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EYECOM: an innovative approach for computer interaction

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EYECOM: AN INNOVATIVE APPROACH FOR COMPUTER INTERACTION

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Approved by
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APPROVAL OF THESIS

We, the faculty supervising the work of Anam Mazhar, affirm that the thesis, *EyeCom: An Innovative Approach for Computer Interaction*, meets the high academic standards for original scholarship and creative work established by the Master of Science in Information Systems and the Weisberg Division of Computer Science. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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ABSTRACT

The world is innovating rapidly, and there is a need for continuous interaction with the technology. Sadly, there do not exist promising options for paralyzed people to interact with the machines i.e., laptops, smartphones, and tabs. A few commercial solutions such as Google Glasses are costly and cannot be afforded by every paralyzed person for such interaction. Towards this end, the thesis proposes a retina-controlled device called EYECOM. The proposed device is constructed from off-the-shelf cost-effective yet robust IoT devices (i.e., Arduino microcontrollers, Xbee wireless sensors, IR diodes, and accelerometer). The device can easily be mounted on to the glasses; the paralyzed person using this device can interact with the machine using simple head movement and eye blinks. The IR detector is located in front of the eye to illuminate the eye region. As a result of illumination, the eye reflects IR light which includes electrical signals and as the eyelids close, the reflected light over eye surface is disrupted, and such change in reflected value is recorded. Further to enable cursor movement onto the computer screen for the paralyzed person a device named accelerometer is used. The accelerometer is a small device, with the size of phalanges, a human thumb bone. The device operates on the principle of axis-based motion sensing and it can be worn as a ring by a paralyzed person. A microcontroller processes the inputs from the IR sensors, accelerometer and transmits them wirelessly via Xbee wireless sensor (i.e., a radio) to another microcontroller attached to the computer. With the help of a proposed algorithm, the microcontroller attached to the computer, on receiving the signals moves cursor onto the computer screen and facilitate performing actions, as simple as opening a document to operating a word-to-speech software. EYECOM has features which can help paralyzed persons to continue their contributions towards the technological world

and become an active part of the society. Resultantly, they will be able to perform number of tasks without depending upon others from as simple as reading a newspaper on the computer to activate word-to-voice software.

CHAPTER 1

INTRODUCTION

1.1 Motivation

Diseases or Violent events can result in paraplegic, or tetraplegic conditions. The degree of damage may be impairment in, or total loss, of motor functions. Individuals so debilitated require assistance from machines or humans for carrying out some functions, or in severe-disability cases even life sustaining functions. Here are two world famous cases: one as a result of disease and the other through an accident.

Stephen Hawking enjoyed a normal boyhood. At the age of 21 while studying for the Cambridge tripos in Cosmology he was diagnosed with Amyotrophic Lateral Sclerosis (ALS), commonly known as the Lou Gehrig disease. The disease kept on worsening; his speech become increasingly slurred. He required 24-hour nursing care. A California computer programmer developed a speaking program that could be directed by head and eye movement. Still later with most motor functions gone, Hawking directed the speaking-program through cheek muscle attached to a sensor. Stephen Hawking occupied one of the most renowned teaching posts in the world: the Lucasian Professorship of Mathematics, at Cambridge for nearly 50 years [1].

Christopher Reeves came from an upper-class family, attended Cornell University, (while working as a Professional Actor), and later attended Juilliard School. He became one of the most sought-after actors of his period; his best-known role was that of Superman. He suffered tetraplegia after a horse-riding accident and died suddenly at the age of 52 after several years of living and working with his severe disability [2].

The foregoing paragraphs present two of the more famous recent cases of damage to the motor-function. In cases where the paralysis progressively worsens, loss of speech can become a concomitant condition. According to Christopher and Dana Reeves Foundation, every year 11,000 new cases of paralysis are reported [3]. This number, large as it is, would increase if the military causalities were to be included. Each year the military reports cases in which army personnel collapse due to a stroke or failure of the nervous system resulting in complete or partial paralysis [4][5].

People who are suffering from debilitation, or loss, of limb functions can communicate through their voice, but those who suffer the additional burden of loss of speech raise real medical challenges to the Medical Practitioners as well as Computer Scientists (note: Speech synthesizer for Stephen Hawking above).

The next section presents different types of debilitations for which function-restorative devices are available. The effectiveness, efficiency, ergonomic quality, and cost of the devices is a factor of standing concern.

1.2 A Short Survey of Assistive Technologies for People with Challenges

The age of micro-devices has ushered in a plethora of devices, some gimmicky and some useful. The section covers some of the assistive devices specifically meant for people with specific challenges.

Utilizing gestures of the body and body-part movements can facilitate communication to some extent, and indeed some technological progress has been achieved in this domain; however, there are several drawbacks associated with this method of communication and these will now be briefly discussed.

1.2.1 Challenges of Sight

- **Braille System —** The system employs six embossed dots for coding alphanumeric characters, somewhat like the ASCII (except that the basic symbol is embossed instead of being punched) [6]. Braille code was defined/codified in 1829.
- **Finger-Reader —** It is another device for the Visually Impaired [7].
- **Be-My-Eyes —** This system relies on crowd sourcing for its operation. The needy person sends out smart-phone signals (text/photos), and any person from among the available volunteers can respond. It is of rather limited utility [8].

1.2.1.1 Challenges of Speech

- **Talkitt —** The tool/device translates unintelligible pronunciation into understandable speech. It compiles a dictionary of unintelligible utterances, which are then assigned their understandable equivalences i.e., the machine does the translation in real-time [9].

1.2.2 Challenges of Movement

- **Sesame Phone —** It is touch free designed for people with restricted physical mobility. The basic equipment is a smart phone, enabled to catch small head movements tracked by its front-facing camera [10].
- **AXS Map —** It is a crowd-sourced map, which demarcates wheelchair accessible restrooms, along major highways [11].
- **Liftware —** It is an ingenious device; it is self-stabilizing handle which can be attached to a fork or a spoon. It is of assistance to those suffering from hand tremors or other forms of motor disorders [12].

1.2.3 Challenges of Hearing

- **The UNI System —** This is a two-way communication tool, using Gesture and Speech Technology. The system captures hand gestures and using an algorithm converts them to text [13].
- **Trans cense —** The system aids the Hearing Challenged to participate in group conversations [14].

The section concludes this brief survey of ‘Assistive Technologies’ for remediating loss or reduction of bodily-capacities. In the next section, author develops a Statement of the Problem and in the subsequent section, author defines the Scope of the Thesis (the work author set-out to undertake).

1.3 Towards Problem Definition

1.3.1 Strand 1: The Physiological State

Focusing on Physical and Mental dexterity as the two facilitative components of performance, those with physical challenges (albeit muscle wasting type of conditions) are often unable even to deploy their innate skills and knowledge gained through education and experiences (acquired prior to; or sometimes even after, the onset of serious debilitations) in a satisfying and/or gainful manner.

Where only the body part fails (such as leg, heart, or breast), prosthesis can replace a body part. Intelligent-Prosthetic devices can take signals from (some part of) the body and then assist in the performance of a specific function, as presented in the vignette on Stephen Hawking’s case in section 1.1. To continue building the case, some terms need definition.

While the suffix -**Paresis** denotes a “weakness”; -**Plegia** defines a “total loss.”

- **Paraplegia** is the paralysis of the legs and the lower body.
- **Hemiplegia** is the paralysis of one side of the body.
- **Monoplegia** is the paralysis of a single limb (usually the arm) – the other arm might have monoparesis.
- **Quadriplegia** or Tetraplegia is the paralysis of all four limbs.
- **Ophthalmoplegia** is the paralysis of the muscles within or surrounding the eye.

In cases of muscle-strength loss, in organic development (as opposed to a sudden/violent event), at onset the condition might be –Paresis, and deteriorate to a –Plegia. The thesis **concentrates** on the cases of **deterioration in the muscle strength** i.e., cases of paresis (in the absence of ophthalmoplegia).

Literature available indicated that the population we chose for our research is essentially underserved. The reason for underserved population is suppressed demand (as opposed to need) and underdeveloped technology:

- Technology too complex/intricate for the average person. No standard; no manuals.
- Individual Fitting. As most devices are built from scratch, it becomes too expensive for the average person.
- Lack of Big Data (large enough data set) to formulate ergonomic design parameters.
- The greatest drawback is that available wearable devices are not wireless, and this curtails the availability of the technology to specific locations/stations.

1.3.2 Strand 2: Communication through the Eye

This research stems from recent research on Communications through EyeBlink. The author here deals with Physiological-Mutism, which is in- or reduced- ability to speak, coherently, as in the case of Stephen Hawking presented in the Vignette (section 1.1)

While trying more fully to understand Stephen Hawking's case, I first learned of the "Locked-in Syndrome" through the article, meant for Patients and Families, published by the National Organization for Rare Disorders (Reference). An excerpt of the article's abstract is listed below [15]:

> *"Locked-in syndrome is a rare neurological disorder in which there is complete paralysis of all voluntary muscles except for the ones that control the movements of the eyes. Individuals with locked-in syndrome are conscious and awake but have no ability to produce movements (outside of eye movement) or to speak (aphonia). Cognitive function is usually unaffected. Communication is possible through eye movements or blinking. Locked-in syndrome is caused by damaged to the pons, a part of the brainstem that contains nerve fibers that relay information to other areas of the brain*."

From the above lead, author's research focused on published material on EyeBlink Communication. A seminal article on EyeBlink Communication was published in 2012, in the *Annals of Rehabilitation Medicine*. An excerpt of the article's summary is listed below [16]:

> *"Locked-in Syndrome is a severe pontine stroke causing quadriplegia, lower cranial nerve paralysis, and mutism with preservation of only*

vertical gaze and upper eyelid movement in a conscious patient. We present a case of a Locked-in Syndrome patient who received communication training with augmentative and alternative communication equipment by using eye blinks. After 3 weeks of training, the patient was able to make an attempt to interact with other people and associate a new word by Korean alphabet selection. Augmentative and alternative communication equipment which uses eye blinks might be considered to be beneficial in improving the communication skills of locked-in syndrome patients."

1.3.3 Strand 3: Communication with the Computer

In the beginning of the computer age, human-computer interactions (HCI) were through machines known as teletypes. Teletypes had keyboards (similar to the typewriters of old) and were equipped to print both the inputs to the computer as well as the computer's response.

Later developments introduced the combination Display Screen and Keyboard for Input-Output. The Keyboard remained the input device. A keystroke created the respective image on the screen while it sent the code corresponding to the keystroke to the computer. Output was displayed exclusively on the screen.

Now, a screen is a two-dimensional digital device. Objects, including text, can be placed on any part of the two-dimensional space. This aspect of the screen was used to advantage with the advent of ancillary pointing device. One such pointing device, ubiquitously used for input, known by its moniker is the 'mouse.'

Mouse as an input device is especially useful in Automation of Questionnaires and Formfilling – Graphical User Interfaces (GUI).

Author decided to use the mouse as a complementary input device, to fulfil the spatial necessities that author foresaw for her research endeavor.

1.3.4 Bringing the Strands Together

The envisaged device operations would be as follows:

1. The person, with the detreated muscle functions as defined in Strand-1, will use the residual ability of one of the limbs to move the mouse pointer to the desired location on the screen.
2. Using EyeBlink should be able to simulate the mouse functions.

Thus, the research problem was to build a functional prototype of a robust but low cost EyeBlink Assisted Communication Device. Hence the substance of the thesis will be referred to as: Eye-Communication (EYECOM)

1.4 Delimiting the Scope of the EYECOM

The motivation for this thesis emerged from the life-experience and educational background of the author, who comes from Pakistan, and has a bachelor's degree in Electronic Engineering. Pakistan is a low-income country and does not have a HealthCare program worth mentioning. I wanted to see if using Commercial off-the-shelf, COTS, based electronic microcircuit components a prototype of a fully functional device could be built, to restore communication functions to those simultaneously afflicted by loss of motor- and speech-functions.

The starting point of most Applied Research Projects is the construction of a Prototype. The Prototype is vigorously tested for component failures, component interactions issues, and component connectivity problems, strength of signals, etc.

In the next phase, focus of attention shifts to desired physical characteristics (size, weight, colors, etc.), and the ergonomic characteristics as perceived and experienced by the user-group. The next phase is that of manufacturing. Subsequent to manufacturing are the marketing and servicing phases.

The author undertook this study as a 6 Academic Credit Hours effort (of a 36 Credit Hours; Master of Science Program). The supervisor and author agreed to limit the thesis in researching the techniques needed to put together such as the Technical, Proof-of-Concept level, i.e., building a fully functional Prototype. The main objective of the thesis is to develop a solution that facilitates handicapped individuals by refurbishing the diminishing capabilities and turning their physical weakness to their personal and social strength. The solution proposed provides a technological way out to the people who have enough brain potential to develop ideas but are unable to implement it as well as perform daily routine tasks in an effective manner.

1.5 Thesis Scope

There are stages of paralysis and at each stage the patient has unique challenges when it comes to the usage of technology and computers. Access to technology and immobility can immensely depend on the severity of the paralysis. There are many forms of paralysis. If the paralysis is of type Monoplegia or Hemiplegia i.e., affecting one arm or leg, the person can interact using his/her two limbs and may communicate verbally. If the paralysis is of type Paraplegia, which affects both the legs, the patient can still effortlessly communicate with others as well as digital devices as both hands are perfectly working. The challenge arises if the paralysis is of type Quadriplegia, also known as tetraplegia, where all four limbs are affected usually due to the injury of the spine. If the Quadriplegia is not of severe type i.e., a person has some remaining muscular activity strong enough to move a mouse or at least press a button on a keyboard that has a simple command associated with it ultimately communicating with others for his/her needs. If the Quadriplegia is of type ‘severe’ (and the person is not brain dead), the communication becomes a challenge.

The scope of the work presented in this thesis is confined to a person suffering from Quadriplegia paralysis, with mild severity, where he/she has a healthy mind, complete control over the eye movements, and possesses some muscular activity in any one of the limbs to move it to a limited capacity.

The thesis provides a user-friendly and extremely convenient solution called EYECOM, specifically for paralyzed patients to operate. This system works with the help of eyeglasses which have infrared (IR) sensors for computer cursor clicking. Additionally it has an accelerometer that allows mouse cursor movements over the computer screen along x and y-axis. The system is developed using simple traditional eyeglasses which requires minimum movement of body parts that allows a paralyzed person to explore the world of technology through computers [17][18].

This thesis work is a contribution towards the practical and productive utility of the time of paralyzed people. It will not only allow them to use the system independently, but also provide them a better medium for the constructive use of their mental capabilities and effective time utilization.

