IMPLEMENTATION OF A LOW COST HANDS FREE WHEELCHAIR CONTROLLER

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ABSTRACT

The aim of this project is to ease mobility for people with upper and lower disability in order to live independently. This paper presents the design steps and specification to a low cost hands free eye-blink controller to control and electric wheelchair. Nowadays, people are using joystick to control motorized wheelchair. The eye-blink controller technology gives an alternative solution to mobility problem; especially for the people who are quadriplegics. By interfacing eye-blink controller, the directions of the wheelchair are controlled. This report will provide the designing step, related solutions, and component details and specifications.

Keywords: mobility; smart controller interface; disability; assistive technology; embedded systems

1. INTRODUCTION

Nowadays, a very important goal for motor disabled people is to be autonomous in their mobility. They want to be able to depend on themselves on their daily life tasks. Unfortunately, around 15% of the population worldwide lives with disability according to World Health Organization and disability means losing the mobility (WHO, 2017). But nowadays there are many choices for electric power wheelchair and the common one is are joystick control, but this kind of electric wheelchair cannot be used for all disabled people who suffer from the disability of the upper part of the body.

However; many hand-free controllers have been developed for disabled people to make their mobility easier such as: voice recognition technique, head control, eye movement, and chin control. But each one of those different designs has at least one disadvantage for example the voice recognition technique is not appropriate in noisy places. Moreover; in the eye movement technique the user cannot see his surrounding freely, he must concentrate on controlling the wheelchair.

For this, the propose of this paper is to design a new hand-free method to control the wheelchair depending on eye blinking , so the user can move freely with blink his eyes and the wheelchair will move to a specific direction forward, right, left and stop. The controller will be applied on a GoPiGo robot instead of electric wheelchair for demonstration purposes. Next, the literature review will be mentioned, followed by the solution selection, design schematic, experimental results, discussions, and conclusion.

2. LITERATURE REVIEW

The electric wheelchair is very popular and has been around since the mid of the last century. Early electric wheelchairs simply used the frame of a manual wheelchair and added an electric motor to it. Unlike manual wheelchairs, which require a great deal of upper body strength to use, electric wheelchairs require virtually no effort on the part of the user. They are also often referred to as power chairs or electric power chairs.

Most electric wheelchairs use a joystick control that is mounted to the armrest of the chair. This design is the same used on the first electric wheelchairs and can be configured for use on the left or right side of the power chair. There are also a number of alternate controls available for those who are not able to operate the joystick. (ARSHAK; BUCKLEY; KANESWARAN, 2006)

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Perhaps the most common alternate wheelchair control allows the wheelchair to be controlled by the user's breath. Blowing into the wheelchair moves it forward and breathing in moves it backwards. The direction of the wheelchair can also be controlled. Different types of wheelchairs were designed with different types of controllers such as head, chin, tongue, eye gaze and sip-and-puff.

There are many types of wheelchair's controllers that serve several types of upper body disabilities in order to meet the challenges and the needs of the patients. Among these, several effective ideas of controllers that help mobility will be reviewed as the following.

Standard joystick controller

This type of controllers helps alders and people with legs disability to move the electric wheelchair. The joystick controller controls the electric wheelchair manually by moving the joystick in different direction. After specifying the command from the user, specific signal will be sent to the microcontroller where it identify the command and execute it. Thus, the command will be send to the motor as a digital signal. (HOVEROUND, 2012)

Sip-and-puff controller

The sip-and-Puff controller is an assistive technology that sends signals using air pressure by sipping (inhaling) or puffing (exhaling) through a tube in order to move the electric wheelchair. The idea of this design is based on a pressure sensor (absolute air pressure) connected to a microcontroller circuit. The sensor measures the pressure and sends it to the microcontroller. Then the microcontroller converts the analog signal into a digital signal and sends it to the wheelchair controllerto perform the wanted movement action. (MOUGHARBEL et al., 2013)

Eye-blink controller

This type of controller controls the electric wheelchair by how many times the eye blinks. The eye blinking mechanism is designed to produce commands forward, backward, right, left and stop. This system involves three stages: image detection, image processing and sending signals to the wheelchair controller. The eye blinks are detected using a camera and sensor that are placed in front of the user. The sensor will send the data to microcontroller which will process the information in an embedded computer and then send the corresponding output signals to the wheelchair controller to start moving the wheelchair. (PURWANTO; MARDIYANTO; ARAI, 2017)

