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EyeCom-An Innovative Approach for Computer Interaction

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Abstract

The world is innovating rapidly, and there is a need for continuous interactions with the technology. Sadly, there do not exist promising options for paralyzed people to interact with the machine, i.e., laptops, smartphones, and notepads. A few commercial solutions such as Google Glasses are costly and cannot be afforded by every paralyzed person to interact with the machine. Towards this end, the paper 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, infrared light emitting (IR) diodes, and accelerometer). The EyeCom can be easily mounted on to the glasses. The paralyzed person using this device can interact with the machine, using simple head movements and eye blinks. The IR detector is located in front of the EyeCom to illuminate the eye region. As a result of the illumination, the eye reflects the IR light, which includes electrical signals. As eyelids close, the reflected light, over all of the eye surface is disrupted, and the change in reflected value is recorded. On the other hand, to enable cursor movement onto the computer screen on behalf of the paralyzed person a device named accelerometer is used. A microcontroller processes the inputs from the IR sensors and accelerometer and transmit them wirelessly via Xbee wireless sensor (i.e., a radio) to another microcontroller attached to the computer. With the help of the proposed algorithm, the microcontroller attached to the computer, on receiving the signal moves the cursor onto the computer screen and facilitate performing actions, as simple as opening a document, to operating a word-to-speech software.

Keywords: IoT; Wearable technology; Smart glasses

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1. Introduction

Patient suffering from paralysis (partial or severe) do not have many options available to use technology or interact with the computer. These patients cannot speak or use their limbs to operate a computer. There are many forms of paralysis. If the paralysis is of type *Monoplegia* or *Hemiplegia*, i.e., effecting 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 person does not have much problem in interacting with others as well as technology. The challenge arises if the paralysis is of type *Quadriplegia*, also known as *Tetraplegia*, where all the 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, to execute a command or an speech application, the patient can let other people know what he/she needs. If the Quadriplegia is of type 'severe' (and the person is not brain deed), the communication becomes a challenge.

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

The paper provides EyeCom — a patient-friendly system for paralyzed patients to operate. The system includes eyeglasses which have IR sensors that enable mouse clicking on behalf of a patient. There is also an accelerometer that allows mouse cursor movements over the computer screen along x and y-axis. The system is made in the simplest form of eyeglasses which requires minimum movement of body parts that make a paralyzed person explore the world of technology through the computer[1][2].

2. Related Work

There exist several existing work/efforts in the literature that are geared towards providing assistive support to paralyzed people. Whether, it's a movement-based controlling of events for the paralyzed people or assisting them with voice or vision aspects. Below, we detail the work related to the proposed methodology, contrast it with our work, and highlight the gaps.

Zhang Li, Huanng, 2014, in their research implemented the proof of concept of the communication system for the SMART glasses. The glasses allow the paralyzed patient to express his/her interest with the help of eye gaze. Eye gaze is an attention driven suite of networking that allows the patient to provoke events of their interest over screen via just a gaze. Capturing the patient's attention and target via low-resolution eye camera is the key motive of this work [3]. Both the research and the proposed methodology are based on smart wearable computing devices that specifically fit into low budget. In contrast to Zhang work, our proposed prototype has an added advantage of portability and mobility, i.e., the patient can carry our proposed prototype and move it around in the range of a standard size room.

Wehl et al., 2015 research is geared towards improving the potential ways that paralyzed people can control video games. They made the famous game 'Pacman' playable via head movements. This was done by using right hardware, sensors with appropriate protocols that allow the patient to control the movements in Pacman game. Heart rate information of the patient is also added as an enhancement to the prototype[4]. The main drawback of the prototype proposed by Wehal's was that it allowed users to only make the on-screen movement in "to and fro" and "front and back" directions of the Pacman screen. Whereas, EyeCom prototype provides greater control on cursor movements along x-axis and y-axis on the computer screen.

Haisiang Yu et al., 2015 developed a hand gesture control framework using sensors and camera that helps in detecting hand gestures for a number of useful applications such as controlling wheelchair and home automation systems. The drawback of this frame is that it is only beneficial to paralyzed person who have complete movement in their hand(s) and arm(s).Whereas, our proposed EyeCom prototype is a wearable device that uses eye movement and minor movement in any part of body to perform cursor movement and attain mouse functionality on computer screen [5].