1.6 Thesis Approach

The thesis details the EYECOM which has been synthesized as a prototype. Chapter 4 delineates the approach and working of the EYECOM. The EYECOM requires off-the-shelf electronic components for its operation. It allows a paralyzed person to use his eyes to control the mouse, navigate the computer screen and select or open computer applications with the eye blinking.

The EYECOM consists of two modules: (a) wearable module and (b) fixed module. The major components included in the wearable module are infrared module, Arduino Microcontroller, and Xbee wireless sensors. The infrared (IR) sensor is the combination of IR photodiodes and two IR light emitting diodes. The IR sensor is placed in front of the eye to illuminate the eye area. As a result of the illumination, the eye reflects the IR light which includes electrical signals. As eyelids close, the reflected light over the eye surface is disrupted, and the change enables EYECOM to perform the programmed instructions on behalf of the patient.

The Fixed Module consists of the Xbee wireless sensors (transmitter/receiver) and Arduino Leonardo microcontroller, which are responsible for receiving all inputs originating from the wearable module. The fixed module is attached to a computer such as a laptop or a desktop computer via a USB port. It controls the movement of the cursor and its related functions based on the inputs received from the wearable module. Once the signal is received by Arduino Leonardo, and IoT device, it is programmed to process the inputs and convert them into the conventional mouse signals of the computer.

Using EYECOM, paralyzed people can perform on-screen interaction with computing technology by moving their body parts and then selecting their desired files, folders or software applications. With EYECOM, having eye blinking mechanism, it is immensely convenient to interact with the selection procedure on the screen. For example, if the eye is blinked once then a single click option is performed. Similarly, if the hand/limb is moved slightly up and down then the cursor will also move accordingly.

This approach will assist disabled people to have numerous benefits such as:

- They will be able to accomplish their routine tasks, for example they can ask for basic needs such as water and so on by clicking on customized software applications.
- They can use it for creativity such as paintings, making movies, editing pictures and other useful activities.
- The patients can use it for academic and learning purposes by opening a book to read, scroll the web pages by movement of the accelerometer.
- It can be used for entertainment purpose e.g., turning on a tv, listening to music etc.

1.7 Organization of Thesis

The thesis is divided into six chapters. Chapter 2 describes the background of Amyotrophic Lateral Sclerosis (ALS) disease, human-computer interaction, and wearable technology. In Chapter 3, related work/research of different researchers is listed and contrasted. In chapter 4, EYECOM methodology, its workflow, pin description, and operational steps are detailed, while chapter 5 illustrates software section which provides information on the program logic and the software needed for the operation of EYECOM. Finally, Chapter 6 concludes the thesis, describes the limitation of EYECOM, and lists future work.

CHAPTER 2

BACKGROUND

This chapter highlights the rationale for providing the viable solution to paralyzed people who are determined to keep their life at the same pace as healthy human beings around them. This section of the thesis will illustrate human-computer interaction, ALS disease and the technology which is being utilized to complete EYECOM.

2.1 Background

The history of paralysis or more specifically Amyotrophic Lateral Sclerosis (ALS), goes far back to ancient Egypt [19]. Paralysis is a medical condition resulting in the immobility of specific body area either complete or one-sided which disrupts the standard functionality of the human body. This condition can cause fatality if caused by stroke, disease or accident. Furthermore, it can also be due to birth defect. Every year in the USA approximately 1.7 percent of the U.S. population or 5,357,970 people reported were living with some form of paralysis [20] whereas in other countries the count is 1.2 million [21] of people who suffer from this disease. This ailment directly affects the communication of body muscles and brain neurons deteriorating the physical movement in the affected area. It damages the nervous system and specifically the spinal cord which is responsible for the effective mechanical operation of the entire body.

Additionally, this condition can sometimes escalate from a small area and spread in the entire body, rendering it dormant. Consequently, the patient is completely bed ridden, immobilized and unable to even communicate verbally. In contrast, sometimes the ailment remains confined in a specific area by unknown causes and does not immerse the entire body in it. A few of the causes of paralysis and their influence over the human body are highlighted below:

- A spinal cord injury resulting from a severe stroke or accident is one of the typical causes of paralysis.
- Trauma can also lead to nervous system injury causing paralysis, spina bifida sclerosis, poliomyelitis Parkinson’s disease, multiple sclerosis and could be from Guillain-Barre syndrome [22].
- Another form of temporary paralysis is called waking paralysis that is often observed by people during rapid eye movement (REM) sleeping [23].
- Curare drug is also responsible for improper nervous system functioning and causes paralysis [24].

The thesis is based on an artificially intelligent innovation, where the computer follows the paralyzed person’s movements and works as a controlled device. The proposed solution is not just limited in identifying the paralysis victim movements but also in assisting them in using computers. Furthermore, this device can aid in earning a livelihood for themselves and their families which ultimately brings back their lost confidence and motivates them to become a part of the society by playing a valuable role in it. Reforming the human capabilities using technology, this invention will be truly valuable for letting the patient or disabled person control the computer with just their limb/head movements.

2.2 Human-Computer Interaction

Owing to increased dependency on technology and engineering transformations, today humans rely on such innovations when it comes to pragmatic complications and issues. To facilitate human requirements, sole technological grading and advancement is not enough; it is imperative that human efficiency is also increased with the increase of human-computer interaction. It has become the dominant domain of present due to increased focus towards automation process for all real-life aspects. The developments made in this field are specifically intended to bring out the ease and utility towards human-computer usage. Particularly human-computer domain is closely connected with the planning, designing, and implementation of a working model illustrating an effective patient experience with the computing machines. A healthy human being also faces several challenges when it comes to new technology, but people with disabilities face double the number of challenges in using such new technologies as compared to the former.

There are two categories of operations when it comes to human-computer interaction platform i.e., the machine side and the human side. Advancement in both sides is crucial for a proper human-computer interaction and keeping right balance between both, is the core motive of this platform. Not only the terms bound with the standardized human behaviors for the HCI mediums are required; it is also required for effective catering of varying behaviors and disabilities as well [25]**.** It is a wide domain that covers not only the linguistic variance with humans but also various norms and behaviors as well.

The core of HCI is mainly to develop the right communication channel across the system, to make it both understandable and beneficial for the humans.

2.3 Humanitarian Engineering

Humanitarian engineering is an application of engineering which develops new technologies for the benefit of mankind. It does not only include innovation but also involves science, technology, engineering and mathematics (STEM) education, advancing healthcare technologies and applied energy generation technologies.

From rudimentary stage, humanitarian engineering has been assisting in the solution of practical problems in the world e.g., maintenance of clean air, water, eradication of pollution, technological access for the disabled, disaster management, disease treatment and many more. Technologies like cloud computing, Internet of Things (IoT) and Artificial Intelligence (AI) have become part of daily life including healthcare, beauty as well as smart home automations. Therefore, it is very important to incorporate these technologies into the life of people with special needs or disabilities.

For several years, humanitarian engineering has pondered over aiding people with special needs through technological advancements. Using the process of automation, robotics can help in eliminating the immobilization of disabled people. Additionally, automation helps in reducing the complexities of using the new devices and technologies. The STEM education, advanced healthcare technologies, and the energy related applied technologies are few examples of automation.

2.3.1 Internet of Things

Internet of Things, abbreviated as IoT, is the concept of a large number of physical devices that are connected to the internet to share or collect the data. In figure 1, IoT technology transforms a simple device into a smart computing peripheral that functions to merge the digital and physical worlds of human beings. Controlling a device via network transforms it into an Internet of Thing object [26].

An example of this could be taken as of a light bulb, which is operated via mobile phone. It is turned into an IoT object when it transforms from the traditional button-based on/off mechanism to the mobile controlled on/off operations. These devices can range from a kid toy to a driverless vehicle; all depends on how well they are functioned to facilitate human needs [27].

Figure 1: Internet of Things
The figure illustrates the IoT devices.
https://www.inloox.com/company/blog/articles/the-importance-of-the-internet-of-things-iot-for-project-management/ [26]

The backbone operation of wearable computers is the sensors connected to it. Currently, IoT has been used in many devices which provide the patient a sense of independency even with paralysis. In other words, living with paralysis becomes much more convenient with such devices. These sensors used are largely facilitated with IoT technology and advanced gadgets allowing them to not only operate the objects near them or remotely but also allows them to function normally with other people [28]. Nevertheless, this technology, when utilized in implementing health care devices, is not only expensive but also available only in hospitals or clinics rendering them inaccessible.

2.3.2 Wearable Devices

Humans use wearables to assist them with their computing needs. The domain of wearable devices is very vast, and it can easily range from the ordinary wristwatch to smart mobile phones, glasses, headsets, etc., which humans use today. Wearables have numerous benefits e.g., Fitbit can measure a person's heart rate, active hours, sleep and other health factors. These devices are not only meant for healthy human beings but can also be customized for disabled humans. A completely immobilized person can communicate with his family as well as the whole world. These devices can reduce the social barrier between paralyzed people and healthy people exiting them from the outcast community. Wearable technology enables both mobility and handsfree device usage as well as eyes-free functionality for the patients [29].

Wearable device plays a prime role in the life of paralyzed people. It can also act as the human organ lost by the disabled persons. Moreover, it can function as an eye for a blind person, like an ear for a person with hearing disability, etc. Smart watches and wearables also contain security features. A disabled person, if lost can contact his/her emergency contact by pushing a simple notification button as well as informing services in case of critical situations. Future advancements in smart wearables would likely have many additional features e.g., remembering the way home, home security and intruder alert. In figure 2, it is shown that the wearable computer functions like a reciprocal medium between computers and machines [30].

Figure 2: Wearable Devices
The figure shows the wearable devices.
https://www.laptopmag.com/articles/the-time-for-wearable-computers-has-finally-arrived [30]

2.4 Amyotrophic Lateral Sclerosis (ALS) And Paralysis

Amyotrophic Lateral Sclerosis (ALS) or, as it is also known, Lou Gehrig's disease is a form of the neurodegenerative disease that is responsible for the destruction of the body's moving neurons. It reduces the functionality of the body, such as walking, talking, running, moving from one place to another. Because of this deadly disease, the paralysis spreads in the patient's body. Studies have been made to discover the actual reason for this severe ailment, but there is a need for more research on the organism that is responsible for this disease in the human body. A few of the biomedical effects such as aging and the family background of the patient are the influential factors over the happening of this disease. It can be a genetic disease as well. This disease is of a progressive nature, and it worsens the patient's condition day by day. The number of people suffering from this disease is exceeding, and the number of deaths increase nearly every year [31].

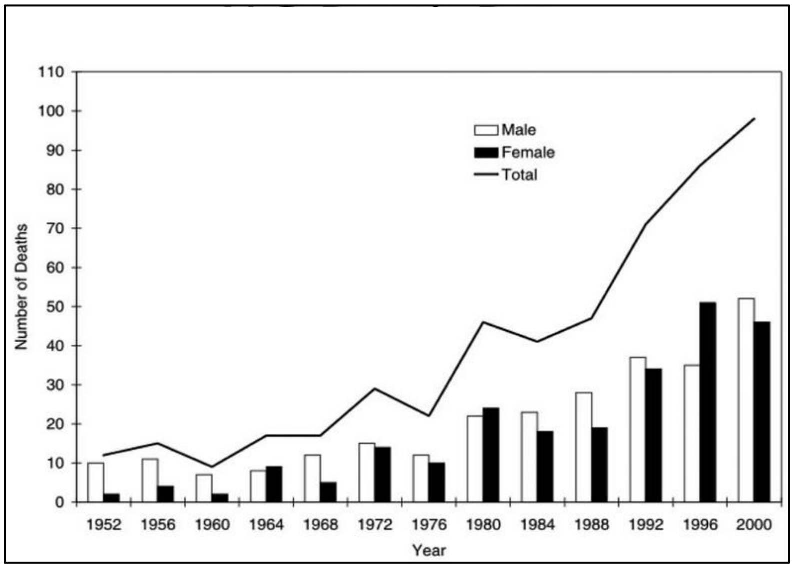

Figure 3: ALS Death Rate
The figure, showing the graph for no. of deaths due to ALS.
https://globalwarming-arclein.blogspot.com/2017/10/stumbled-upon-do-we-have-cure-for-lou.html [31]

In figure 3 [31], the graph indicates scaling death toll for the men and women who have been a victim of the ALS disease. It can be clearly observed that count for deaths is increasing every year.

The famous British physicist, Stephen Hawking, lived for five decades with ALS disease. It was an exception to the average cases where a victim's life was shrunk from 2 to 5 years' time span. So, on the brighter side, there are always exceptions when someone has the will to contribute positively to the society, no matter what disability life brings their way. The ailment is not fully curable, but the symptoms can be managed with the help of assistive wearable computing devices and smart computing technologies [32].

2.5 Background Summary

In conclusion, this thesis is based on providing a technological solution to patients who are diagnosed with ALS disease. Using this innovative and low-cost device, a patient can confidently spend his life by keeping his professional career, learning in different fields, and helping other people by using this wireless technology. This device is also user friendly as it uses wearable technology along with the moving sensor technology that helps in controlling the operations of the computer. Moreover, new technology helps in achieving a low-cost wireless solution so the patients can operate the computer from a flexible distance.

CHAPTER 3

RELATED WORK

There are several researches that have been done in helping paralyzed people, whether it was a movement-based controlling device for paralyzed people or voice recognition based electronic gadgets. For this thesis, we have explored both the ACM and IEEE explore digital libraries. Given below is the chapter that details the major research publications related to the work presented in the thesis. These publications are also summarized under the Table 5 in Appendix C.

3.1 Visual Attention Driven Networking with SMART Glasses

[Zhang Li, Huang, 2014]

This research has been made to implement the proof of concept for the communication system inside SMART glasses. In SMART glasses system, the glasses allow the paralyzed patient to express their interests with the help of eye gaze. Eye gaze is an attention driven suite of networking that allows the patient to convey their interests over screen through gazing. Capturing the patient's attention and targeting via low-resolution eye camera is the main motive of this work [33].

How this research relates to the thesis?

Both the research and the thesis are based on smart wearable computing devices that are specifically designed for low budget consumers. The research and thesis both target the patient's interest over the computer screen with the help of effective hardware and software systems. However, our proposed prototype has an additional advantage of portability, flexibility, and ease of use, i.e., with the help of wireless eyeglasses unit, the patient can use it flexibly in a standard size room.

3.2 Using Smart Glasses as Wearable Game Controller

[Wahl et al., 2015]

In this research, the author has provided a prototype of the wearable game controller for the paralyzed people.

