Eye-Controlled Wheelchair

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***Abstract*— This document outlines a method for implementing an eye tracking device as a method of electrical wheelchair control. Through the use of measured gaze points, it is possible to translate a desired movement into a physical one. This form of interface does not only provide a form of transportation for those with severe disability but also allow the user to get a sense of control back into their lives.**

I. Introduction

A powered wheelchair is a mobility-aided device for persons with moderate/severe physical disabilities. Various kinds of control interfaces have been developed for wheelchair control: such as joystick or head control. These forms of interface may not be accessible or practical for all people. Through the use of an eye tracker, a different form of wheelchair control is possible. This paper presents the design, development, and medical impact of an eye controlled wheelchair.

II. Prior Work/Medical Impact

Patients who have no use of their limbs are extremely restricted in terms of mobility. Certain ways of movement such as sip and puff wheelchairs provide an alternative, but restrict the ability to speak and may be difficult for those with respiratory problems. Our eye controlled wheelchair has little to no restriction on the user's other four senses and even sight will not be totally impaired due to the front camera stream being displayed on the movement screen.

Eye-Tracking wheelchair control has been a region of study for quite some time now. Many project teams have achieved Eye-Tracking controlled wheelchairs but each having unique benefits and faults. Investigating these designs allowed us to learn and improve our design by avoiding certain design downfalls.

In 2006 a group of Taiwanese engineers developed a "Powered Wheelchair controlled by Eye-Tracking system" [2]. They used pupil-tracking goggles linked to a computer in order to translate gaze direction into chair movement (Figure 1). This technique allows for consistent Eye-Tracking regardless of head movement. The user's eyes would be mapped to a position point within the screen shown in Figure 2. This gaze position to direction correlation is similar to ours.

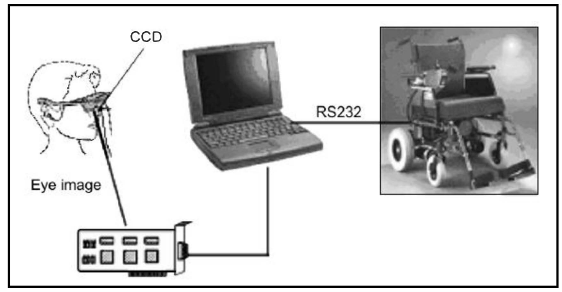

Fig. 1. Example of Project Setup

In 2011 an Italian group of engineers published a paper [1] discussing the disadvantages of eye-controlled electric powered wheelchair (EPW) systems. This paper brought to our attention that when the user is attempting to move the wheelchair by gazing at the screen, he would not actually be seeing where he is going. This general flaw in eye-controlled EPW systems encourages the addition of a video screen on the display. Therefore a design similar to Figure 2 should is desirable that uses the IDLE space as a webcam environment that presents what is in front of the user when using the device.

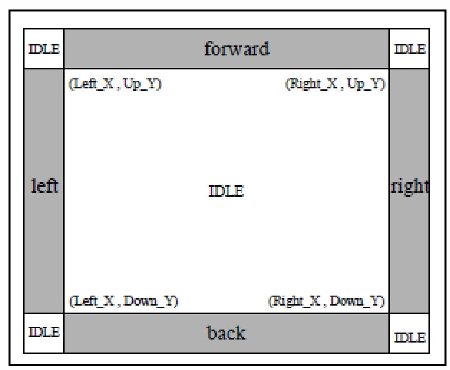

Fig 2. Display Setup of Italian Group

In 2012 a group of engineers had a paper published [3] discussing a new method to guide and control a wheelchair. This group suggested a contact lens with a reflected coating or reflective coating to administer onto the subject. The advantages of this method are "high accuracy and nearly unlimited resolution in time". This would be an interesting addition to our design but for practicality and the purpose at hand, we chose to make our design as noninvasive as possible.

We foresee this project significantly improving the quality of life of impaired persons. By allowing below the neck disabled individuals to regain command of their movements,

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2014 IEEE Canada International Humanitarian Technology Conference - (IHTC)
978-1-4799-3996-1/14/$31.00 ©2014 IEEE

we hope to return a sense of security and control to their lives. The chance to be free from being bed ridden will be given to those with the ability to move their eyes, allowing them to once again, or possibly for the first time, to integrate themselves with society.