Masai et al. developed the wearable prototype that detects seven different facial expressions. The facial expressions include neutral, angry, disgust, surprise, smile, sad and laughing expressions of the human face. With the help of developed "Facial Action Encoding" system, an accuracy of categorization up to 98.7% was achieved

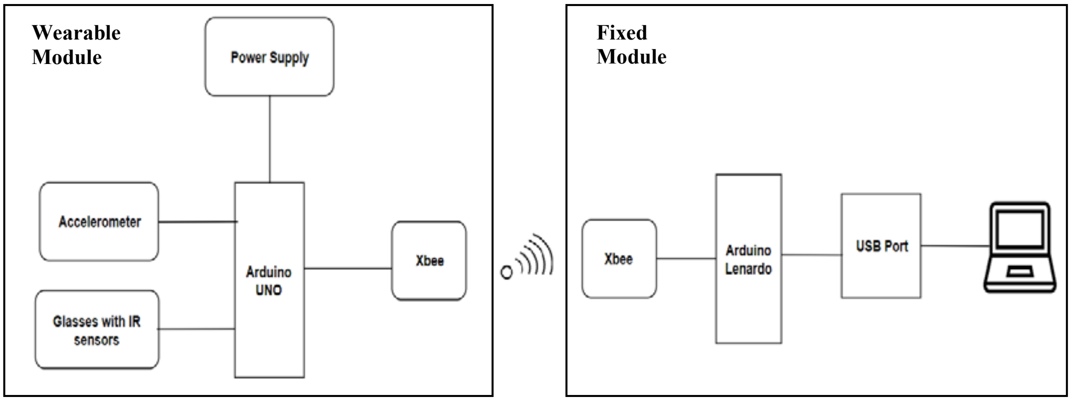

Fig. 1 High-level architecture of EyeCom

[6]. *Masai* bridged the gap between a few non-verbal gestures of human communication and the technology. However, the prototype is limited to the identification of seven human gestures. The prototype do not facilitate robust interaction of paralyzed person with technology, i.e., operating a computer.

Chatzopoulos et al., 2017 developed a wearable prototype called Hyperion, in which users are able to extract the text content from the ambient environment. Hyperion is based on google glass framework which is able to fetch the textual information in different usage modes including driving, exploring, reading and meeting modes. Wearable Augmented Reality (WAR) system is used in this research, which is supported by the Google glass architecture [7].

Ha et al., 2014 developed a wearable prototype, also based on google glass, for providing assistance to the paralyzed patients for face recognition, object recognition, optical character recognition, and motion classification. Their prototype has a few limitations, which includes low battery life and network failures that can reduce the performance of the cognitive assistance [8].

3. Proposed Innovation

The section provides a high-level overview of the working of the EyeCom components and its features. The EyeCom for its operation requires off-the-shelf electronic components. The EyeCom allows a paralyzed person to use the eyes to control mouse, navigate the computer screen, and select or open an application with the eye blink. The EyeCom consists of two modules: (a) wearable module and (b) fixed module as shown in Fig. 1.

3.1. Wearable Module

The module is called ‘wearable’ since it can be mounted on the glasses and worn by the patient. The major components included in the wearable module are (a) an Infrared module, (b) Arduino Microcontroller, and (3) Xbee wireless sensors.

3.1.1. Infrared Module

The infrared (IR) module is the combination of IR photodiodes and two IR light emitting diodes. It is the heartbeat of the system. The IR LED consists of OB704, which has an IR transmitter and IR receiver inside the back plastic jacket. The IR LED, which is used inside OPB704, is called OSRAM SFH485. 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 limits of exposure 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 [9]. 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 so to produce good signals, amplifier is