This research is geared towards adding the entertainment factor of games and improve the potential ways that paralyzed people can enjoy playing video games. The famous game "Pacman" is made playable with the help of head movements. In this research prototype, authors have done detailed work on getting output from the head movements of the patients and it is closely related to our proposed solution. Authors have produced a prototype by using effective designing of hardware and sensors, associating with communication protocols that help patient to control moving directions in Pacman game. Heart rate information of the patient is also added as an enhancement to the prototype [34].

How this research relates to the thesis?

This proposed solution is the work done by Wahl et al. By converting traditional eyeglasses into a smart wearable computing gadget, Wahl's research has close resemblance to the prototype, proposed in our thesis. Wahl prototype allows users to make the on-screen movement in "to and fro," and "front and back" directions in the Pacman video game whereas our solution provides computer cursor movements along x-axis and y-axis on the computer screen. In our proposed thesis, patients can be able to use computer by using their hand movements, that has an accelerometer mounted on wrist or hand. The accelerometer mounted on hand or wrist helps in movements of the computer cursor which relates Wahl's research with our proposed prototype.

3.3 Hand Gesture Control Framework on Smart Glasses

[Hsiang Yu et al., 2015]

In this research, researchers developed a hand gesture control framework for tracking of hand movements done by the paralyzed people. With the help of programmed smart detection sensors, it detects the hand movements of paralyzed people, which can further be used in number of applications such as hand gesture controlled wheelchair, hand gesture controlled home automation systems and several other applications [35].

How this research relates to the thesis?

In this research, the researcher has developed a computing algorithm that has active sensors and camera to detect hand gestures for number of useful applications such as controlling wheelchair and home automation systems. Whereas, our proposed EYECOM prototype is also a wearable device that uses IR sensors mounted on the glasses for controlling computer cursor to operate different software applications. EYECOM also has an accelerometer which is attached to the hands/wrist of the paralyzed person for controlling directions of a computer cursor. The algorithm used for optimizing performance of EYECOM works on the same principle as utilized by author Hsiang in the "Hand Gesture Control Framework on Smart Glasses."

3.4 Affective Wear: Towards Recognizing Affect in Real Life

[Masai et al., 2015]

In this research, authors have developed the wearable prototype that detects different facial expressions. The prototype can be used to detect facial expressions that include neutral, angry, disgust, surprise, smile, sad and laughing expressions of the human face. With the help of developed “Facial Action Encoding” system, it gives an accuracy of detecting facial expressions up to 98.7% [36].

How this research relates to the thesis?

In this research, researchers bridged the gap between non-verbal gestures of human communication and technology. With the help of active sensors and facial recognition patterns it affectively recognizes the seven human facial expressions. The proposed EYECOM prototype is also based on detecting eye movements of the paralyzed patient and converting those movements to control a personal computer. Our proposed EYECOM prototype is using eye blinking for the purpose of computer mouse clicking, which is related to this research for communicating with the computer using facial expressions.

3.5 Hyperion-A Wearable Augmented Reality System for Text Extraction and Manipulation in the Air

[Chatzopoulos et al., 2017]

In this research, researchers have developed Hyperion, a wearable prototype, in which users are able to extract the text content from the ambient environment. Hyperion is based on Google Glass framework which can fetch the textual information in different environments such as driving, exploring, reading and meeting environments. Wearable Augmented Reality (WAR) system used in this research is supported by the Google Glass architecture. The proposed Hyperion solution enhances the patient’s ability to extract the textual information around them in different environments [37]. In our proposed EYECOM prototype, patient will be able to control the computer with the help of eye blinking and hand/wrist movements.

How this research relates to the thesis?

In this research, authors have developed a wearable augmented reality system that helps the patient to extract textual content from real-time environment around them. Our proposed EYECOM prototype allows paralyzed people to control the computer with the help of eye blinking and hand/wrist movements. EYECOM and hyperion both are correlated to each other as both are developed on the bases of Google Glass architecture.

3.6 Towards Wearable Cognitive Assistance

[Ha et al., 2014]

In this research, authors have developed a prototype for cognitive assistance in the real-time environment which includes Optical Character Recognition (OCR) and Object recognition. Researchers have also developed a wearable prototype based on Google Glass. This research is focused on providing assistance to the paralyzed patients for face recognition, object recognition, optical character recognition, and motion classification through accelerometer mounted on the body of the paralyzed person. Authors have also discussed about the limitations in this developed prototype which includes low battery life and network failures that can reduce the performance of the cognitive assistance [38].

How this research relates to the thesis?

In this research, authors have provided cognitive assistance to the paralyzed patients in object recognition such as can of Coke and text recognition from the real-time environment. The proposed EYECOM prototype aids paralyzed patients in controlling the computer with the help of eye blinking and hand/wrist movements. In our proposed EYECOM prototype, eye blinking mechanism performs the computer cursor clicking functionality and hand/wrist movements perform computer cursor operations in a specific direction.

3.7 Glass Gesture: Exploring Head Gesture Interface of SMART Glasses

[Yi et al., 2016]

The authors in this research have developed a prototype that is based on the authentication of the patients with the help of head gestures. This research has provided the enhancements in Google Glass by introducing gesture recognition for the patients. According to this research, authors have performed extensive experiments for gesture recognition that yielded above 95% accuracy. Moreover, authors have also measured 99% of accuracy for the authentication of unauthorized usage of Glass Gesture [39].

How this research relates to the thesis?

In this research, authors have developed an enhanced security feature of authentication for the users of Google Glass. Authors have also added head gesture control functionality in Google Glass wearable device. However, in our proposed EYECOM, we are providing human-computer interaction with the help of eye blinking and hand/wrist movements. Our prototype is focused on little to no body movements for making it easier for paralyzed patients to control their personal computer.

CHAPTER 4

METHODOLOGY

4.1 EYECOM Working — In a Nutshell

The section provides a high-level overview of the working of the EYECOM components and its features. The EYECOM requires off-the-shelf electronic components for its operations. The EYECOM allows a paralyzed person to use his eyes to control a computer mouse, navigate the computer screen and select or open an application with the help of an eye blink.

The EYECOM consists of two modules: (a) wearable module and (b) fixed module as shown in figure 4. The major components include a wearable module in which there are infrared modules, Arduino microcontroller, and Xbee wireless sensors [40]. The infrared (IR) module is the combination of IR photodiodes and two IR light emitting diodes which are the heartbeat of the system [41]. The IR sensor is placed in front of the eyes to illuminate the eye area. As a result of the illumination, the eyes reflect the IR light, which includes electrical signals. As eyelids close, the reflected light over all the eye surface is disrupted and the change of signals enables EYECOM to perform the programmed instructions on behalf of the paralyzed person. In simple words, the main function of the IR module is to convert the emitted light into digital signals so that the input, i.e., the eye blink, can be recorded in the digital memory. To make the IR module robust and to prevent noises in the recorded signals, signal filters are used in photodiodes. Filter helps to skip the modulation process and give more protection from normal and room light. Further, the electrical signals are amplified and transferred to the microcontroller, where Arduino compares it with the inputs from the accelerometer to perform the programmed tasks.

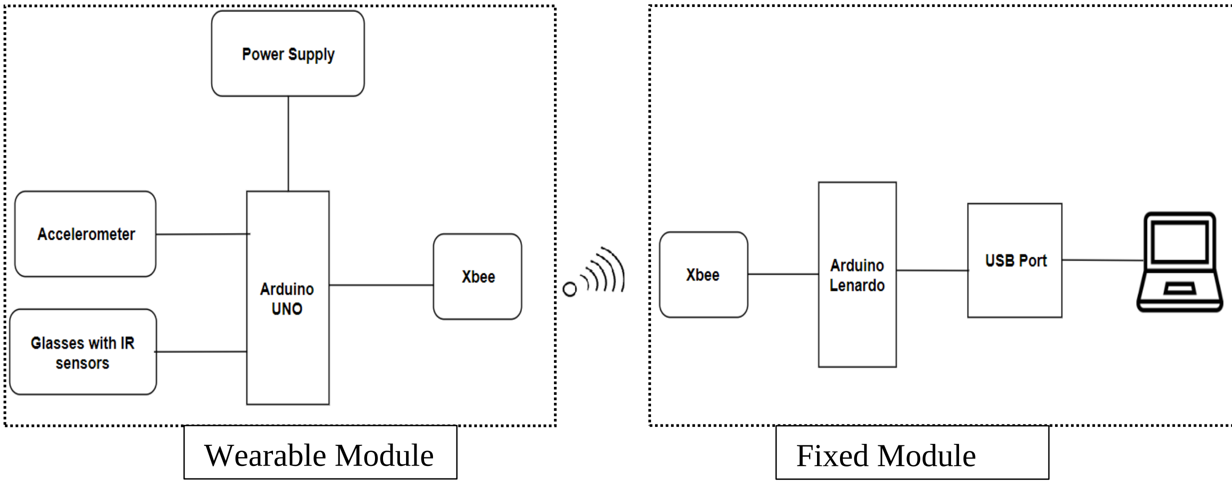

Figure 4: EYECOM
This figure illustrates the block diagram of wearable module and fixed module of EYECOM.

Another essential part of the EYECOM is to enable cursor movements on the computer screen. For this purpose, a device named "accelerometer" is used. The accelerometer is a small device equal to the size of phalanges or a human thumb. This device operates on the principle of two-dimensional motion sensing [42]. In case of EYECOM, the accelerometer acts as an input device which collects the signals from the hand/wrist motion and then compares those signals to the signals generated by cursor movements. Once the accelerometer records the signals, then the signals are forwarded to the Arduino UNO microcontroller. The Arduino microcontroller is programmed to process the inputs from the IR sensors and the accelerometer. The microcontroller is responsible for managing the inputs and then transmitting via the transmission (Tx) port through the Xbee wireless radio (transmitter).

The fixed module consists of the Xbee wireless radio (receiver) and an Arduino Leonardo microcontroller, which are responsible for receiving all the inputs coming from the wearable module. The fixed module is attached to a computer, such as laptop or a desktop computer, via USB port. It controls the movement of the cursor and associated operations based on the inputs received from the wearable module. Once Arduino Leonardo receives the signal, it is programmed to process the inputs and convert them into the traditional mouse system of the computer.

After this process, the patient can interact with the computer via movement of the mouse cursor. Patients can also use the keyboard feature of the computer with the help of on-screen keyboard software. The below sections provide the control flow of the EYECOM, as well as provide detailed information on the modules.

4.2 Operation Flow of EYECOM

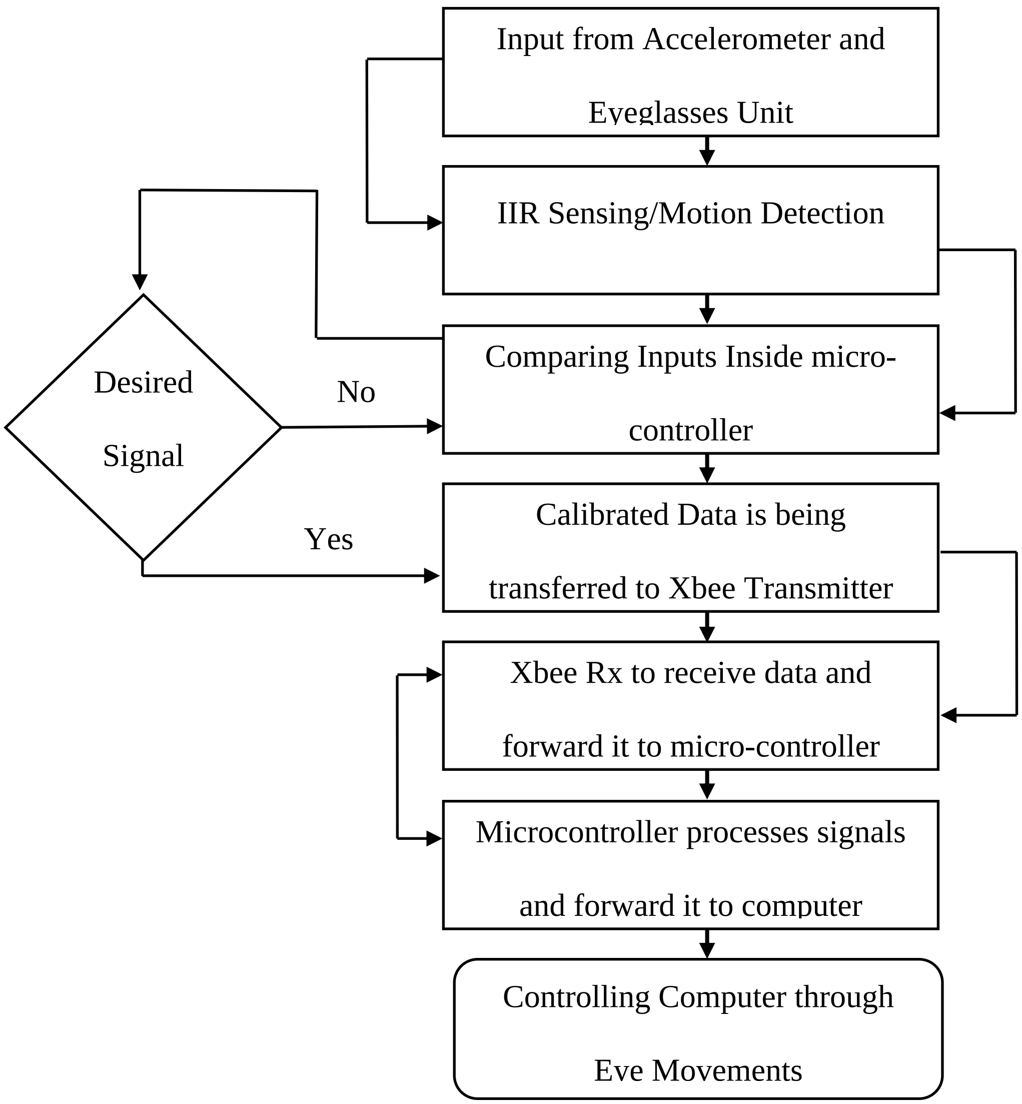

Figure 5: Operation of Cycle
This figure describes the operational flow of EYECOM.