Head motion controlled wheelchair

This type of electric wheelchair has a tilt communicator system that responds to head movements. It could be used by disable persons who cannot move their hands and legs but they can move their head. In addition, it works by using tilt sensors. In addition, it's a plan to fit the disabled person setting on it and have a weight up to 100 kg. (NEHRU, 2012)

Voice controlled wheelchair

This system is designed to control the wheelchair through the voice recognition. The components of this system are microcontroller with microphone sensor, motors to move the wheelchair and ultrasonic sensor to detect if there is any obstacle in front of the wheelchair to stop it. (PIRES; NUNES, 2002)

The next Table 1 shows a comparison of the five above mentioned techniques.

Table 1: Comparison of 4 different wheelchair controllers.

Controller type	Joystick control	Eye- blink control	Sip& puff control	Voice control	Tilt control
Power consumption	Low	Average (IR)	Avg.	High	Avg.
Processor Speed	Low	High	High	High	High
Causes user's fatigue	After heavy usage	After heavy usage	After light usage	After light usage	After light usage
Used with upper limb disability	No	Yes	Yes	Yes	Yes
Additional controller cost	No	75 USD	140 USD (MOUGHAR BEK; El-HAJJ; GHAMLOUCH; MONACELLI, 2013)	160 USD (PIRES; NUNES, 2002)	150 USD (NEHRU, 2012)

3. SOLUTION SELECTION

The five different designs that were mentioned in the previous section meet the user needs. Among them, only one proves its quality and effectiveness based on some requirements and criteria. A comparison of these designs will be mentioned to choose the appropriate one.

According to the table data Table 1, the eye blink has the highest power consumption since it has camera screen, unless it uses less power requiring equipment such as IR sensor. The sip-and-puff controller uses average power consumption since it uses microcontroller and microprocessor in its design unlike the joystick controller that requires low power

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consumptions because they don't contain additional components. Regarding to the fatigue caused on the user, the sip-and-puff, tilt, and voice controllers cause the most fatigue, while the others cause less fatigue.

This is due to the fact that the lungs will be tired of inhaling and exhaling additional air for a long period, the voice will be tired talking all the time, and the neck muscles will be exhausted. Although the joystick controller has no additional charges like the others, but it is not of practical use if the user has upper limb disability. Therefore, the eye-blink controller is chosen to be implemented due to its reasonable price, not causing fatigue, and its suitability for upper extremities handicap. (PURWANTO; MARDIYANTO; ARAI, 2017; Spd.org.sg, 2017; Rehabmart.com, 2019)

4. DESIGN SCHEMATIC

The high-level design is distributed into several small blocks. The wheelchair block is interchanged with GoPiGo robot controller for the sake of experimentation.
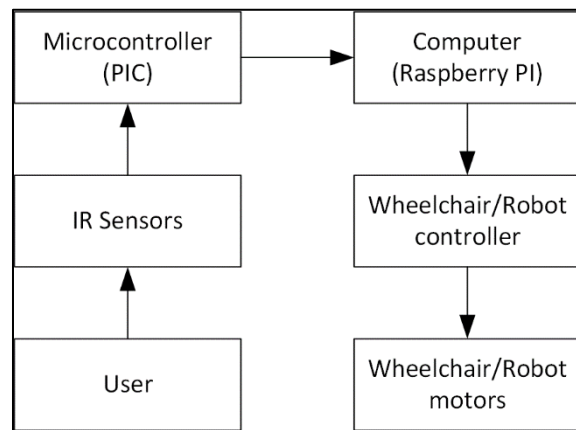

Figure 1: System's high level design

IR Sensors

The first block after the user is the two Infra-Red sensors, one for each eye. It is considered as a main part of the design. The functionality of these sensors is to detect an eye blink from the user's left and right eyes. The sensor produces analogue signal as output, which is sent to the microcontroller. (AGARWAL ET AL., 2015)

Microcontroller Circuit

The second block is the microcontroller that takes the analogue signals from the IR sensors and converts them into digital signals which distinguish four states: no blink, left eye blink, right eye blink and both eyes blink. These signals will be sent to the embedded computer

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board for further action. The microcontroller used in our prototype is a PIC16F877A microcontroller. (MILAN VERLE, 2008)

Computer board (Raspberry Pi)

The third block is the Raspberry Pi computer. It acts as the brain of the controller because it reads the data from the microcontroller and converts it into commands that are sent to the robot's or wheelchair's controller. (TechRepublic, 2017).

