. To detect the temperature, these sensors are to be kept in contact with the body of the baby. These temperature sensors provide high accuracy over an operating range of nearly 55^0C to 150^0C. LM35 has 3 pins. Looking from the flat surface, the first pin is voltage pin (+5v), the middle pin is analog output pin and the third pin is a ground pin.

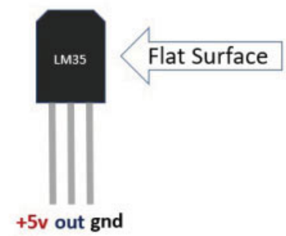

Figure 19.9 LM35 Temperature Sensor

2. **IR Temperature Sensor**: IR Temperature Sensors are also known as non-contacting sensors. They work by transmitting and detecting Infrared signals. If the sensor is held towards the body, it detects the temperature of the body depending on the level of radiation the body is emitting.

Figure 19.10 IR Temperature Sensor

19.5.2 Soil Moisture Sensor

The soil moisture sensor is used to measure the moisture content in the soil. It is ideal for applications in soil science, environmental science, agriculture science, botany, Gardening etc. The moisture in the soil is measured indirectly by measuring the conductivity of the soil. The sensor has two long conductors called electrodes, separated by some distance. Moisture content in the soil is directly proportional to the conductivity in the soil. Means more the conductivity the more it is moist.

There are three pins on the sensor.

1. Vcc
2. Ground
3. Signal

Along with it, it also has one digital pin which provides high or low signal directly. Signal pin gives the analog value proportional to the amount of moisture in the soil. The two electrodes are inserted in the soil to measure the moisture content. The voltage value is the potential drop at the electrodes. The potential drop changes with the change in conductance of the soil. It can only detect the change in the moisture content but cannot directly measure the standard value. For measuring the standard value, more accurate calibration is needed.

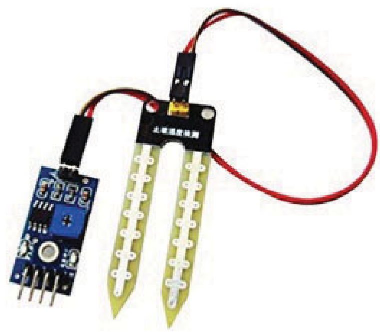

Figure 19.11 Soil Moisture Sensor

Apart from its usual applications, the sensor can also be used in various other applications too. The module has been developed which uses soil moisture sensor to check whether the baby has urinated or not. The sensor is in the interface with LM393 which helps to obtain analog as well digital output of the sensor. The output of the sensor is then given to the microcontroller which is connected to the sensor. The microcontroller used here in an Arduino. The circuit is placed under the cloth on which the baby is sleeping. Whenever the moisture is detected, it gives the output between 300 and 950 depending upon the moisture content. Moreover, there are few modules which have been used to send the data to parents so the parents can know that their baby needs a diaper change.

Table 19.2 Minimum and maximum value obtained from soil moisture sensor

	Minimum Value	**Maximum Value**
Voltage Range(V)	3.3	5.0
Current Range(MA)	0.0	35
Output Value		
The sensor in dry soil	0.0	300
The sensor in humid soil	300	700
Sensor in water	700	950

The modules used here are:

1. GSM module.

2. Email module (*MIME library*) in python.

3. Push notification (*using Firebase*).

This way the parents do not need to worry about their child all the time.

19.5.3 PIR (Passive Infra-Red) Sensor

It is an electronic device which helps to detect the presence of a human being or any animal. It also senses the motion and hence can detect whether anyone has moved out or in of the sensor range. Human beings/Animals emit heat energy in the form of infrared radiation. The fact that human beings and animals emit infrared radiation helps this device to detect them. PIR sensor consists of a Pyroelectric sensor which generates energy when exposed to heat. The Pyroelectric sensor detects the level of infrared radiation. The sensor is encapsulated with a metal plate which consists of a rectangular glass crystal on top of it. The detection range of the sensor is between 5m and 12m. It is an inexpensive, small and an easy to use the device.

Figure 19.12 PIR Motion Sensor

The sensor is actually divided into two halves. When any human or animal comes in the range of a sensor, the radiation is detected by the first half, due to which a positive differential change is caused between two halves of the Pyroelectric sensor. When human/animal leaves the area in range, the situation reverses, causing a negative differential change between two halves. This change in temperature is what is detected to detect the presence of any warm body in the sensor range.