In figure 5, operational flow of EYECOM is being illustrated, beginning with the initialization of the inputs, to the controlling of the computer (i.e., mouse movements on the screen). The operational life cycle begins with input coming from the IR sensors and the accelerometer in the form of digital signals. Depending upon the patient, the accelerometer can be placed on the wrist or held in hand. As a next step, these signals are transferred to the microcontroller. If the accelerometer detects any movement in the form of digital signals, then it provides this input value to the Arduino UNO R3 microcontroller. The UNO R3 compares different types of inputs from EYECOM and passes these input signals to the Xbee wireless transmitter module to transmit input signals to the microcontroller installed in the fixed model. The Xbee transmitter in the wearable module amplifies the signal and removes the noises before sending the data to the Xbee. Thus, the strong signals are received by the Arduino Leonardo which is attached to a computer via Xbee receiver. The Arduino Leonardo communicates using computer mouse protocol and enables the movement of a cursor on the computer screen based on the strong digital signals, received as an input from the wearable module.

4.3 Block Diagram of the EYECOM

This section provides details on the working of the wireless module of EYECOM. In this module, the Xbee interface is used to communicate between the wireless module and the fixed module i.e., attached to the computer. In the block diagram of EYECOM, the accelerometer can be attached to any body part that can initiate movement (i.e., head, arm, wrist, leg, and feet) and where the patient feels comfortable to wear it. This accelerometer is responsible for recording the movements in the digital form so that Arduino UNO microcontroller will process it.

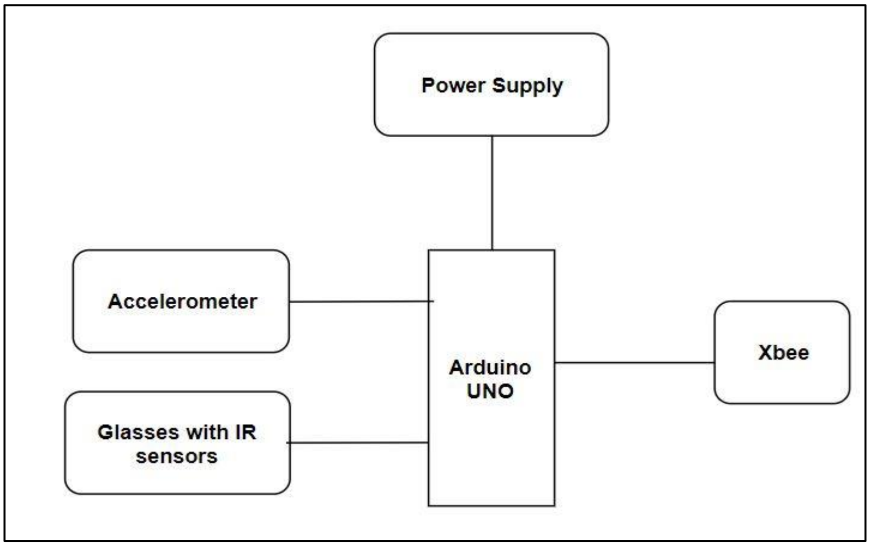

Figure 6: Block Diagram of Wearable Module
This figure shows the block diagram of wearable module.

Figure 6 shows the block diagram of the wearable module having an IR module attached. This wearable module is responsible for receiving input signals coming from the human eye and then transmitting those input signals to Arduino UNO microcontroller for processing and comparing with the input signals from accelerometer. In this comparison process, the wearable module with IR sensors perform the operations related to the computer's "Cursor Clicking." The paralyzed individual will use this "clicking" for selecting any on-screen software applications i.e., any object on the screen of a computer by using his/her eyes.

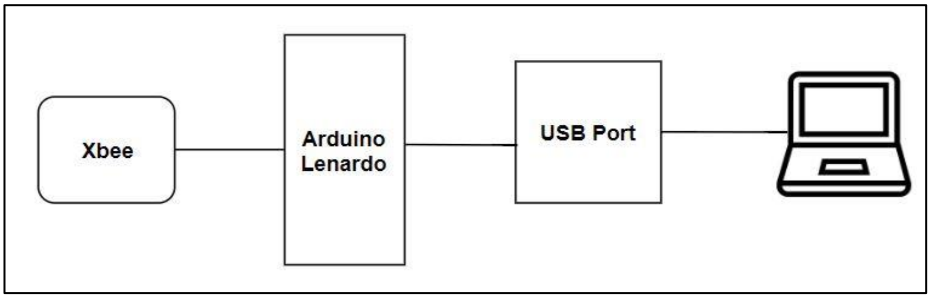

Figure 7: Fixed Module (Computer Interface Section)
This figure illustrates the block diagram of fixed module.

In figure 7, the high-level block diagram of the ‘fixed module’ is being shown. The module is called ‘Fixed module’ because the unit is stationary and is directly connected to a computer via a USB port. In this module, the Xbee wireless module acts as a receiver and receives the signal from the transmitter i.e., Xbee wireless module of the wearable module. Then the wireless module transfers the signals to the attached Arduino Leonardo microcontroller. Afterward, microcontroller transfers the signals from serial port to the USB port and then forwards it to the laptop or PC. The fixed module has been programmed with the traditional mouse operations. The programmed operations allow the module to move the cursor along x-axis and y-axis. Both the wearable and fixed module have an Xbee wireless transmitter/receiver module connected to them. Therefore it helps to make EYECOM a wireless wearable device.

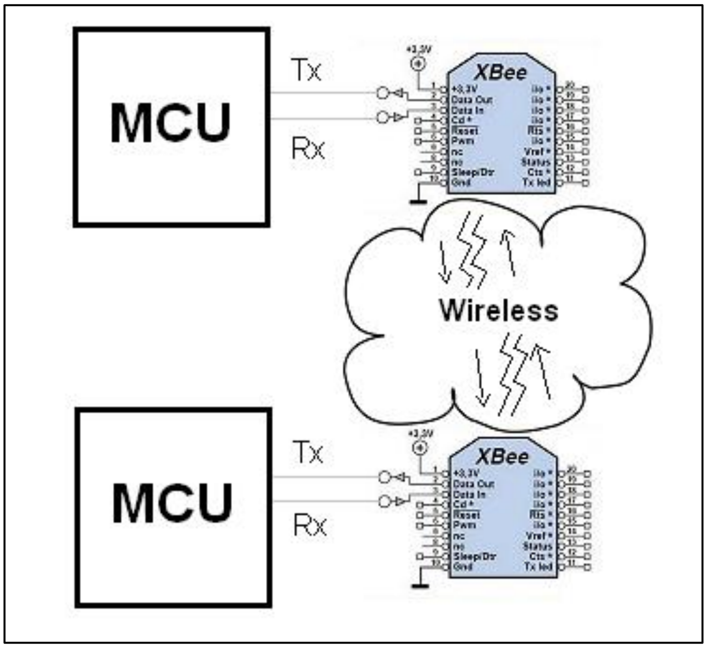

Figure 8: Xbee Transmitter and Receiver Modules
This figure shows the transmitter and receiver side of Xbee.
http://www.pyroelectro.com/tutorials/xbee_wireless_interface/theory.html [43]

Figure 8 [43], shows the typical wireless communication occuring between Xbee transceivers (i.e., transmitter and receiver) for EYECOM. In the wearable module of the EYECOM, Microcontroller Unit (MCU) is programmed to control the signals that are being transmitted over Xbee transmitter. On the fixed module of the EYECOM, the Xbee receiver, receives wireless signals and then forwards it to Microcontroller Unit (MCU) to perform further actions. To use wearable module more conveniently for the paralyzed person, the range between the wearable module and fixed module can be set up to 10 meters as a default range defined by IEEE 802.15.4 technical standards [43].

4.4 Eye Blink Detector Circuit

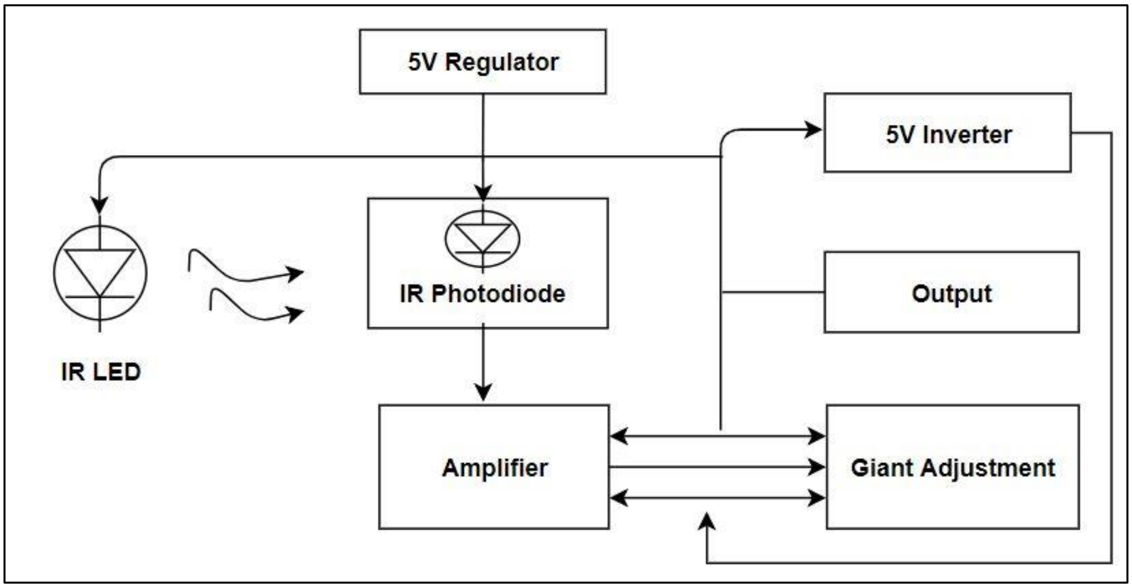

Figure 9: Detailed Circuit Diagram
This figure illustrates the circuit diagram of eye blink detector.

IR sensors have a large capacity to eradicate all environmental and surrounded noise using high amounts of frequency and pulse of IR light. In figure 9, the eye blink detector circuit is shown for the EYECOM. The IR sensors emit radiations which are not detectable through the naked eye. The emission of the light is being done by IR LED, and the receiving of the emitted light is done by IR photodiode. IR photodiode can detect the light of the same wavelength that is being emitted by IR LED. Once the light from IR LED is received by IR photodiode after reflecting through some surface, it results in the change of resistance and the output voltage. This mechanism helps in detecting the eye blinking system. In eye blink detector circuit, IR LED emits the light, which is reflected by the eyeball surface, falls on the IR photodiode and changes the output voltage. The change of output voltage is detected in the UNO R3 microcontroller as the eye blinking occurs. During this process, some unwanted noises, such as room light, can also create some problem for light emissions from IR LED. Therefore, amplifier is being used to strengthen the IR LED light to overcome the signal noises. The whole IR sensing mechanism plays a vital role in EYECOM by providing computer mouse clicking functionality.

4.5 Working Principle of Wearable Module EYECOM

The IR light emitting diodes are used to detect the signals coming from the eyes. The IR LEDs are installed inside the glasses which cover the illuminated eye surface. The IR sensor has an IR LED and a photodiode, which operates at a working distance from the leading edge of the plastic jacket. Figure 10 shows an IR LED sensor in a wearable module mounted on the glasses.

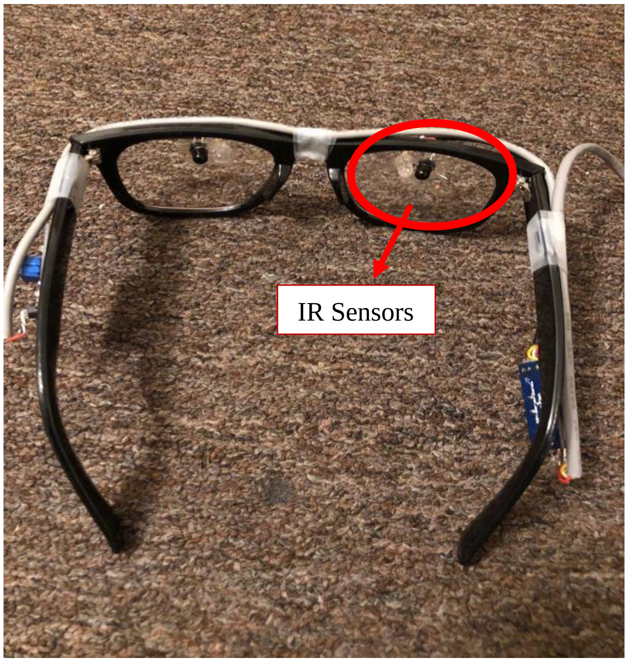

Figure 10: Eye Blinking System Prototype
The figure illustrates the wearable module which is glasses with IR sensors.

The IR LED consists of OPB704, which has an IR transmitter and IR receiver inside the black plastic jacket [44]. The IR LED which is used inside OPB704 is called OSRAM SFH4852.

The cable which connects a sensor to detector circuits is about 1.5m thin and shielded. To improve the current flow capacity of the IR light emitting diode to produce good signals, the project used amplifier, to amplify the signals along with a photodiode and a four-core cable for the light emitting diode which includes two cables for each pair of light emitting diode (LED), one for 'anode' and other for a 'cathode.'

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) confirmed that exposure to the radiation intensity never caused for any significant health risks such as skin cancer. As per guidelines on exposure limitations of IR radiations published by International Commission on Non-Ionizing Radiation Protection (ICNIRP), the sensor radiation's intensity has no effects to eyes below the defined limits. Silicon photodiode (light to current conversion) phenomenon states that 17 mm distance is enough to cover a normal eye surface by IR Sensors [45].

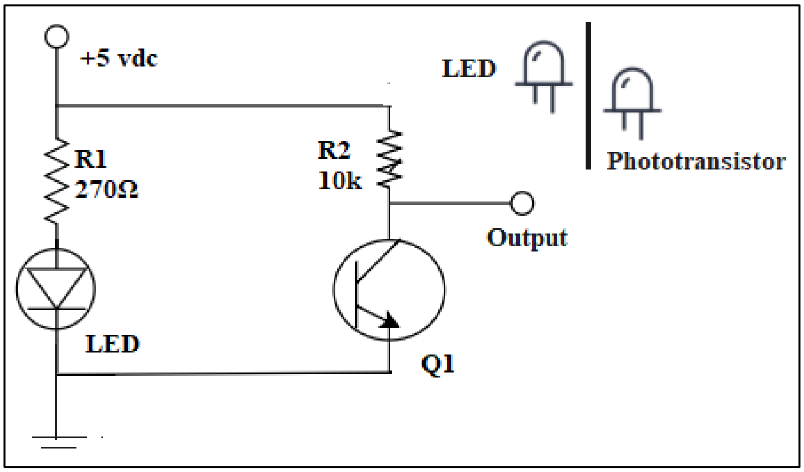

Figure 11: IR Eye Blinking Mechanism
The figure shows the detailed flow of current in eye blinking circuit.