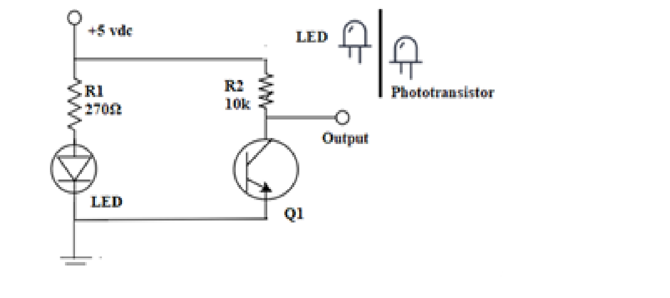

Fig. 2 Current flow in eye blinking circuit

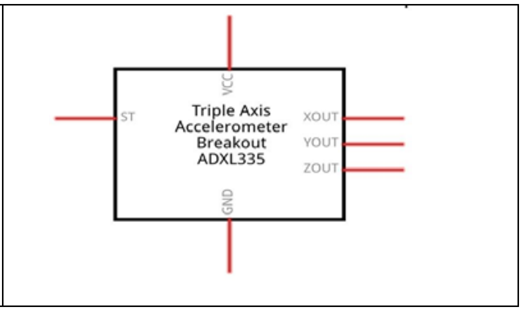

Fig. 3 Schematic Diagram of ADXL 335

used to amplify the signals, along with a photodiode and a four-core cable for the light emitting diode, i.e., two cables for each pair of light emitting diode (LED), one for anode and other for a cathode. Fig. 2, is the block diagram of the IR Eye detecting mechanism. The figure details the current flow in the eye blinking circuit. Following mechanisms are used for getting input signals, i.e., capturing eye blink:

1. Modulation (variation analyzation) by IR sensor.
2. Optimal placement — to make sure the deep contact of field sensors with eye surface, the sensors are placed at the distance of 17 mm from the retina. At such distance, the IR sensors have the capability to completely illuminate the targeted area of the eyes.

In the above mechanism, the infrared LED (a) emits the invisible light which is detected by the IR photodiode and (b) transforms the received light into electrical signals. 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 are later converted into electrical signals. As eyelids close, the reflected light, overall the eye surface is disrupted, and the change enables EyeCom to perform the programmed instructions on behalf of the patient.

At the simplest, the main function of the IR module is to convert the emitted light to digital signals so that the input, i.e., the eye blinks, can be recorded on behalf of the paralyzed person.

Table 1. Pin Configuration of ADXL 335

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	ZOUT	Z Channel Output
9	NC	No Connect
10	YOUT	Y Channel Output
11	NC	No Connect
12	XOUT	X Channel Output
13	NC	No Connect
14	VS	Supply Voltage (1.8 V to 3.6
15	VS	Supply Voltage (1.8 V to 3.6
16	NC	No Connect

Table 2. ADXL 335 pin interfacing with Arduino

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

Fig. 4 Xbee Module

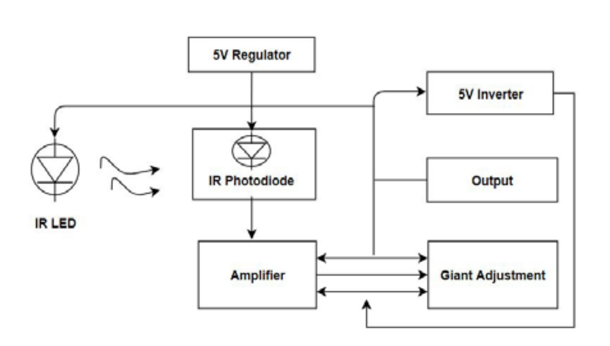

Fig. 5 Blink Detection Circuit

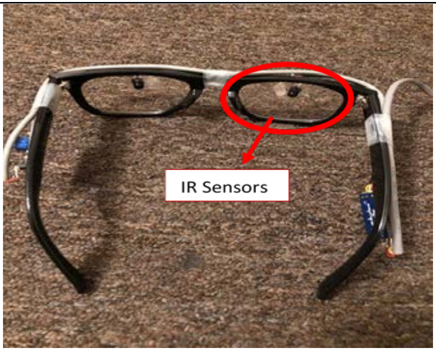

Fig. 6 EyeCom Prototype

To make the IR module robust and to prevent noises in the signals, a few measures have been taken which includes adding a light filter in photodiodes. This 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. The microcontroller, i.e., Arduino, compares it with the inputs from the accelerometer to perform the programmed tasks. The incorporation of accelerometer module is detailed in section 3.1.3.