Wheelchair or Robot controller

The fourth block is the controller of the wheelchair or the robot. In our prototype, it is the controller for GoPiGo robot. It receives the commands from the Raspberry Pi and sends the actions to the robot motors in order to move the robot accordingly. (D. Industries, 2018)

Wheelchair or Robot motors

The fifth and last block is the motors of the wheelchair or the robot. In our prototype, it is the motors for GoPiGo robot. They move according to desired directions sent by the robot's controller board.

The figure below shows the detailed connections. The green board on the right is the Raspberry PI. The red board is the GoPiGo controller. The black chip is the PIC microcontroller. The two similar components down are the IR sensors.
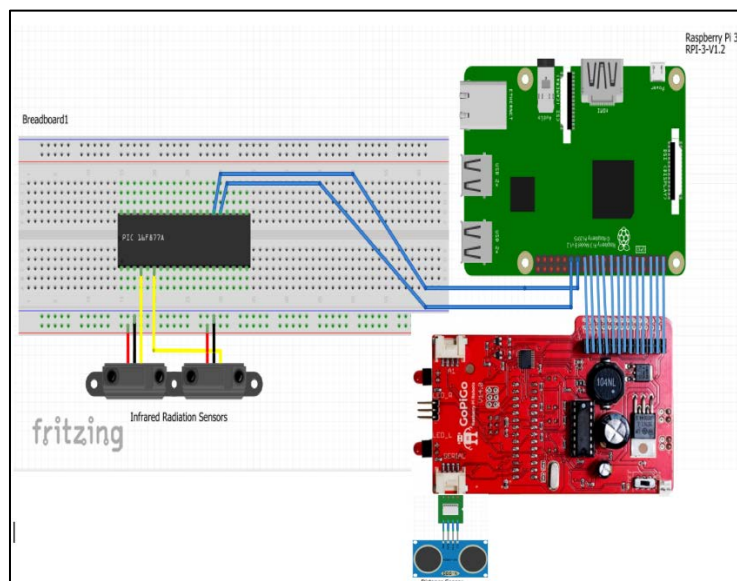

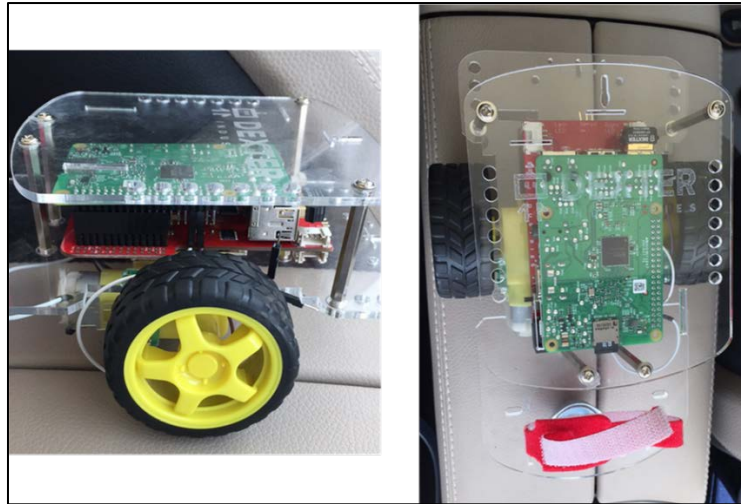Figure 2: System's low level connection
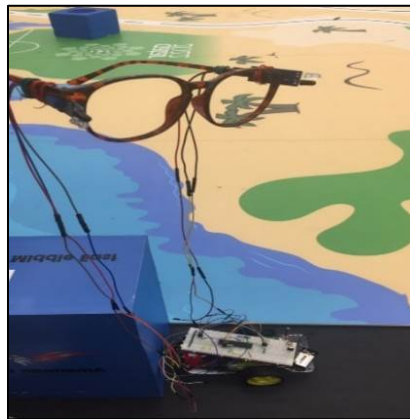
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Figure 3: GoPiGo robot used in the prototype