Figure 11 shows the detailed current flow in the eye blinking circuit. The circuit uses the following mechanisms to ensure robust input signals:

i. Modulation (variation analyzation) by IR sensor [46].

ii. To make sure the deep contact of field sensors for eye surface reflections, these sensors are placed at the minimum distance of 4mm from the eye. At such distance, the sensors can illuminate the targeted area of the eye [47].

In the above mechanism, the infrared LED (a) emits the invisible light which is being detected by the IR photodiode and (b) transforms the received light into the electrical signals.

4.6 Electrical Components

4.6.1 Xbee Wireless Module

Nowadays, wireless technology is becoming more affordable and has high data transfer rates. Nevertheless, there had been a need for wireless technology that consumes less power, more affordable, and more efficient. Thus, an innovative WPAN 802.15.4 was developed, and it is also known as Xbee [48]. Xbee's name is stimulated by the communication pattern of a bee. When a bee finds a new food source, it communicates with other bees in zigzag waggle movements. Xbee's unique name implies the dancing movement of a bee.

It is designed as a standard for a set of protocols that assists in information sharing with lower data rate and good range with less power consumption. In the standard design, wireless devices work on the frequency of 868 MHz, 915 MHz, and 2.4 GHz bands to operate [49]. The higher data rate is 250 K bits per second that Xbee modules can support. Affordability, efficiency, and long battery life are the core requirements of Xbee. It also has a sleep mode feature which means it stays in the active mode once it is transmitting data, and when it is not sending data, it goes to sleep mode. This is the common principle that other technical devices also use for consuming less power and communicating only when there is a requirement. Sleep mode avoids battery consumption, which makes Xbee last for longer time.

The standard Xbee wireless sensor is an inexpensive wireless solution that works with the Industrial, scientific and medical (ISM) radio band [50]. It can also operate automated and remote-controlled applications. Xbee supports the binary phase shift keying (BPSK) modulation scheme that can transmit data in extremely low power consumption.

Table 1: Characteristics of Xbee
The table shows the characteristics of Xbee.
https://link.springer.com/book/10.1007/978-3-030-32523-7 [51]

Frequency Band(MHz)	868.3	902-928	2400-2483.5
Bandwidth	600	200	5000
Data rate (kbps)	20	40	250
Symbol rate (kbps)	20	40	62.5
Area of use	Europe	USA	World Wide
Frequency Stability	40ppm	40ppm	40ppm
No. of Channels	1	10	16

Table 1 lists the characteristics of Xbee. The frequency band used in the thesis is 868.3 Mhz. It is because the Xbee Series 1 Module operates on the frequency of 868.3 MHz [51]. Figure 12 [52], shows the Xbee module (hardware) which is used in the construction of EYECOM.

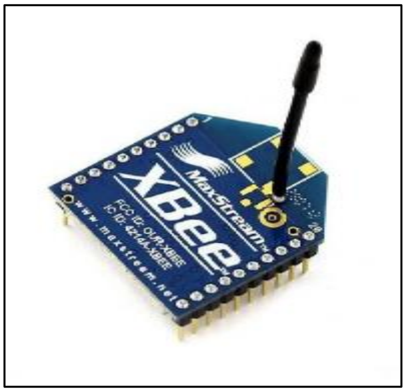

Figure 12: Xbee Module
The figure shows the Xbee module.
https://home.roboticlab.eu/en/examples/communication/zigbee [52]

The following technical constructs are kept under consideration before implementation of the Xbee wireless module:

- VCC, GND, DIN, DOUT, RTS, and DTR are the minimum connections needed to update the firmware.
- The signal direction is specified concerning the module.
- The module includes a 50k Ω pull-up resistor attached to reset.
- Several of the input pins can be configured using the PR command.
- Unused pins should be left disconnected.

Figure 13 [53], is the schematic diagram that shows the basic connections of the Xbee module. Pin configuration of Xbee is shown in table 2 [54].

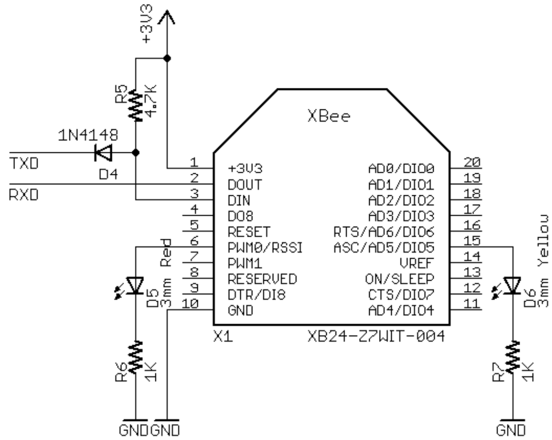

Figure 13: Schematic Diagram of Xbee Module
The figure shows the schematic diagram of Xbee.
https://ieeexplore.ieee.org/document/5944230 [53]

Table 2: Pin Configuration of Xbee
The table shows all the pins and their description.
https://www.digi.com/resources/documentation/digidocs/pdfs/90000982.pdf [54]

Pin #	Name	Direction	Description
1	VCC/VDD	-	Power Supply
2	DOUT	Output	UART DATA Out
3	DIN/Config	Input	UART DATA In
4	DO8	Output	Digital Output 8
5	RESET	Input	Module Reset
6	PWMO/ RSSI	Output	RX Signal Indicator
7	PWM1	Output	PWM Output 1
8	Reserved	-	Do Not Connect
9	DI8	Input	Digital Input 8
10	GND	-	Ground
11	AD4/DIO4	Either	Analog Input 4 or Digital I/O 4
12	DIO7	Either	Digital I/O 7
13	ON	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	AD5 / DIO 5	Either	Analog Input 5 or Digital I/O 5
16	AD6 / DIO 6	Either	Analog Input 6 or Digital I/O 6
17	AD3/ DIO 3	Either	Analog Input 3 or Digital I/O 3
18	AD2/ DIO 2	Either	Analog Input 2 or Digital I/O 2
19	AD1/ DIO 1	Either	Analog Input 1 or Digital I/O 1

4.6.2 ADXL335 Accelerometer

The EYECOM prototype used the ADXL335 accelerometer to detect the movements of the cursor. The ADXL335 accelerometer works on the bases of micro-electro-mechanical (MEMS) system. Such systems are based on the silicon wafers. The accelerometer contains polysilicon springs which play their role in moving in all possible directions. These changes in the direction form a capacitance in the plates attached to the structure inside the ADXL335. The capacitance is then transmitted as voltage, with respect to the acceleration to the specific direction, where it deflected. ADXL335 can be used in three axis rotation, but in the EYECOM only two directional axes, i.e. x-axis and y-axis, are being used so that it will be easy for usage [55].

Some of the common application areas of the accelerometer are:

- Used for mobile/cell phones.
- Medical treatment equipment.
- Input interfaces for different gaming gadgets.
- Industrial instrumentation/tools/machines.
- Hard drive/external storage.

4.6.3 Pin Configurations and Functional Description of ADXL

Figure 14 [56], shows the schematic diagram of ADXL335, and in table 3 [57], its pin description is being shown.

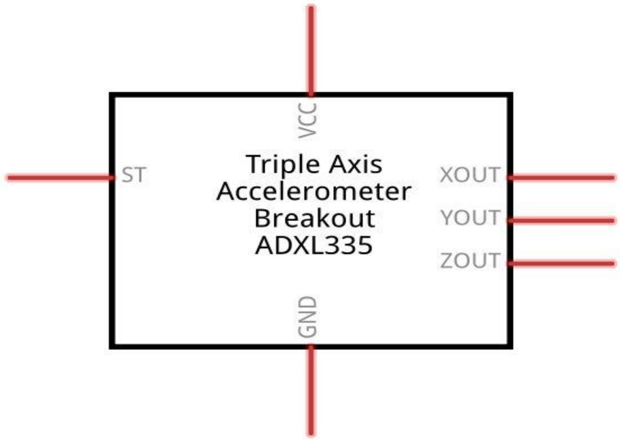

Figure 14: Schematic Diagram of ADXL 335
The figure shows the schematic diagram of Accelerometer.
https://www.geeetech.com/wiki/index.php/ADXL335_Triple_Axis_Accelerometer_Breakout [56]

Table 3: Pin Configuration of Accelerometer
The table describes all the pins, mnemonic and descriptions.
https://www.rhydolabz.com/wiki/?p=1417 [57]

Pin #	Mnemonic	Description
1	NC	No Connect
2	ST	Self -Test
3	COM	Common
4	NC	No Connect
5	COM	Common
6	COM	Common
7	COM	Common
8	Z_{OUT}	Z Channel Output
9	NC	No Connect
10	Y_{OUT}	Y Channel Output
11	NC	No Connect
12	XOUT	X Channel Output
13	NC	No Connect
14	V_S	Supply Voltage (1.8 V to 3.6 V)
15	V_S	Supply Voltage (1.8 V to 3.6 V)
16	NC	No Connect

4.6.4 Integrating with Arduino Microcontroller

Integration of the accelerometer is one of the essential parts of EYECOM. The hardware module of the accelerometer (ADXL335), needs to communicate to the Arduino interface board via specific ports. Therefore table 4 represents the configuration of the Arduino pins that are required to be connected with the accelerometer pin accordingly.

Table 4: Interfacing Pin with Arduino
The table shows the Arduino pin connections with ADXL.

Arduino Pin	ADXL345 Pin
10	CS
11	SAD
12	SDO
13	SCL
3V3	VCC
GND	GND

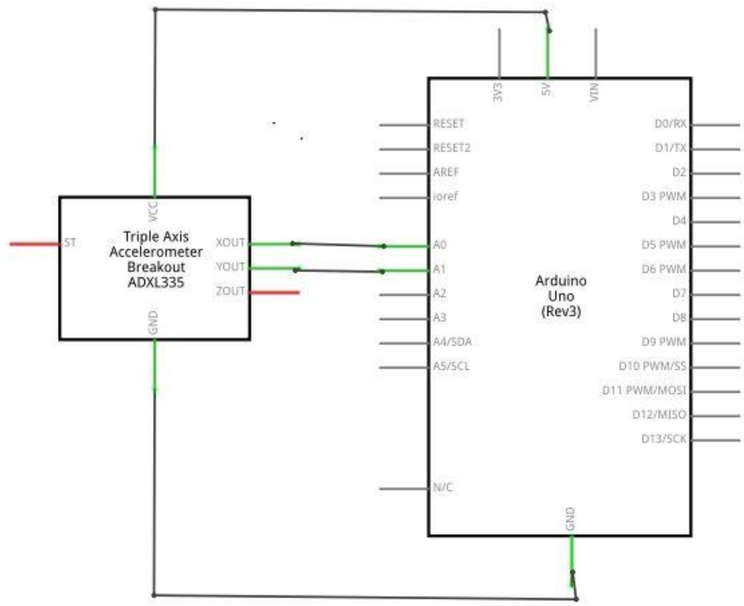

Figure 15: Connections with Arduino
The figure shows the connections of Arduino Uno with Accelerometer.
https://microcontrollerslab.com/adxl-335-accelerometer-interfacing/ [58]

The connection between pins of the Arduino and the accelerometer is observed from figure 15 [58]. The connected pins are responsible for transferring the signals inside the circuit without having noises in between the Arduino and the accelerometer. The pin configuration is significant for the correct operation of the circuit, because, if pin configuration is wrong then the signal from accelerometer will not be relayed to the Arduino UNO for further processing.

4.6 Operational Steps of EYECOM

Using the EYECOM prototype, the patient needs to perform the following steps to control the screen cursor to interact with the computer applications.

- First, the patient will wear the wearable module of EYECOM, mounted on the glasses.
- Next, the patient will mount accelerometer to the hand/limb. The patient will also calibrate the motion of the mouse cursor according to the ease of use.

- The calibration will enable patient in moving cursor according to his/her capability of rotating his body part.
- In a further step, the fixed module of EYECOM will transfer inputs coming from a wearable module of EYECOM to the computer via USB port.
- In the next step, the communication between two modules (wearable, fixed) is initiated, and EYECOM becomes ready to use by the patient. The blinking LEDs on the fixed module and the wearable module of EYECOM confirm that the modules are talking to each other.
- Further, the patient will move the hand/limb having an accelerometer mounted on it. By moving the accelerometer, it will enable the movement of a cursor on the computer screen. The operational model of the accelerometer works in a way that when a patient tilts the accelerometer downwards, then the cursor of the mouse also moves downwards on the screen of the computer. Similarly, if the patient tilts the accelerometer upwards, the mouse cursor correspondingly moves towards the upwards direction of the computer screen. Similar movements will happen for right and left directions.
- Next, the patient can click on any icon or folder on the computer screen, by blinking the left eye one time. The left eyeblink enables opening the folder on the computer screen for the user.
- Furthermore, the patient can operate the on-screen keyboard as well. On screen keyboard is operated by using cursor movements and mouse clicks.

All the above steps enable a patient to interact with computer using EYECOM and become part of the digital society.

CHAPTER 5

SOFTWARE MODULE

This section of thesis details the software modules (i.e., Integrated Development Environment (IDE), programming language and software libraries) that are required to control the hardware listed in chapter 4 and enable their smooth and cohort execution to attain the functionalities of EYECOM.

5.1 Arduino Software

The arduino software is a cross-platform and runs on Windows or Linux operating systems. It is based on processing programming languages, Avr-Gcc, and other open source software. Arduino IDE stands for "Integrated Development Environment." IDE can compile and upload codes to the Arduino board via USB port. The IDE is designed to introduce the patients with programming who are unfamiliar with the software development. It includes a code editor, automatic indentation, API lookup capable of compiling and uploading programs to the board with one click [59].

Arduino IDE comes with a C/C++ library called 'wiring' which makes input and output operations easy. Programs are written in C/C++. Code written in Arduino is translated into C language, passes onto the Avr-Gcc compiler that makes the translation into the language understood by the microcontroller. Patient has to define two functions to make an executable program [60].

- Setup() – Called once in the start of the program, used to initialize the variables.
- Loop() – Used for the repetition.

5.2 Starting Software

When Arduino IDE starts working, a working window like figure 16, appears on the screen with five drop-down menus i.e., file, edit, sketch, tools, and help which is used for specific functions.