3.1.2. Eye Blink Detector Circuit

IR sensors have a large capacity to eradicate all environmental and surrounded noise using large volumes of frequency and pulse of IR light. Fig. 5 shows the block circuit of the eye blink detection mechanism employed in the proposed EyeCom. In EyeCom, IR sensors emit radiations which are not detectable through 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 has the capability to detect the light of the same wavelength that is being emitted by IR LED. Once the light from IR LED is being 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 blinking 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 by the UNO R3 microcontroller as 'eye blink' and is then transformed into a mouse click command. During the process, some unwanted noises, such as room light, can also create some problem for light emissions from IR LED. Therefore, an amplifier is used to strengthen the IR LED light to overcome the signal noises. The whole IR sensing mechanism plays its vital role in EyeCom by capturing the eye blinks of paralyzed person.

3.1.3. Accelerometer Module

Another important part of the EyeCom is to enable cursor movement onto the computer screen on behalf of a paralyzed person. For this purpose, a device named the accelerometer is used. The accelerometer is a small device, size of phalanges, a human thumb bone. The device operates on the principle of axis-based motion sensing. In the case of EyeCom, the specific accelerometer ADXL335 is used. It acts as an input device which collects the signals for the motion, analogous to of the cursor movements, made using a computer mouse. The accelerometer contains polysilicon springs which play their role in moving in all possible directions. These changes in the direction forms a capacitance in the plates attached to the structure inside the ADXL335. The capacitance is then transmitted as the voltage with respect to the acceleration to the specific direction where the accelerometer is deflected. ADXL335 can be used in three axis rotation. However, for the purpose of EyeCom, only two axes, which are X and Y, are used to simplify the cursor movement on to the computer screen.

Once the signals have been recorded by an accelerometer, 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 Tx port through the Xbee wireless sensors.

3.1.4. Integration of Accelerometer module

Integration of the accelerometer with Arduino microcontroller is one of the important steps toward the construction of EyeCom prototype. Fig. 3, shows the schematic diagram of ADXL335. Whereas, Table 1 lists its pin description. The hardware module of the accelerometer (ADXL335), needs to communicate with the Arduino interface board via specific ports. Therefore, Table 2, represents the configuration of the Arduino pins that are required to be connected with the accelerometer pin accordingly. The connected pins are responsible for transferring the signals inside the circuit without having noises in between. The pin configuration is very important 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.

3.2. Fixed Module

The Fixed Module as shown in Fig. 1 consists of the Xbee wireless radio (receiver) and an Arduino Leonardo microcontroller, which is responsible for receiving all the inputs coming 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 cursor and its associated clicks based on the inputs received from the wearable module. In Fixed module, the Xbee wireless module acting as a receiver, receives the signal from Xbee wireless module (transmitter) of wearable module. It transfers the signal to the attached Arduino leonardo microcontroller. The microcontroller transfers the signals from serial port to the USB port and then forward it to the laptop or PC. The module has been programmed with the traditional mouse instructions. The instruction allows the module to move the cursor along x-axis and y-axis.

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 fixed module has a wireless radio that receives the instructions in digital format from the wearable module. Below section detail the wireless radio operation.

3.2.1. Wireless Communication

The wearable and fixed module each have a Xbee wireless transmitter/receiver module connected to it. The module therefore helps to make EyeCom a wireless wearable device. Fig. 4 shows the Xbee module used for constructing the EyeCom prototype. Xbee is designed as a standard for a set of protocols that assists in information sharing with low 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. The higher data rate that Xbee module can support is 250 K bits per second. Beside other wireless radios, we choose Xbee as the wireless communication module for the EyeCom because of its affordability, efficiency, and long battery life. It also has sleep mode feature which means it stays in the active mode once it is transmitting the 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. Sleep mode avoids battery consumption, which makes Xbee last for several years.