The sensor is encapsulated with a lens called Fresnel lens which focuses the infrared radiation which comes from human/animal body on the Pyroelectric sensor. With the help of this component(lens), it becomes easy to detect the radiation. There are three pins on the PIR sensor.

1. Vcc

2. Signal

3. Ground

Generally, power is 3-5 VDC but it can go up to 12V. The output signal is high when any warm body is detected. We can also adjust the sensitivity and delay time of the sensor. The sensitivity of a sensor can be ranged up to 7m and delay time can be adjusted between 3s-5mins. The sensor also consists of two triggers.

19.5.3.1 Non-repeatable trigger When sensor output is high and delay-time is over, it automatically changes the output from high to low.

19.5.3.2 Repeatable trigger This trigger keeps the output high all the time until the warm body is present in the sensor's range.

This sensor can be used in various applications. One of them is Smart Home Automation Module. Being a human-being it is natural to forget sometimes. It might happen that the person in the room forgets to switch off the device before leaving. This results in wastage of electricity and ultimately saves the extra cost on the electricity bill.

19.5.3.3 Sound Sensor Sound sensor detects the presence of any kind of sound in the environment. It provides both digital and an analog output signal which represents its amplitude. Its one of the main components is its microphone. The sensor detects the sound through a microphone and converts it into the electrical signal to amplifier part. It is an operational amplifier that increases the signal from the microphone.

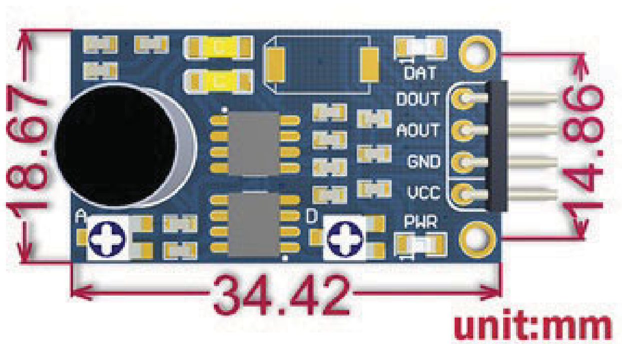

Figure 19.13 Sound Sensor

There are four pins on the sound sensor.

1. Vcc
2. Ground
3. An out (*Analog output*)
4. D out (*Digital output*)

The sound sensor has been used to amplify sound, to detect sound level etc. There are many applications in which sound sensor can be used.

A module has been developed which sends the data through GSM module or activates the alarm to alert the parents as soon as it detects the crying sound of an ina fant. A lullaby player is connected to the module. As soon as the infant starts crying, the sound is converted into an electrical signal which is transmitted to ta he lullaby player by the Arduino system. As the player gets the signal, it starts playing the preloaded songs through the speaker to calm down the baby. The module is programmed to wait until 15 secs since the baby started crying. If the crying doesn't stop after 15 secs, the data is sent to the parents through GSM module and it also activates the alarm to alert the parents.

19.5.3.4 Pulse Rate Monitor Pulse rate sensors work on the basis of differential absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light while deoxygenated hemoglobin absorbs more red light. This pulse rate sensor is very easy to use. Just by putting finger on the top of the sensor, it detects a pulse by measuring the change in the light as per expansion of the capillary blood vessels. This sensor has two portions. LED that is present in the center of the sensor. Below LED, a noise Cancellation module is present which cancels noise that can affect the readings. This sensor has 3 pins. First one is Ground (GND) pin, the middle one is Vcc and the last one is analog output pin (A_0). The sensor consists of a bright Light Emitting Diode (LED) and a Light Detector (LDR). The bright light is passed from one side of the finger and the intensity of the reflected light is measured by LDR. The volume of blood inside the blood capillary changes the amount of light reflected. During a heartbeat the heart pumps the blood resulting in the absorption of light and thus there is a decrease in the intensity of the light received by LDR. This increases the resistance value of LDR. This resistance variation is converted into a variation of voltage using a circuit called OP-AMP. Before passing the signal to microcontroller the signal is amplified. The microcontroller is then made to count a number of an interrupt or count the pulse every minute. Thus, the value of pulse per minute will give the heart rate in bpm i.e. Beats Per Minute. This sensor can be attached to the wrist of the baby. And the microcontroller is programmed in such a way that if the pulse rate value exceeds the limit according to the age of the baby then quickly alert is sent to the parents as well as to the doctor.