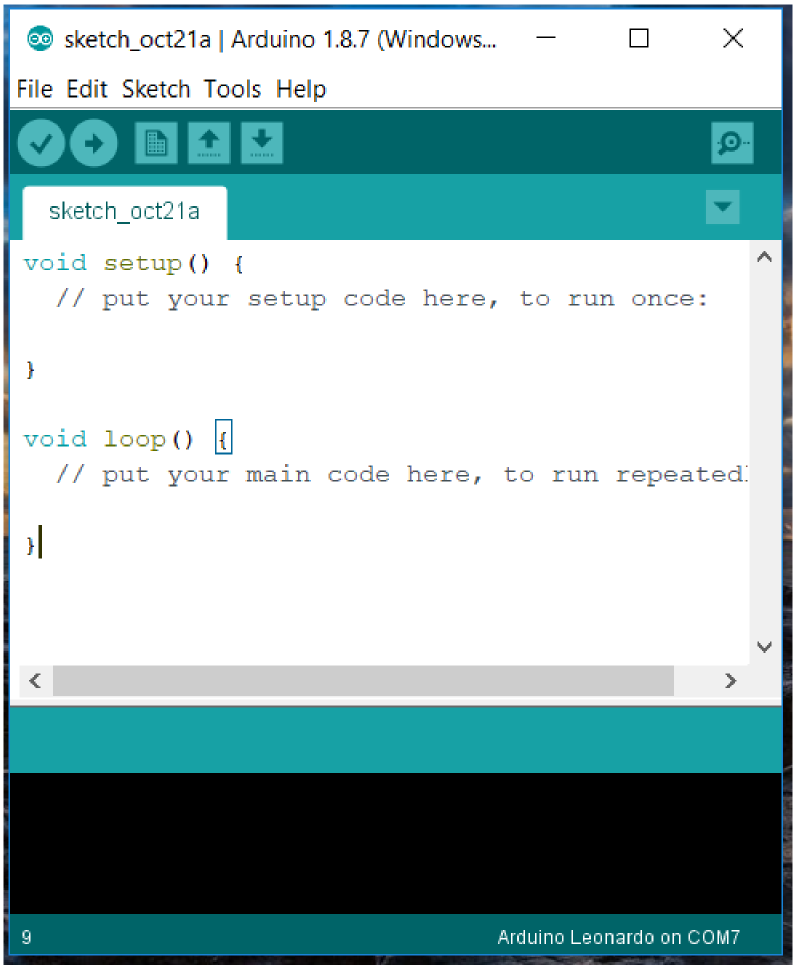

Figure 16: IDE Application
The figure shows the front end of the application.

For programming on the Arduino microcontrollers, there is a need to select the specific type of Arduino microcontroller such as Arduino Leonardo or Arduino UNO R3 under the Tools tab in the Arduino software. Besides this, whenever the board is chosen, the port is also needed to be selected, as shown in figure 17.

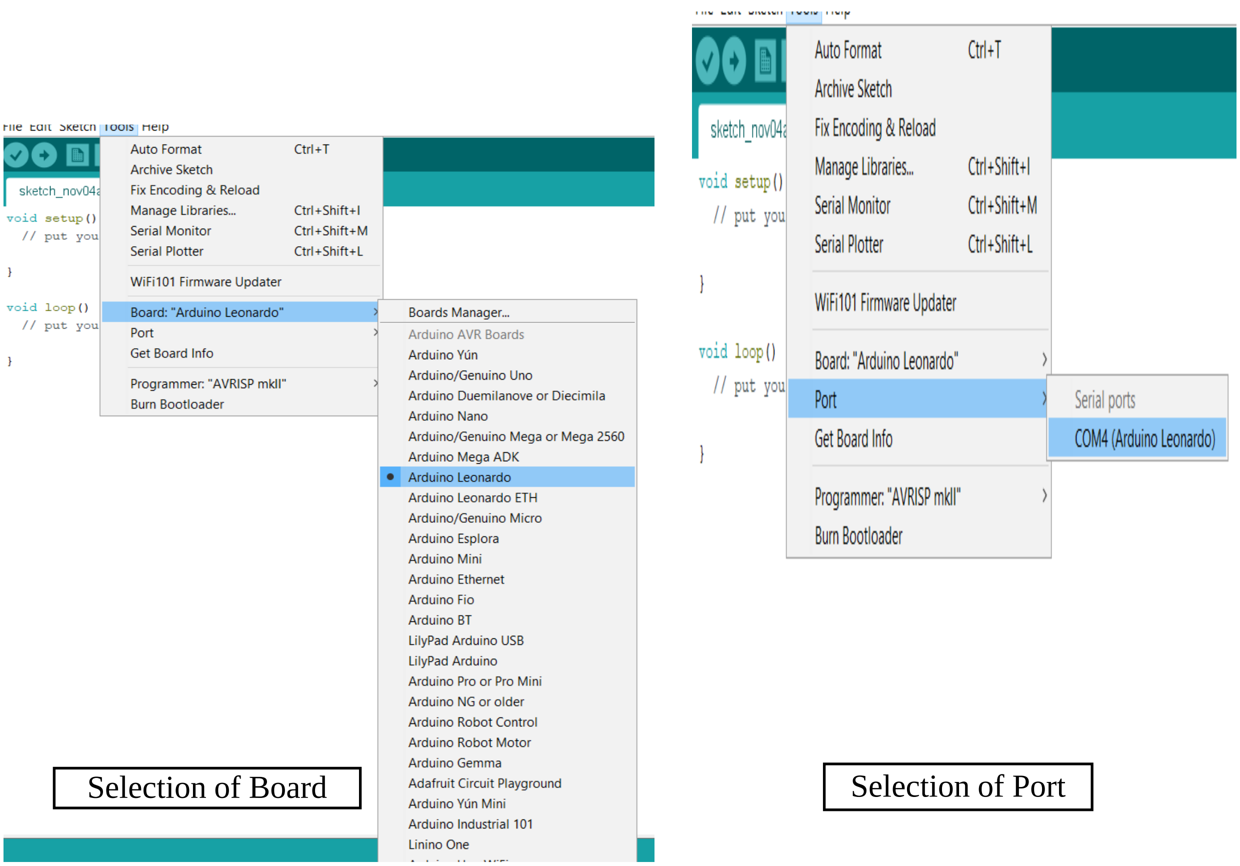

Figure 17: Arduino Board
The figure shows how to select the board and associated port.

Next step is to verify and upload the code on the microcontroller as shown in figure 18.

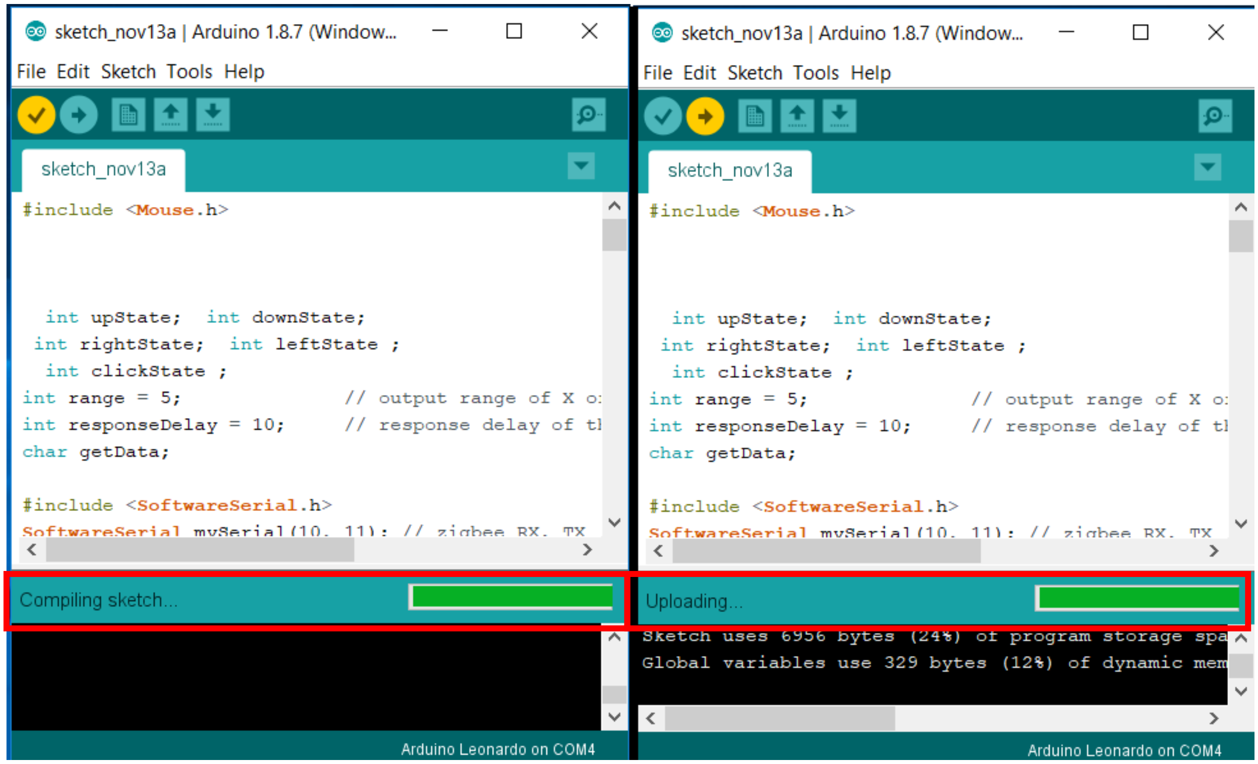

Figure 18: Compiling & Uploading
The figure shows that code is compiling and uploading on the board.

5.3 Test Runs

For the optimized performance of EYECOM, various test runs have been performed. The test runs have been made on XCTU software which is a multi-platform application and graphical network viewer of the network. Following are the test runs of EYECOM after implementations of the code on the Arduino microcontrollers. Initially, Xbee is calibrated and checked the results for sending and receiving data via Xbee wireless modules. One Xbee module acts as a sender and other acts as a receiver. Xbee module, which is acting as a transmitter, transmits the initial request for connection establishment. Once the connection is established, the message will be written which is sent towards the receiver. On the other end, Xbee module on the receiving end will receive signals from Xbee transmitter and shows the results in the RF data window.

In the other test runs, software stubbing is being performed for the movement of mouse cursor by the help of Arduino and accelerometer. The test runs have resulted in the expected outcomes of EYECOM operation, which in turn proved that EYECOM has an advantage over other similar products in the industry.

5.4 Visualization of Test Runs

5.4.1 Xbee Transmitter

In this visualization section, Xbee communication is shown, where Xbee is acting as a transmitter and transmitting the data. In the first window of figure 19, Xbee transmitter is initiating the request for the communication. In the second window of figure 20, transmission message is shown which is requested to send to Xbee receiver.

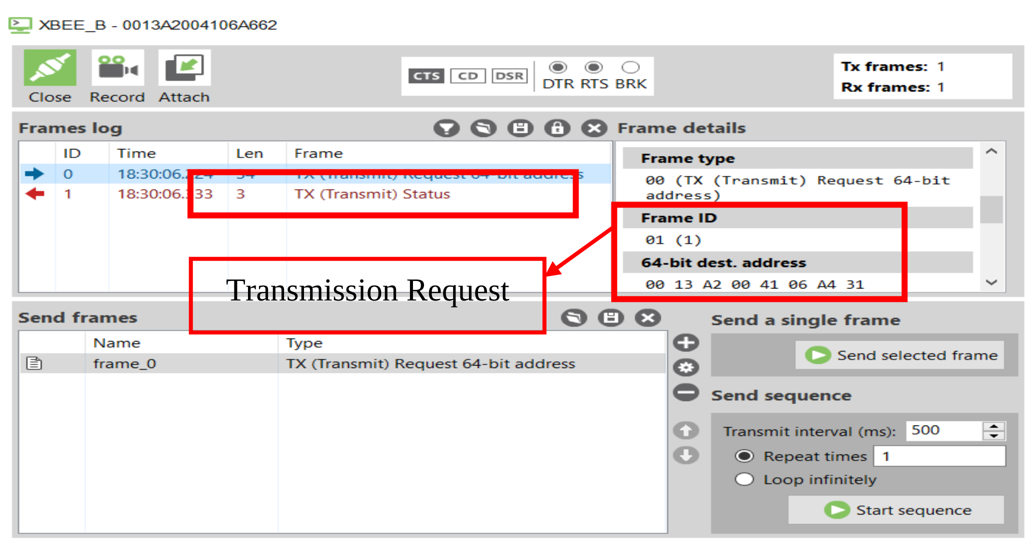

Figure 19: Xbee Transmit Request
The figure shows the transmission request is initiated.

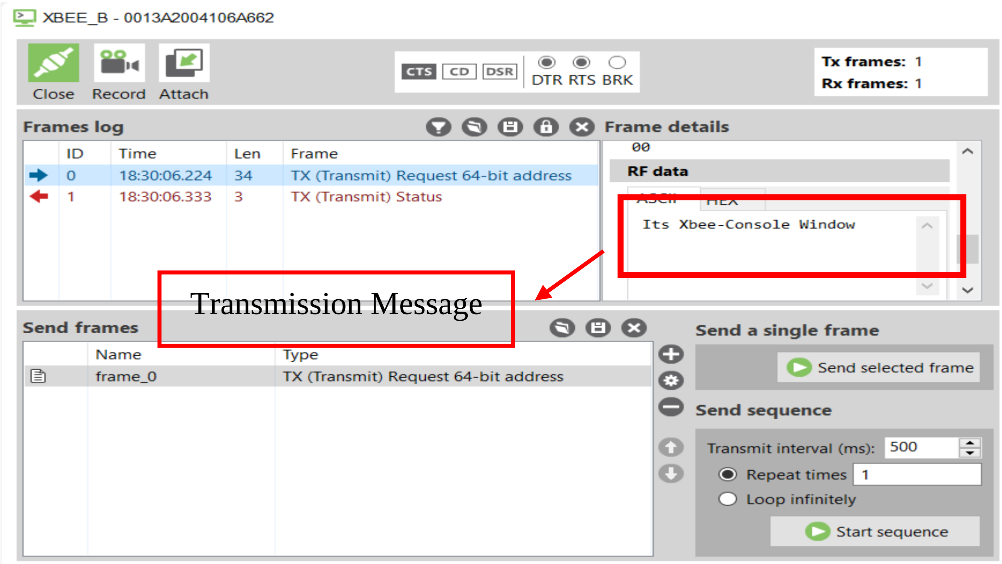

Figure 20: Xbee Transmitter Message
The figure shows transmission message, which is received.

Figure 21 shows that transmission status is successful, which means data is successfully transferred to the Xbee transceiver. This request for data transfer is depicting that the communication has been established, and both the Xbee transmitter and receiver modules are synchronized with each other.