III. Specifications

Our proposed design for an eye controlled electric powered wheelchair has the same range of motion and ease of movement that a standard joystick powered wheelchair has but with the addition of several features. The most notable feature is the purpose of this design; all movements are generated solely by eye commands. The setup of our wheelchair consists of a mounted display in the form of a laptop screen with an eye tracking unit located 6 inches above the users lap and approximately 18 inches to 24 inches away from the user's eyes. The laptop and eye tracker setup are placed on a holding tray spanning the two armrests. It will be through the laptop display that the user can choose what direction they wish to move in, anywhere from forward to backward movements, and left and right rotations for turning. The interface display also contains a live stream from a webcam directed towards the front of the wheelchair to prevent even the slightest impairment of vision when commands are being entered. Commands can only be entered when looking at the screen, preventing any accidental movements from occurring when looking around. When the gaze is directed outside of a directional command range, whether on screen or off, the wheelchair will remain stationary or, if it was in motion, come to a stop.

The wheelchair has the mobility to handle most flat and bumpy terrain due to its six wheel design and ATX Suspension system. The on board battery offers 4 to 6 hours of usage with a top speed of 4mph to allow a safe, comfortable pace of movement. The interface is not limited by the time of day with a LCD screen and infra-red eye tracking; directional commands do not cease functioning in the dark. The battery on board the wheelchair powers the motors, the eye tracker, and charges the laptop battery, so that no individual components must be charged separately.

IV. Design Overview

This design is an intricate integration of hardware and software. The hardware has to first observe the surrounding environment and send necessary data to the computer. Then the computer has to run software in order to analyze such data and make a decision as to where it is significant and if so, where to direct the wheelchair. Once a wheelchair direction is decided upon, the laptop software is to tell the DAQ hardware what voltage to send to the wheelchair.

A. Hardware

The prototype begins with the eye tracker (Figure 3) that uses infrared technology to track the users gaze location. The user stares at a specified location on the screen in order to move in a desired direction. The tracker contains two IR (infrared) source patches that shine onto the user's eye. The IR sensor then locates the IR reflection and transfers eye location data to the computer. At start up, the user will need to calibrate his eye location through a set calibration program.

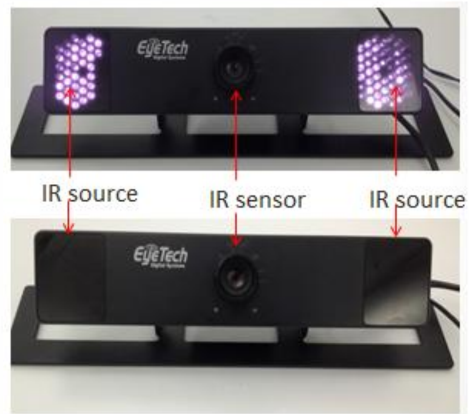

Fig 3. Eye Tracker

The data transfers from the eye tracker to a laptop which is positioned on top of the wheelchair tray located above the user's lap. The eye tracker is placed on top of the laptop keyboard. The computer then sends data through LabVIEW into a DAQ (Data Acquisition) unit (Figure 4). This unit is a software friendly device that allows LabVIEW programs to output analog and digital voltage signals easily. Through LabVIEW, we are able to translate the eye data provided through the eye tracker, into output voltages that indicate desired movement directions.

Through thorough testing and probing, it was found that the original joystick, attached to the main control module of the wheelchair, outputs basic analog voltages directly proportional to the physical movement of the joystick. The joystick is connected to the control module through a pin connection. The pin layout is shown in Figure 5 on left. These analog voltages are detected by the controle module through the pin connection and used to determine how to move the wheelchair. It was discovered that a voltage of 2.5V at certain joystick pins kept the wheelchair idle and any variation caused different movements. These voltages were programmed through LabVIEW to be outputted from the DAQ into the control module that contained the joystick. The joystick was thus removed permanently and replaced by wires connected to the DAQ. The picture on the right of Figure 5 shows the control module and the red circle indicates where the joystick was once mounted. The diagram on the left of Figure 5 indicates in green what voltages needed to be created by the DAQ and provided to the chip while pins in red are to be left alone and served the purpose of powering the original joystick.