The pulse rate sensor has 3 pins:

1. Ground
2. Vcc
3. Analog (A0)

Figure 19.14 Pulse Rate Sensor

19.5.3.5 ADXL335 (Accelerometer) An Accelerometer is capable of measuring acceleration in all the three orthogonal axes which are *X*, *Y*, and Z respectively. Acceleration is the measurement of change in speed or velocity with respect to time. ADXL335 is one type of accelerometer sensor. The sensor works by sensing the static acceleration of gravity. The measuring range of the sensor is 3 g in all the three directions. It gives output in analog representation. The output is basically in the form of a voltage which is in proportion to acceleration.

An Accelerometer can measure the following entities when it is set in different modes:

1. Velocity and Position
2. Orientation and Inclination
3. Vibration (Shock)

This sensor has 5 pins on it out of which three are output pins for *X*, *Y*, and *Z* axis as mentioned in the Figure 19.15. All these pins give an analog output which ranges from 0 to 1023.

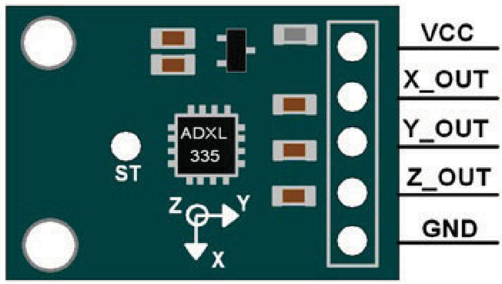

Figure 19.15 Accelerometer ADXL335 Module

Have you ever wondered how the compass app in the smartphone works? Or how an app for finding the constellation in the sky works? Smartphones have accelerometer IC (*Integrated Circuit*) installed in them and hence these apps work with the help of an IC. The accelerometer can also be used to detect the earthquake.

Acceleration is the function of displacement represented as $a = f(x)$ where a is the acceleration and x is the displacement, so acceleration can be measured by measuring the displacement. The methods which are used to sense the displacement are Resistive technique, Capacitive technique, and Inductive technique. As these techniques are all mechanical in nature and are not eligible to be used in smartphones, developers came up with a single structure called MEMS (*Micro Electro Mechanical System*). This is inside accelerometer IC.

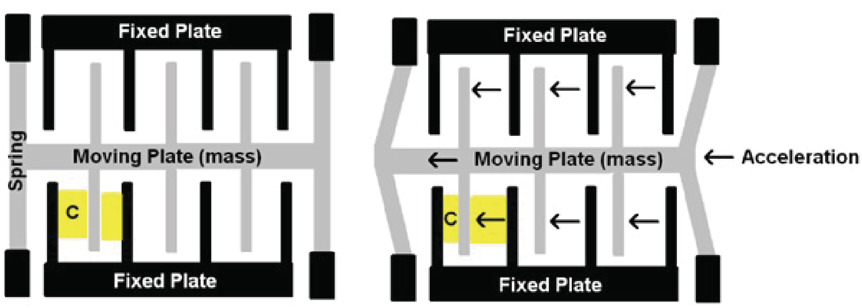

Figure 19.16 Accelerometer sensor MEM mechanism

There are two structures inside the IC, the outer assembly having fixed plates and the internal movable assembly. It has a small mass and is connected to the outer assembly using spring contacts. The movable assembly also has plates which form a capacitor. As the module moves due to acceleration, the internal assembly moves which cause the change in displacement and ultimately change in the value of the capacitor. By measuring the change in capacitance, the value of acceleration acting on the body is calculated. An accelerometer gives the reading of acceleration in a different direction as seen by the body.

In the above section, the common applications of the sensor are mentioned. To extract the most out of it, one can implement this sensor in various other applications. One such module has been developed for working parents to monitor their baby. ADXL335 is used in this module to monitor the orientation and movement of the baby. The sensor is connected to a microcontroller which is Arduino to send that data. The data then is sent to that parents to let them know whether their child is awake or sleeping. If no movement is recorded within the given time, the module sends the message to the parents which say ”Your child is sleeping peacefully”. The module is programmed in such a way that it waits for 10sec before sending the data to parents through GSM module. Because it might happen that the baby is just changing gesture in sleep. This way, this module is helpful in giving live updates to parents about their child.