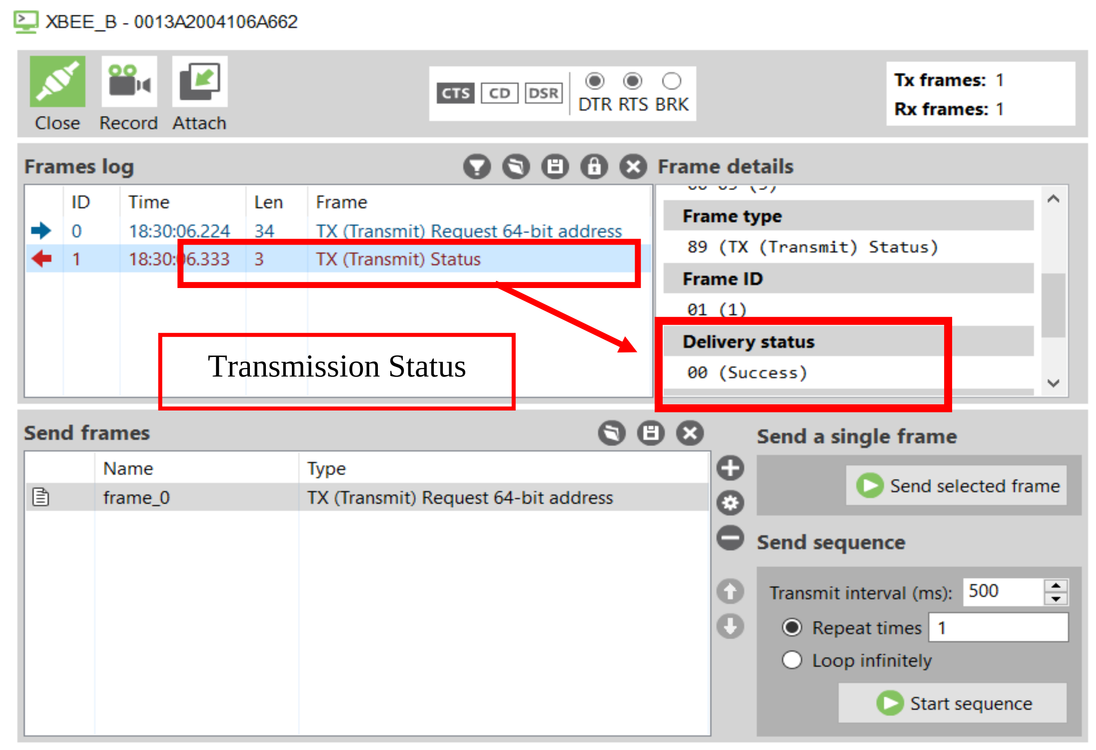

Figure 21: Xbee Transmit Status
The figure shows the transmitter status, which is successful.

5.4.2 Xbee Receiver

Figure 22 is showing the receiving status of Xbee module, and in the next figure 23, received data is being shown. In the figure 22, Xbee receiver is showing that it receives the signals coming from the Xbee transmitter and the connection is established. In figure 23, Xbee receiver is indicating that the message is being received with no data loss.

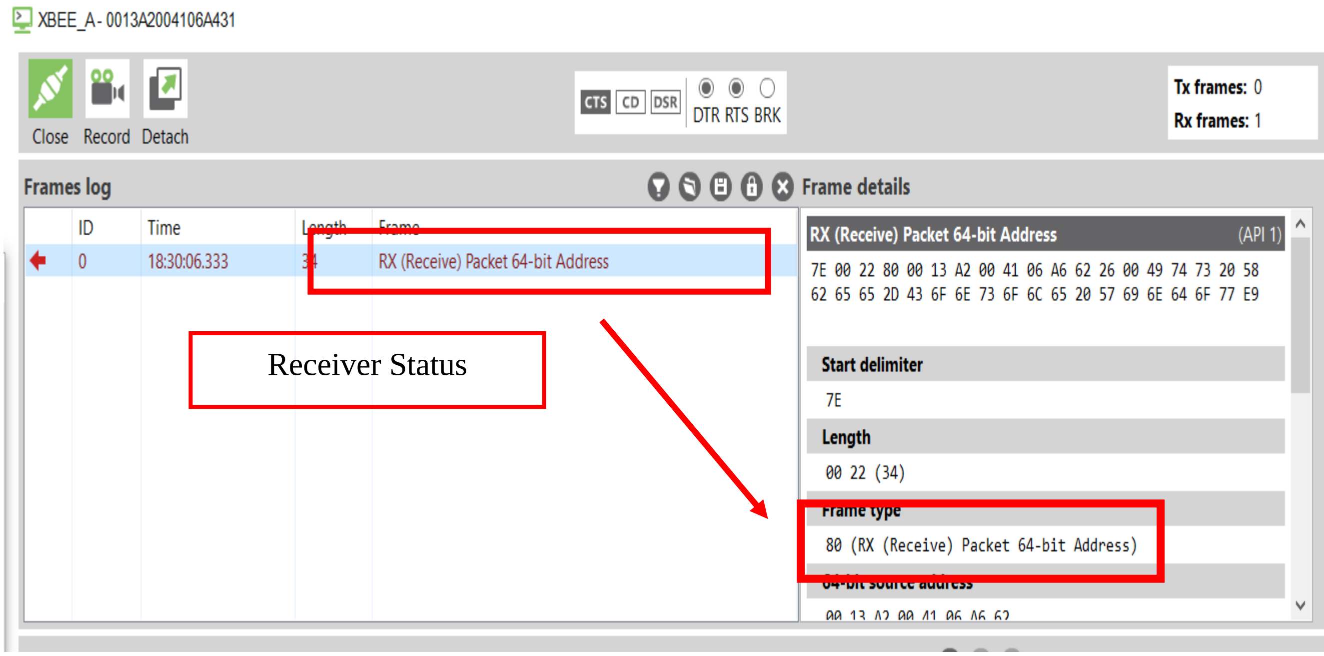

Figure 22: Xbee Receiver Status

The figure shows the receiver status along with frame type.

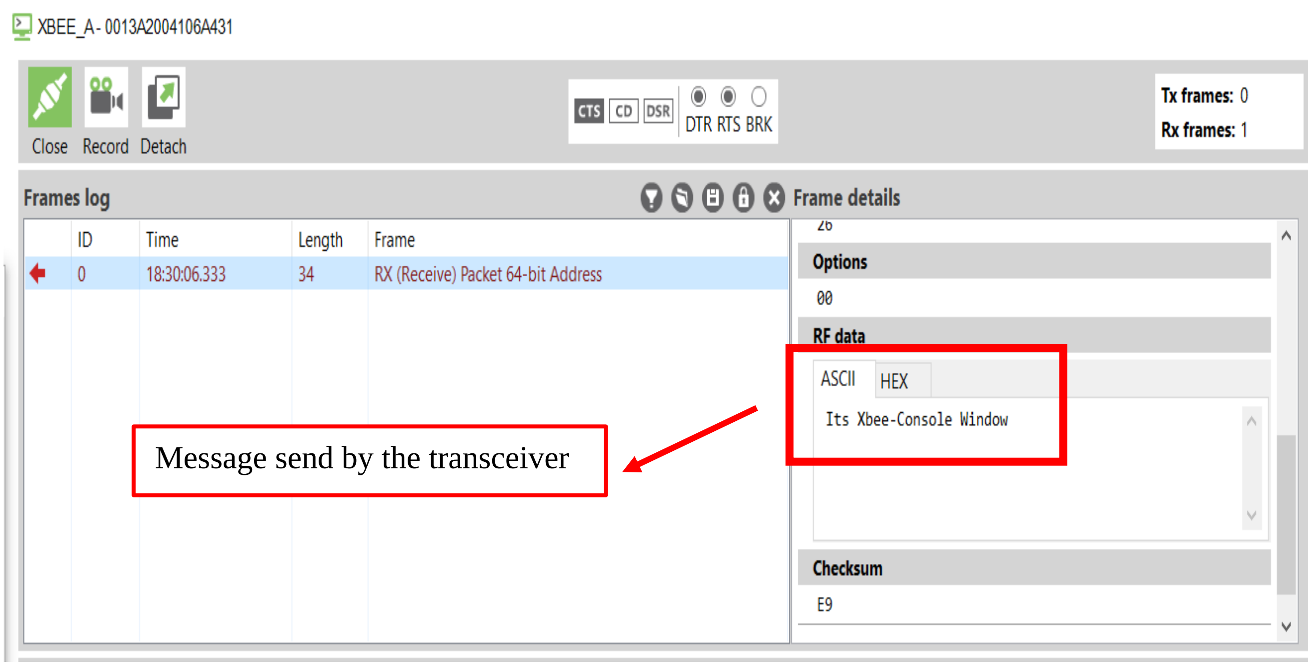

Figure 23: Xbee Received Message

The figure shows the received message in ACSII.

5.5 Visualization of Mouse and Eye Blinking

This section shows the results of the accelerometer movements and eye blinking. In beginning, the accelerometer is calibrated and then set the values of the axis. Here, only two axes are used i.e., x-axis and y-axis. In EYECOM z-axis is not used, and the reason is that, it is hard for paralyzed patient to operate cursor in all directions.

In figure 24 and figure 25, movement of the accelerometer is shown. Every movement is initialized with a specific number. The first column in figure 24 and 25 is showing the direction of cursor movements. The “UP” movement of the cursor is initialized with “1,” “DOWN” movement with “2,” “RIGHT” movement with “3,” and “LEFT” movement with “4.” The second column is showing the movement of the cursor in x-axis and third is y-axis.

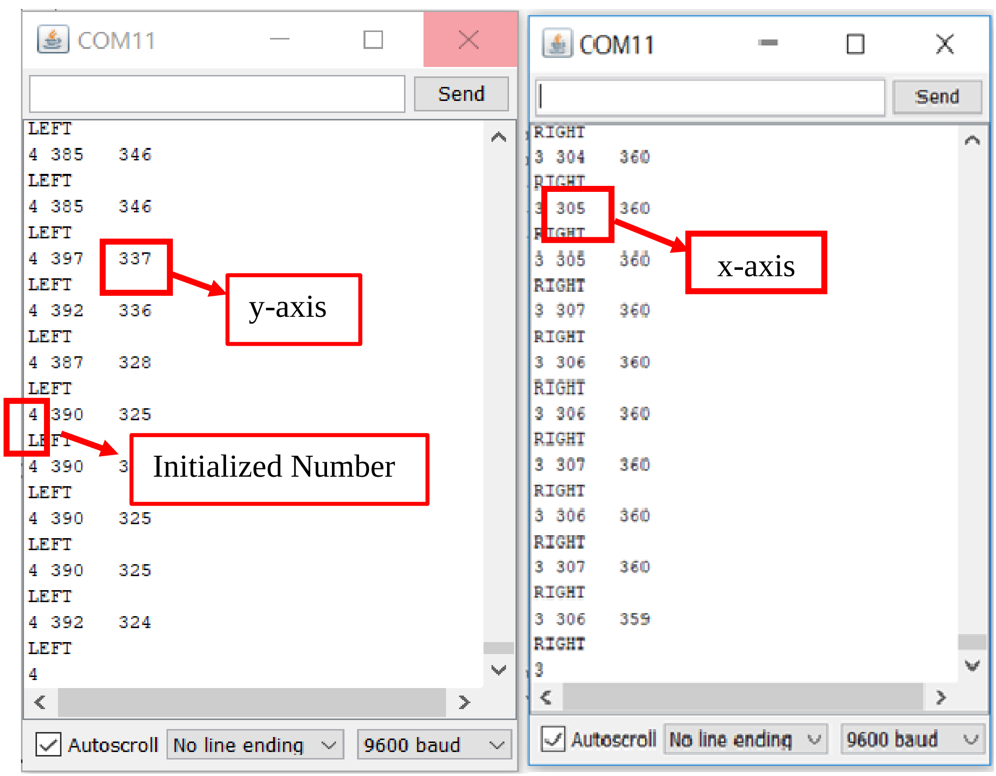

Figure 24: Cursor Left & Right Movement
The figure shows the movement of cursor along x-axis and y-axis.

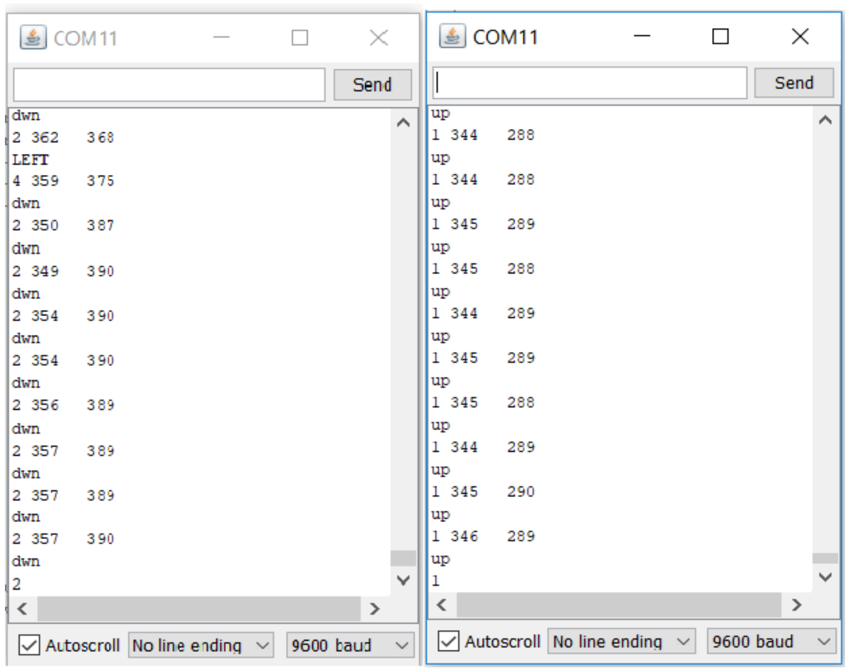

Figure 25: Cursor Down & Up Movement
The figure shows the movement of cursor in upward and downward direction.