Fig 4. Data Acquisition Unit

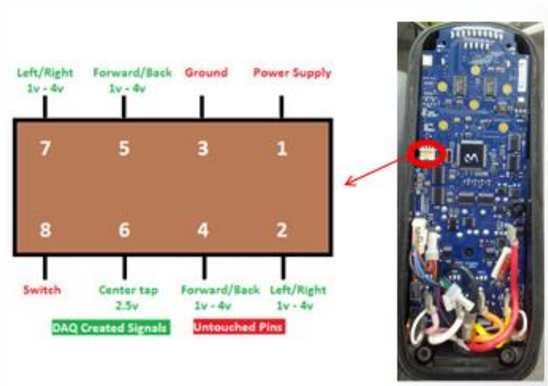

Fig 5. Pin Layout (Left); Control Module (Right)

B. *Software*

The software utilized in our eye controlled electric wheelchair prototype is divided into two distinct components. The first is a C++ script that controls the eye tracker and generates XY coordinates of the users gaze, and a LabVIEW program which processes this data to determine the appropriate voltage commands to be generated for the motors. A general block diagram for this can be seen in Figure 6.

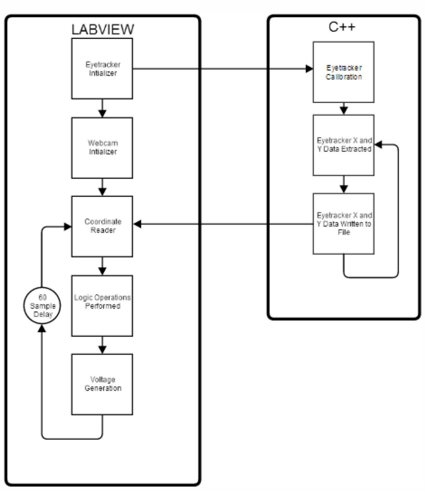

Fig 6. Software Block Diagram

The C++ script was donated along with the eye tracking unit. It was modified slightly to remove the need for password protection and to eliminate the camera stream from the infrared lens. The data writing process was also implemented into the code to provide a way to transfer the gaze coordinates to the LabVIEW program. Then the device is powered on and the calibration process starts. This calibration consists of staring at several consecutive circles located at different locations on the laptop screen. Once completed, the calibration window will close and X and Y coordinates of the average gaze location of both eyes begins to be outputted. This data is continually written to a simple .txt text file where it is then imported into LabVIEW.

As Figure 6 shows, the LabVIEW component can be divided into 4 modules:

1) Eye Tracker Initializer: This is the first section of the program to be run. It calls the C++ script that controls the eye tracker and initializes it by prompting the calibration process. Once calibration is completed, it minimizes all unnesscary command windows as the script begins writing gaze data to text files.

2) Webcam Initalizer: As the calibration process is being completed, the webcam is powered on. The webcam is connected to the laptop through a USB port. A window in which the video will be streamed is also generated along with the interface command structures. The interface command structures. are preset visual ranges that correspond to each directional command. The webcam spans a 135 degree view and is continuously utilized by LabVIEW to stream a realtime feed of what is in front of the wheelchair. A picture of the control interface can be seen below in Figure 7:

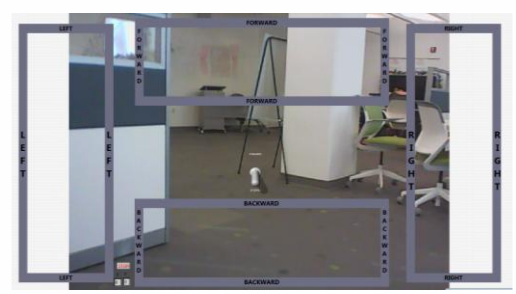

Fig 7. Control Interface

3) Coordinate Reader and Data Delay: Once calibration has been completed and data is being written into a text file, the program begins importing the data. The text file is read during breaks in the writing operation. The XY location values are then converted to a numerical variable for processing. This is done with a simple string to double conversion of each line of the text file where the first line corresponds to the X coordinate on the screeen and the second corresponding to the Y coordinate. The converted data is then passed to logic operators once every sixty loop iterations. The purpose of the data import delay is to prevent any slight or unintentional movement of the wheelchair. For example, if the user were to quickly move their gaze across the interface screen without the intention of prompting a command, no response will be registered.