Figure 4: System's eye glasses with sensors

The next figure shows the system flowchart that illustrates the full process. At first the IR sensor will detect the eye blink. If the right eye blinked, then the motor will move to the right direction. If the left eye blinked, then it will move to the left direction. If both eyes blinked, and the motor is stopped then the motor will go to forward direction. Finally, if both eyes blinked and the motor is not stopped then the motor will stop.
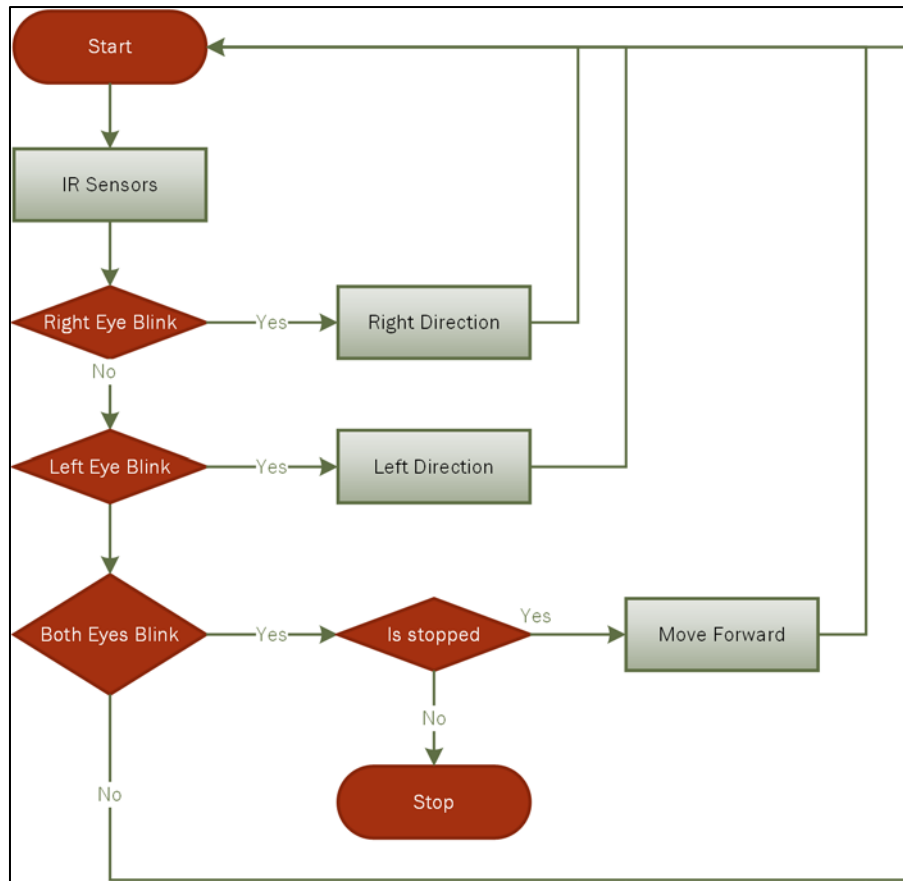
Figure 5: System's flowchart

5. EXPERIMENTAL RESULTS

In order to validate the prototype, we need to test it on different scenarios and compare the results to the ones without the eye-blink, in the latter case using the wheelchair's joystick with the hands. In the case of GoPiGo robot, we will compare the eye-blink controller with the normal GoPiGo touch control panel.

In particular, three different path scenarios were used for testing the eye-blink controller:

- Straight path

- Curved path

- Maze path

Straight path

The idea is to move straight between two points A and B with the eye-blink controller and without it, as shown in the following figure. In this test, the starting point is the orange

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box, and the target point is the blue box. This test took 4.3 seconds to perform with conventional control, and 7.3 seconds with eye-blink control. This is the easiest test that includes moving in just one direction then stopping. The incurred delay was just for the user to blink his eye and the microcontroller getting the sensor's reading then sends it to the Raspberry PI computer.