19.5.3.6 Respiration Monitor System Respiration monitoring module analyses a person’s respiration patterns on the basis of breathing rate. The module uses Piezoelectric Film sensor to track the breathing rate. The word Piezo is a Greek word which means ”Press” or ”Squeeze”. It is highly sensitive and gives analog output. The sensor measures displacement variation induced by inhaling or exhaling. The sensor is placed in a wearable elastic belt, the length of which can be adjusted. This is usually placed slightly above the belly so that the breathing rate can be tracked effectively. This sensor also monitors respiratory rate, respiratory cycle regularity, the relative amplitude of the cycle, and others.

The Piezoelectric film forms a circuit with a voltmeter which measures the voltage produced by the Piezoelectric film sensor.

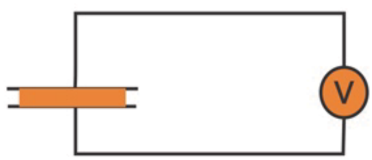

Figure 19.17 Sensor with neutral position

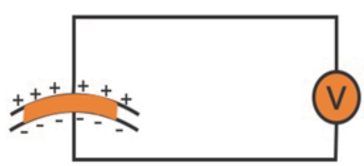

Figure 19.18 The sensor in a flexed position

When the sensor is in the neutral position or at rest, there’s nothing special observed. The voltage produced by the sensor will be equal to zero. But when you bend or flex the sensor, that mechanical work translates into a charge displacement. Non-zero voltage is observed. Positive charge accumulates on one side and negative on the other. The structure becomes like a charged capacitor. Like any other charged capacitor, the charge ultimately gets combined after some time and becomes normal again. This change in voltage is recorded and is given as output.

Given below is a table of the respiratory rate for almost all age group which helps to analyze whether a person's respiratory rate is normal or not.

RESPIRATORY RATE: The module has already been developed to monitor the baby which uses the respiratory monitoring system to monitor the breathing activity of a child. The baby is made to wear this soft elastic belt. The belt is placed slightly above the belly. The sensor is connected to an Arduino micro-controller board which collects the data given by the sensor and send it to the parents when an unusual activity is recorded. The normal respiratory rate has been specified in the above given table. If the breathing rate increases or decreases with respect to the normal respiratory rate, then an alert message is sent to the parents through the GSM module. The message will also be sent to the doctor if the details are added to the database so that the condition of the baby can be more precisely analyzed. This way baby's health can be monitored using a Piezoelectric film sensor.

Table 19.3 Respiration rate as per the age group

Age group	Respiratory rate
Adults	12-20 breathes/minute
Infants (¡12 months)	30-60 breathes/minute
Toddler (1-3 years)	24-40 breathes/minute
Pre-school (4-5 years)	22-34 breathes/minute
School age (6-12 years)	18-30 breathes/minute
Adolescence (13-16 years)	12-16 breathes/minute

19.5.3.7 ACS712 Current Sensor ACS712 is made by a company called Allegro, it is an American company. In this ACS712 we have 3 pins:

1. Power supply (Vcc)
2. Output
3. Ground

And we have a couple of clusters in this sensor. We have little LED and resistor in it.

The ACS712 is called Hall Effect sensor because the person who measuring current this way was Edwin Hall. This is ”ACS712 30A” because it is capable of measuring up to 30Amperes of current. This is an analog device. It is to be read in an analog pin in the Arduino, we power this up with 5 volts, another one connects with the ground and output pin goes to an analog input pin on the Arduino. It follows low noise and analog signal path is really a good thing about the sensor. We have 66 to 185 millivolts per ampere output sensitivity range. We get this range of sensitivity just because there is a different type of submodules are there, and the submodules are like 5 amperes, 20 amperes and 30-ampere version are there. So, for this module the sensitivity we taking in a count is 66 mV per ampere, if we want to pull 1 Ampere of current through this chip then the output of the chip to the Arduino would be 66mV. If we pull 2 Amperes through this chip then