4) Logic Operators and DAQ Voltage Generators: It is in this module of the program that XY data is interpreted as directional commands. Conditional operations are performed on the imported gaze data to test whether the location of the gaze falls within one of the preset ranges of the four available directional windows. These are shown at the four sides of the control interface displayed in Figure 7. If the user is looking at one of the directional boxes located on the interface screen, then a logic True is passed on which in turn prompts a motor response. If the XY coordinates of the gaze fall outside of one of the four ranges, then no signal is passed along and the motors do not receive any signal.

There were several different evaluations done on our eye tracking wheelchair system in order to test the effectiveness of our design. Co-author Domenico Repice acted as the operator during the trials due to his familiarity with the program LabVIEW and because he was the one who designed the layout of the control interface.

Testing was initially done to determine the best position for each of the command blocks shown in Figure 7. The original design of the interface had all blocks touching with a small space in the middle for a no-input zone. This proved unreliable because it was too easy to accidentally jump to another command input.

With the rough placement of each command block, now as outlines to allow more webcam streaming visibility, the following testing procedure was followed to determine the appropriate spacing between blocks: the user must be able to hold the current command by looking at the edge of a command block for at least 15 seconds without accidentally inputting a different command. This was done to ensure the maximum size of the block was being used along with minimizing the risk of an accidental command input.

V. FUTURE RECOMMENDATIONS

There are several areas of improvement we discovered along the way in our design process. The current wheelchair tray that is equipped is a plastic desk chair fastened to the arm rest. When the wheelchair changes direction quickly, the tray will slightly move due to lack of stability. The laptop will move along with the tray. If the laptop moves, the reading by the camera will be less accurate than desired. A store bought wheelchair tray or something with a stronger durability such as wood or metal, is suggested.

Another recommendation would be to reinstall the joystick. Currently the wires coming from the DAQ take the place of the physical joystick causing the wheelchair to be immobile if the laptop is not up and running. A switch could be added that can actively switch inputs from the DAQ to taking inputs from the joystick. Although this feature would be unnecessary for our target user, those with severe paralysis of limbs, it would be useful for any assistants that need to move the chair or if anyone with a less severe injury/handicap were to need the chair. Furthermore, it would add a more esthetically pleasing look to the wheelchair.

A recommendation involving the web camera would be to include more web cameras. With more resources it would be possible that every block of the control interface be its own web camera stream. This would allow the user to look at the "Backward" control block and the user would actually be able to see behind them as they go.

The final recommendation is to create a one-click system. Currently the system requires the user to be able to understand and run LabVIEW. They have to open up the program and run it. Also, the user currently has to calibrate their position every time the program is run. A one-click system would have only one icon on the desktop of the computer that when clicked, would run the program and would have saved the user's calibration scores. It makes sense to save the calibration scores for there will most likely only be one person to use the wheelchair. It is assumed that someone is with the user for assistance and will one-click start the system.

VI. CONCLUSION

Wheelchair control through the use of an eye tracker is possible and has been achieved. The design presented allows control of a wheelchair through a plethora of hardware and software components to create an effective system. This system included an eye tracker, a laptop, a DAQ, an inverter, a web cam and electric wheelchair. These pieces comprised the hardware. The software included LabVIEW programs and C++ scripts used to process the data and interact with the DAQ and eye tracker. While not a perfect system the wheelchair now stands able to be controlled solely through eye movement and thus help persons with moderate/severe physical disabilities.

VII. ACKNOWLEDGMENTS

The authors give thanks to the project advisor, Dr. Mark Jupina, for his valuable input and guidance. Also we give thanks to Mr. Simmons for donating an electric wheelchair and to Eyetech Digital Systems for donating the Eye-Tracking sensor. These people were essential to the success of this project.

VIII. REFERENCES

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