In the wearable module of the EyeCom, Microcontroller Unit (MCU) is programmed to control the signals that are transmitted over Xbee transmitter. On the fixed module side of the EyeCom, the Xbee receiver, receives wireless signals and then forward it to Microcontroller Unit (MCU) to perform further operations. To make wearable module more effective and mobile for the paralyzed person, the range, between the wearable module and fixed module, can be set up to 100 feet as a default range defined by IEEE 802.15.4 technical standards.

4. Operational Control

This section provides detail on the working of the wireless module of EyeCom. The Xbee interface is used to communicate between the wireless module and the fixed module attached to the computer. The accelerometer can be attached to any body part that can enable movement (i.e., head, arm, wrist, leg and feet) and where the patient feels comfortable to wear it. In case of the EyeCom prototype, the module is mounted onto the glasses. The accelerometer is responsible for recording the movements in the digital form so that it can be processed by Arduino microcontroller of the wearable module. Figure 6, shows the block diagram of the wearable module having an IR module attached, which is responsible for taking input signals coming from the human eye and transmitting to

Arduino UNO microcontroller for processing and comparing with the inputs received from the accelerometer. The comparison enables the wearable module with IR sensors to map eye blinks to the operations related to computer's "cursor click." The paralyzed individual will use an eye blink for selecting on-screen items.

The operational lifecycle of the EyeCom, beginning with an input coming from the IR sensors and the accelerometer in the form of electrical signals. As a next step, these signals are transferred to the microcontroller. Depending upon the extent of paralysis, the paralyzed person can simply wear the accelerometer on the wrist or hold it in the hand. If the accelerometer detects any movement, then it provides this movement input value to the Arduino UNO R3. The UNO R3 contrast the different types of inputs from EyeCom and passes the signal to the Xbee Wireless Transmitter module to transmit to the other microcontroller present in the fixed model. The Xbee transmitter in the wearable module, before sending the data to the Xbee transmitter attached to the Arduino Leonardo microcontroller in the fixed module, amplifies the signal and removes the noises. Thus, the crisp signals are received by the Arduino Leonardo which is attached to a computer. The Arduino Leonardo, communicates with computer using the mouse protocol and enable the movement of a cursor on to the computer screen, based on the crisp digital signal, received as an input from the wearable module.

5. Challenges and Threats to the Validity

EyeCom is especially 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 the 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, but it is useful for performing different computing tasks. Currently EyeCom is developed with limited features, nevertheless there is a room for further research and enhancement. Below we list a few limitations of EyeCom.

5.1. 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. Thus, even if we add all the axises, it will be difficult to operate for the paralyzed person. For this purpose, further research is needed to introduce omnidirectional movements of mouse cursor.

5.2. 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.

5.3. 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. Similarly, when they need to take off the wearable module, then they 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.

5.4. Calibration

One of the limitations for EyeCom is that it requires calibration before using it. Every patient who is going to use the prototype needs to calibrate the accelerometer and IR sensor according to his/her comfortability. Calibration is needed to match the movement of cursor with respect to the movement from patient as well as its position (sitting, standing, and laying). Calibration is a time consuming process. In future enhancements, pre-defined calibration can be introduced to overcome this challenge.

6. Applications of EyeCom and Future Work

Paralyzed persons usually get cut-off from the society just because they are unable to contribute and interact with the digital world. EyeCom is a solution for paralyzed individuals to perform on-screen computing tasks; especially for those persons, who want to do something valuable for themselves and this entire word by using the technology. EyeCom has a number of applications specifically for the paralyzed people including but not limited to:

- *Information Seeking*: include browsing of the websites, watching movies, reading newspapers, magazines.
- *Entertainment:* Paralyzed persons can also use this device for gaming and entertainment purposes that will let them spend their time in a quality manner.
- *Operating Gadgets:* The best usage of EyeCom for paralyzed persons includes controlling of a personal cell phone with the help of third-party software.

With the help of the proposed innovation, i.e., EyeCom, paralyzed individuals can easily operate the computer and be part of the digital world. In the future, using eye blinks, paralyzed persons can control home automation like controlling home appliances, open and close the doors, etc. One of the major future enhancement planned for EyeCom is to control the electric wheelchair with eye blink(s). The future enhancements, along with new features planned for EyeCom, will bring revolution in the field of the healthcare industry.

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