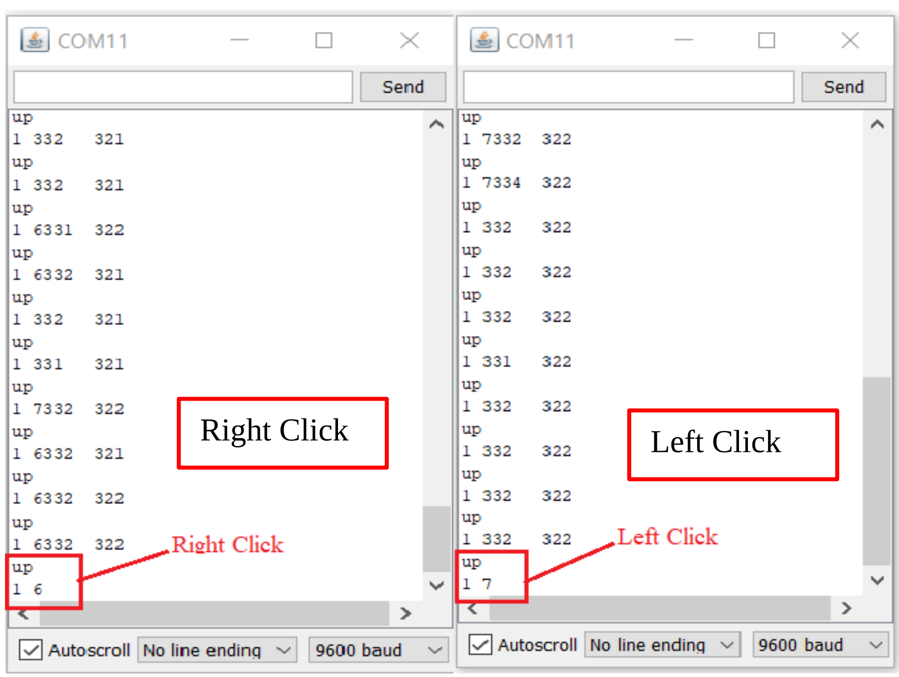

Figure 26: Cursor Clicking
The figure shows the clicking result in terms of number 6 or 7.

In figure 26, eye blinking result is shown, which is programmed to print number “6,” whenever patient blinks right eye, and prints number “7” when a patient will blink his/her left eye. This means that the patient has clicked for performing any on screen function such as opening a pdf document, reading a newspaper and similar computing tasks.

5.6 Integrating Third Party Software Application

In figure 27, the patient may use EYECOM for operating his/her Mobile phone. Operating the on-screen phone will be possible by using a third-party software application such as “Air Droid.” This will also expand the horizon for enabling unlimited features that are being introduced by technology. This is one of the most major applications of EYECOM which will enhance the ability of a patient to explore technical world with ease and more flexibility.

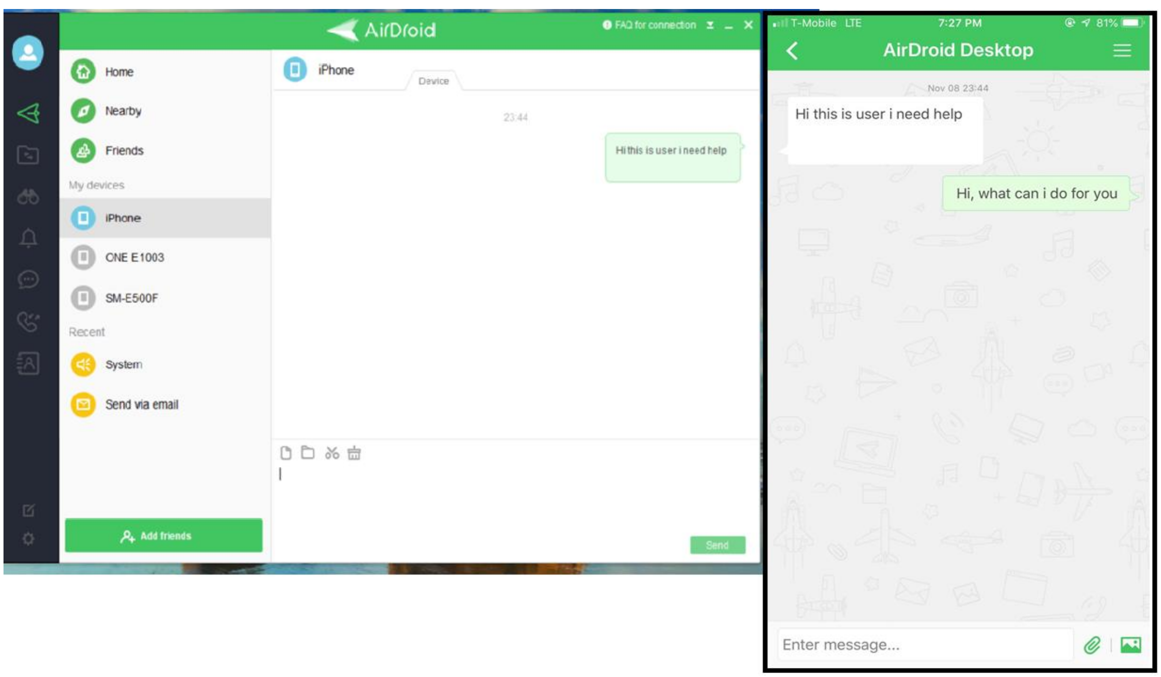

Figure 27: Third Party Mobile Usage Application
The figure shows the application interface of Air Droid.

CHAPTER 6

CONCLUSIONS

EYECOM is particularly developed for paralyzed individuals who are suffering from neurodegenerative disease such as walking, running, moving from one place to another, and even talking. With the help of EYECOM, paralyzed individuals can communicate with technology and continue their routine work such as reading a newspaper, watching a movie, operate a cell phone via third-party software, etc. Although EYECOM is on its initial stages of development, it is useful for performing different computing tasks. Currently EYECOM is developed with limited features but there is room for further researches and enhancements.

6.1 Challenges

The main aim of this thesis is to facilitate paralyzed people with a solution where they can be able to use their personal computers to perform multiple on-screen tasks. There are a number of benefits of EYECOM, but it also has some of the limitations which are addressed below:

i. Omni Direction and Scrolling

The major challenge faced by EYECOM is that it can operate only in two dimensions i.e., x-axis and y-axis. This means that computer cursor can move along x-axis and y-axis. It cannot move in the z-axis and if we try to add all the axes, it will be difficult to operate for the paralyzed person. For this purpose, further research is needed to introduce omnidirectional movements of mouse cursor.

ii. Keyboard Usage

Using the computer's keyboard is another challenge for paralyzed persons. It is because EYECOM has a comparatively slow speed of cursor's movements. Therefore, using the on-screen keyboard on the computer becomes difficult for the paralyzed people. Hence, typing with EYECOM is a time taking task for a paralyzed person.

iii. Use of Wearable Module

One of the minor concerns for using EYECOM is to wear the wearable module which requires some assistance. Therefore, it is hard for paralyzed persons to wear and take off module by themselves. They need some assistance to wear the wearable module of EYECOM. Similarly, when they need to take off the wearable module, they will also require some assistance to take off the module. Especially, people with corrective lenses will get a hard time to focus on the computer screen. Hence, there is a room for further research and enhancements to make EYECOM an easy to wear technology.

iv. Calibration

One of the limitations for EYECOM is that it requires calibration before using it. Every patient who is going to use the prototype will require to calibrate the accelerometer and IR sensor according to their comfortability. Due to the slow speed of cursor, calibration is needed to adjust, and it is a time-consuming process to re-calibrate. In future enhancements, pre-defined calibration can be introduced to overcome this challenge.

6.2 Applications

EYECOM has a number of applications specifically for the paralyzed people. Its best usage for paralyzed persons includes the controlling of a personal cell phone with the help of third-party software. Some of the very highly educated persons are paralyzed and are cut off from society just because they are unable to contribute in the digital world. The number of other applications can be as follows:

- Some of the applications include browsing around the websites, watching movies, reading out newspapers, magazines and there are much useful utility software applications.
- Paralyzed persons can also use this device for gaming and entertainment purposes that will let them spend their time in a good way.

6.3 Future Work

Commercial Scientists commonly divide the work into following phases:

1. Analysis (of the problem) resulting in Definition of Requirements.
2. Prototyping (compounding all the functionalities defined in the analysis, testing the inputs/outputs).
3. Designing the Prototype (considering the Economic, Ergonomic and Esthetic, considerations).
4. Manufacturing.
5. Marketing.
6. After Sales (repairs, complaints, new ideas, etc.).

The thesis reported herein was directed at building a prototype, focusing on Economic considerations only.

The thesis could be furthered academically through co-operation between the College of Engineering, the College of Business, and the Byrd Institute for Advanced Flexible Manufacturing.

With the help of this prototype, paralyzed individuals can easily operate the computer and continue their required work. Building-upon the thesis work, paralyzed persons, with the help of eye blinking, can control home automation like controlling home appliances, open and close the doors, etc.

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APPENDIX A

IRB LETTER

MARSHALL UNIVERSITY.
www.marshall.edu

Office of Research Integrity

November 19, 2018

Anam Mazhar
411 Hal Greer Blvd, Apt 8
Huntington, WV 25701

Dear Anam:

This letter is in response to the submitted thesis abstract entitled *"EyeCom: An Innovative approach for Computer Interaction."* After assessing the abstract, it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Code of Federal Regulations (45CFR46) has set forth the criteria utilized in making this determination. Since the information in this study does not involve human subjects as defined in the above referenced instruction, it is not considered human subject research. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director

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APPENDIX B

ACRONYMS

ALS Amyotrophic Lateral Sclerosis

HCI Human-Computer Interactions

GUI Graphical User Interfaces

EYECOM Eye-Communication

COTS Commercial off-The-Shelf

OCR Optical Character Recognition

IR Infrared

REM Rapid Eye Movement

STEM Science, Technology, Engineering and Mathematics

IOT Internet of Things

AI Artificial Intelligence

WAR Wearable Augmented Reality

MCU Microcontroller Unit

ICNIRP International Commission on Non-Ionizing Radiation Protection

ISM Industrial Scientific and Medical

BPSK Binary Phase Shift Keying

MEMS Micro-Electro-Mechanical System

IDE Integrated Development Environment

APPENDIX C

TABLE OF RELATED RESEARCH WORK

Table 5: Related Research Work

This table describes the detailed research work of all mentioned authors.

Paper Title		DEMO: Visual attention During Networking with Smart Glasses	Using Smart Eyeglasses as a Wearable Game Controller	WISE Glass: Multi-purpose Context-aware Smart Eyeglasses	Rotation Vector Sensor Based Remote Control of a Humanoid Robot through Google Glass
Objectives		Communication system for smart glasses, allows paralyzed persons to express their interest with the help of eye gaze	Smart glasses are used to control game Pac-Man through head movements. And sensors are used to check the heart rate.	In this paper, researchers have proposed the digital eye glass which can detect multi-mode motion sensing and can visualize the motion sensing. This paper shows the result accuracy at 70% which can help in detecting when a user is cycling or working on anything.	Google Glass-based system which can control a Robot by head movements
Used		Academic	Academic	Academic & industrial	Academic
Prototype		Yes	Yes	Yes	Yes
Sensors		Gyroscope, Magnetometer,	Accelerometer, Gyroscope, Magnetometer, Motion Processor	Accelerometer, Gyroscope, Magnetometer, Motion Processor, IR Sensor	Accelerometer, Gyroscope, Magnetometer
Other Input Methodology		-NIL-	-NIL-	-NIL-	Google Glass usage with the head movements and Wifi technology to be sent to the Nao Robot
Evaluation Matrices	***Precision***	Less than 1mm	-NIL-	-NIL-	Perfectly working
	Recall	-NIL-	-NIL-	-NIL-	97.4% (with 16 sensors)
	Accuracy	Yes	-NIL-	Yes	Yes
Processor + Language	***Hardware***	Raspberry Pi II	-NIL-	-NIL-	-NIL-
	Software	C++	Python	Java	-NIL-

Paper Title		Glass Gesture: Exploring Head Gesture Interface of Smart Glasses	Affective Wear: Recognizing Affect Towards in Real Life	iBlink: Smart Glasses for Facial Paralysis Patient	A Hand Gesture Control Framework on Smart Glasses
Objectives		Purpose a solution specially for disable person who can't speak, can control anything by head gesture	Glasses that can recognize 7 facial expressions.	Assist facial paralysis patients to blink	To provide help in hand gesture-based applications
Used		Academic	Academic	Academic	Academic
Prototype		Yes	Yes	Yes	Yes
Sensors		Gyroscope, Accelerometer,	IR Sensors	IR Sensor	Accelerometer, IR Sensors Magnetometer
Other Input Methodology		Activity Detector, Gesture Detector	Elastic Nose Pad of Antipollen Glasses	Facial image processing, IR Sensors in Glass, Stimulated Electrodes, Adjustable Regulator	IR Camera Sensors for Hand Gestures, Chamfer Distance Transformation Method,
Evaluation Matrices	***Precision***	Tested	Tested	Tested	Tested
	Recall	-NIL-	-NIL-	-NIL-	97.4% (with 16 sensors)
	Accuracy	96%	97.4%	above 99%	99%
Processor + Language	***Hardware***	-NIL-	Arduino Fio, ion polymer battery	Wifi, Bluetooth	IR sensors Using Glasses
	Software	-NIL-	Java, I Python Notebook, Sci kit-learn library	Raspberry Pi Zero,	-NIL-

Paper title		Smart Glasses Linking Real Live & Social Network's Contacts by Face Recognition	Hyperion: A Wearable Augmented Reality System for Text Extraction and Manipulation In The Air	ADAMAAS-Towards Smart Glasses for Mobile and Personalized Action Assistance	Towards Wearable Cognitive Assistance
Objectives		Used to recognize the faces with the names and individual social network activities	Hyperion is a wearable Augmented Reality system to extract text information from the ambient environment	To move from stationary status diagnosis systems to a mobile and adaptive action support and monitoring system, which is able to dynamically react in a context sensitive way to human error (slips and mistakes) and to provide individualized feedback on a transparent virtual plane superimposed on user's field of view	It combines the first-person image capture and sensing capabilities of Glass with remote processing to perform real-time scene interpretation
Used		Academic	Academic	Academic	Academic
Prototype		Yes	Yes	Yes	Yes
Other Input Methodology		Google-based Wearable AR-Display	Google-glass Based Wearable AR-Display	Epson Moverio BT-200, AR-Display	Google-glass Based wearable AR-Display
Evaluation Matrices	***Precision***	Tested	Tested	Tested	Tested
	Accuracy	96%	Above 90% people who used that technology got satisfied	above 99%	Experimental Project has successes in increasing battery life and efficiency for Google Glass
Processor + Language	***Hardw**are*	-NIL-	Arduino Fio, ion polymer battery	ADAMAAS Adaptive and Mobile Action Assistance	Google Glasses
	***Softw**are*	Android/OS	Android SDK	-NIL-	OpenCV, MSRC21 (Python Language)