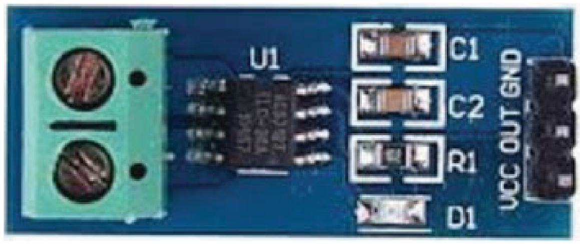

Figure 19.19 ACS712 Current Sensor

the output would be about 132 or 130 mV. He discovered this in the late 1800s when an amount of current passes through somewhere it gives of a degree of magnetism, it is linear with the amount of current that passes through a circuit or conductor or any appliance. This chip basically uses that effect in order to measure the current. When current passes through these two plates here underneath the current goes through the two pins and then it comes back out through another two pins and then back out this plate and through the screw terminal adapter but another little chip measure the hall effect, when it is measured the hall effect there is some bits of processing and then it gets sent out there at where three pins are situated.

From the Output voltage vs sampled current graph, we can conclude its just a margin of error there in the graph. It seems to suggest that it is mainly based on the temperature, there as long as you keep it at 25 degrees Celsius or under then we get a pretty good rate of accuracy. So, how do we measure the AC current using ACS712 current sensing sensor? Basically, in-home we got 200 or 250 volts and 50 Hertz, 50 Hertz means 50 waves per second. Duration of that wave which shown in the figure is 20 milliseconds (1000/50 Hertz = 20). There is wave every 20ms (50 waves per second i.e. 50 Hertz). In DC we took samples everywhere and if we take some sample ones a second because in DC 12 volts are a consistent amount of amperage, voltage won't change in the amperage, it would be fairly accurate.

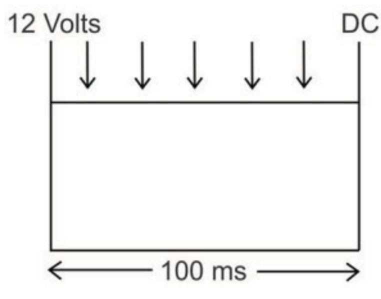

Figure 19.20 Graph 1

But in AC if we have 50 of these waves in one second, now we have to find where will our sample fall at the point shown in Figure 21. We will take some sample ones per second. In our case, if this sensor gives 66mV per ampere then how many millivolts will return, at 0V point, we get 0V because at that point the 0 ampere is flowing through it. If we were to take samples we could fall on that point and it would be a complete waste of

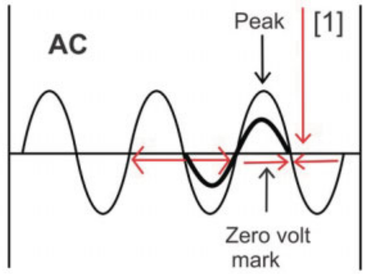

Figure 19.21 Graph 2

time. We can only get current when there is a voltage, if there is no voltage then there is no current. The more voltage there is potentially more current that we would be able to show. So, that really matters exactly where we take a sample. Basically, what we can conclude from this is that unlike DC where everything is stable, linear and does not actually move. We could take some sample ones a second but in AC we have got absolutely no chance. In AC, it will totally have no meaning. So, with AC current we start with taking the 50 waves per second. There is a wave every 20ms. It would not even be sufficient to take one sample every 20ms, it is very short time but for electronic appliance specifically to be able to measure wave which is 20ms long.

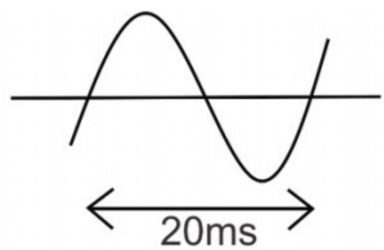

Figure 19.22 Graph 3

It is just not On/Off circuit. We were to take 10 samples every 20ms or every 2ms. Then we would get 5 samples of positive part and 5 samples of negative part of the voltage. After taking 10 samples we miss the peak and the trough then we are not going to get an accurate answer. Even taking 10 samples over one is not enough. Now we take 20 samples over one wave. From this, we get 10 samples per positive half and 10 samples per negative half. It can be sufficient. We have got 1000 samples which we have taken in a second. We get 0mV which is 0 ampere, after that, we get negative 660mV which shows -10 amperes value. If we were to get all those samples and find the mean, we would add them all together and divide by the total amount of sample. We would get 0mV from this calculation. ACS712 current sensor is also known as Hall Effect sensor by which we can measure AC current of any appliance that is present in our home, in home automation we can get data from this sensor and the data will store in the cloud service. It gives analog voltage out proportional to the amount of current which flows through the circuit and it basically works on the principles of magnetism or the relationship between magnetism and electricity.