Figure 6: Straight path test scenario

Curved path

In this experiment, the user will move the robot on a drawn path as in the figure 7. In this test, the starting point and end point is the same. This test took 11.5 seconds to perform with conventional control, and 19.5 seconds with eye-blink control. This scenario is more challenging than the first one because it includes moving straight and turning right and left as required in the path. The user needs to stay close to the path and not deviate by more than 5 cm. At each turn there is more delay for microcontroller response time, which was fixed at 0.5 seconds.

Figure 7: Curved path test scenario

Maze path

In this experiment, the user will try to move the robot from the center of a maze to outside it as shown in figure 8. In this test, the starting point is the center of the maze, and the

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end point is the exit of the maze. This test took 25 seconds to perform with conventional control, and 35 seconds with eye-blink control. This scenario is the most challenging among the three scenarios because it involves moving in all directions while avoiding hitting any of the maze walls. Again the delay here was for microcontroller's response time to the sensor's readings.

Figure 8: Maze test scenario

6. DISCUSSION

The prototype's results are acceptable when compared to conventional joystick control, although not so good. The main reason behind it is probably the 0.5 second delay incurred for the microprocessor to read the data from the sensor. Furthermore, the user needs a proper training time to get used to the eye-blink system. The table below shows the time comparison between regular control and eye-blink control performance for the three different scenarios. On the average, the user needs 50% more time to execute the same task. This result is not optimal, but it is acceptable taking into consideration the user's disability in his upper extremities.

Table 2: Time comparison between standard and eye-blink control.

Scenario	Standard	Eye-Blink	Difference
Straight path	4.3s	7.3s	3s
Curved path	11.5s	19.5s	8s
Maze path	25s	35s	10s
Total	40.8s	61.8s	21s

Enhancements can be made on the prototype to produce better results. The initial delay used by the PIC microcontroller to take the sensor's measurement is set to 0.5 second. Another delay used by the Raspberry PI to read the values sent by the PIC microcontroller is set at 1 second. This makes the total delay of 1.5 second for each movement, which is certainly not acceptable.

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A valid idea is to connect the sensor directly to the Raspberry PI computer, thus eliminating the initial 0.5 second delay, and then using an interrupt to detect the change in the sensor reading by the Raspberry PI computer. This will remove the other 1 second delay. Therefore, all the 1.5 seconds useless delays can be removed per action. If we review the first scenario, it needs only two actions: move forward then stop.

The difference of 3 seconds shown in table 2 reflects the 1.5 seconds delay per move, since we have only two moves (forwards and stop). Ideally, we will reach the same timing as in standard joystick control. This will happen after proper training on the new eye-blink system.

7.   CONCLUSION

In conclusion, helping physically disabled people to increase their mobility and depend on themselves is the main challenge. This challenge is increased when even the upper extremities are not functioning. In this case, an ordinary joystick controlled electric wheelchair is not sufficient to provide autonomous user movements.

In our work, we designed an electrical wheelchair controlled by eye blinking. This is a successful idea to solve the mentioned problem. The user only needs to blink his right, left, or both eyes to drive the wheelchair without using any other part of his body. Our design depends on two Infrared Radiation (IR) sensors to detect left or right eye blinking in order to decide on moving forward, right, left, or stop. This system was built in a prototype that controls a GoPiGo robot, and then tested in different scenarios to produce outputs compared to standard control.

As a future work, the design needs several enhancements, starting by installing the system on a real electric wheelchair instead of a robot.

Furthermore, a hardware redesign can omit the microcontroller's part to reduce delay and cost. A software redesign can add software interrupts that will cause further delay reduction and make the system on same level as a standard joystick control.

Another important enhancement is adding distance sensors that will detect obstacles on the wheelchair's way. This detection can be included in the software's design in order to avoid obstacles.

A third enhancement involves adding a wireless connection (instead of a wired connection) between the glass sensors and the controller.

Further enhancements can include solar energy instead of a regular chemical battery. Also make the controller waterproof so that the chair can be used in outdoor environment. An

emergency special code (in blinking) can be added. This code will cause a GSM modem to send SMS message to an emergency number for help.

8. ACKNOWLEDGMENT

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