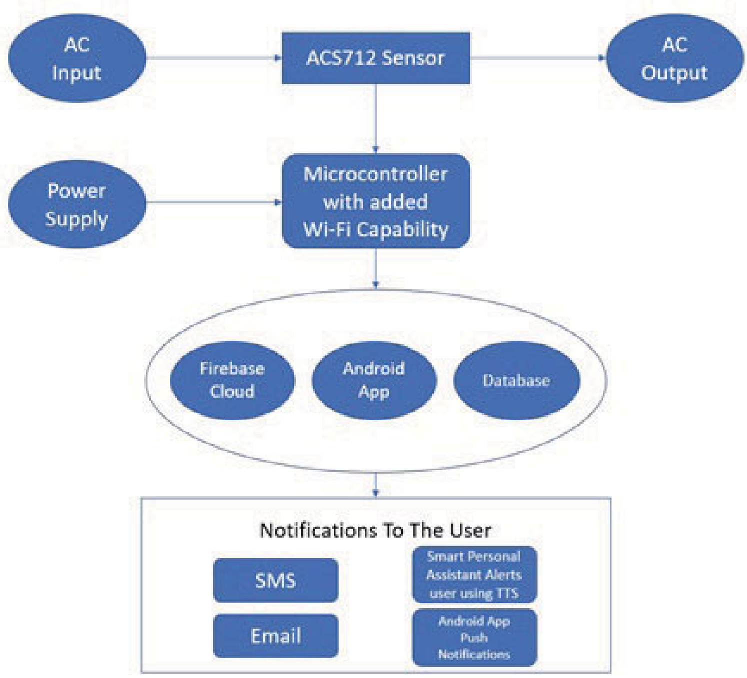

Figure 19.23 Flow of process for Online Energy Meter module

This block diagram shows connectivity of ACS712 Current sensor with Microcontroller having Wi-Fi capability. Input from AC source is given and it goes to the load through theACS712 Hall effect sensor. Input current goes through the load and it gets sensed by the sensor and sensor is connected with an analog pin (A0) of Arduino. Power supply gives power to the microcontroller. The total power and the energy rate is displayed on a LED display. This chip is connected with the database or web application. It will show various parameters of Energy meter.

Real Power (*P*): It is also known as Watt full power. The actual power which is used to produce electric medium in the circuit. The power which is directly transferred to the load. For DC real power is

$$P = I * V \tag{19.1}$$

For AC real power is

$$I * V * cos(\theta). \tag{19.2}$$

Reactive Power (*Q*): The power which oscillates between load and source. It continuously returns back between load and source. For inductor it is positive, for a capacitor it is negative.

$$Q = I * V * sin(\theta) \tag{19.3}$$

Apparent Power (*S*): In circuit when there is no phase angle difference then will be counted. It is a product of *I* and *V*.

$$S = I * V. \tag{19.4}$$

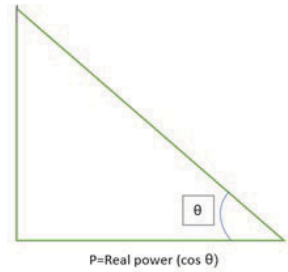

Figure 19.24 Real Power

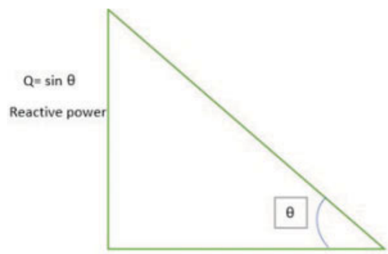

Figure 19.25 Reactive Power

$$S = ReactivePower + RealPower \tag{19.5}$$

$$kvA = (kW + kvAR) \tag{19.6}$$

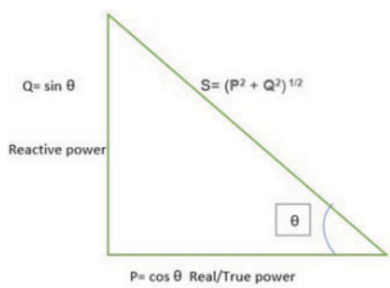

Figure 19.26 Apparent Power

Power Factor (P_f): It is a ratio of true power to the apparent power.

This triangle is known as a power triangle.

To get various parameters there are some formulas. Take the value of V_{pp}, after that divide Vpp by 2 to get V_p.

$$V_{rms} = V_p * 0.707 \tag{19.7}$$

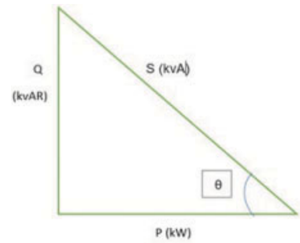

Figure 19.27 Power Factor

$$\frac{V_{pp}}{2} = V_p \tag{19.8}$$

$$V_{pp} = \text{Peak to peak voltage} \tag{19.9}$$

To find V_{rms}, take V_p and multiply it by 0.707. After that multiply sensitivity of ACS712 with V_{rms}, to get I_{rms}.

$$V_{rms} * sensitivity = I_{rms} \tag{19.10}$$

For final answer real power is used because it is the main or actual power which is taking an account.

$$Finalanswer = V_{rms} * I_{rms} * P_f \tag{19.11}$$

$$V_{rms} = 230(i.e.standardvalue) \tag{19.12}$$

$$I_{rms} = \text{Reading of sensor at } P_f = 0.85 \tag{19.13}$$

There are two types of different methods for AC measurement.

1. *RMS: Root Mean Square*: It is a calculation that we do with all of these given values including negative. We do its calculation after performance calculation on them and it gives an amount of average voltage as a positive number, not as a negative number. The peak voltage is about 300 and the trough is -300 but the RMS voltage is approximately 250. By RMS method we can get value or output of ACS712.

2. *Multiply with 0.707*: This method is a lot easier but not as accurate. We get 1000 samples in a second in order to detect the wave, now we are going to eliminate all the negative ones straightaway, any value lower than 0 will automatically eliminate. Then we have to go through all of these numbers and we have to find the peak. We eliminate all the positive numbers too. The only number we are after is the peak. We get the peak which is responsible in this case and the peak value is 660mV. We multiply peak value by 0.707. This value is equivalent to RMS value.

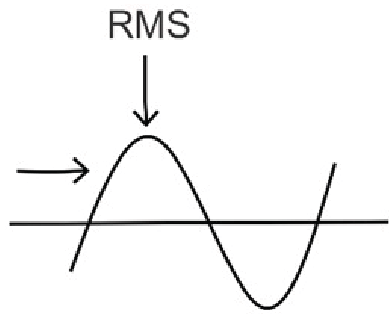

Figure 19.28 Root Mean Square

19.6 Conclusion

Voice Controlled Home Automation is a very different concept than what is presently available in the market. This would make automation more easy and intuitive. The people will be able to interact with the module. It also is an important aspect in the present world where people are so busy, this would help them in easing the basic functionality of their life. The world around us is going digital in every aspect we can imagine and it is happening fast, we also need to move forward with it. This module is a great initial step in automation, it would also provide with security. As it is based on voice recognition we can assign a particular password to each user and the automation will respond to the correct Passwords only. The following are the features of this module:

- Easy to use.
- Saves unnecessary power consumption.
- Low cost compared to other automation systems.
- Easy to implement.
- Could also be used to provide security measures.
- Has good processing power and can handle multiple functions at the same time.
- Uses reliable wireless connection.
- Provides security and personal customization.

The module also has integrated with different modules which are home automation, user control smart home appliances with their voice. Multiple modules can be placed in different rooms in a home for synchronized playback of music. This module will provide a various number of services, both in-house and third-party, are integrated, allowing users to listen to music, control playback of videos or photos, or receive news updates, provide information about power usage by electrical appliances according to that information it will automatically control the usage of appliances.

The output of another module is that it will monitor the activities like crying, sleeping, playing etc. of a baby within the house and shows the pulse rate of the baby. The module will provide a training-suite for baby. It also restricts the entry of unauthorized persons in baby's room with the help of face recognition module. The main thing is that everything will be connected with each other and every module will talk to each other. So, this module is a bundle of everything you need.

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