

A Small and Low-Cost Eye-Tracking System for Amyotrophic Lateral Sclerosis Patients

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Abstract

The human body is capable of anything, from communication to movement; these actions are necessary to participate in today's society. Sometimes, the human body experiences an illness that can impair these abilities. ALS, commonly known as Lou Gehrig's disease, is one of many diseases that can alter a person's life by slowly taking away the ability to move and communicate. To date, a cure for ALS has not been found, but many different products have been and are being created to assist patients to overcome the hurdles of this disease, allowing them to continue participating in society. When ALS causes a person's muscular system to stop working, one of the few things left unaffected are the eyes.

The research reported here is to utilize an existing sensor and develop software that allows a patient to navigate a basic computer screen with only his or her eyes. There are also several commands that will allow patients to have easy access by just hovering over command icons with their eyes. This proposed system will have potential in the marketplace for furthering accessibility for patients with ALS and other muscle degenerative diseases.

The applications of the ALS eye-tracking system are to replace current devices that are used. Current devices that aid patients with communication are expensive, costing from \$5,000 to \$10,000. These devices also tend to be large and difficult to set up. Using cheaper and smaller eye-tracking devices should address the issues with current devices. The research's goal is to find and modify a cheaper device with eye-tracking capability and implement software that will allow its user to control basic PC functions, such as moving the cursor and clicking. Another goal is to allow the user to have some feedback from the tracking software, such as turning on or off an LED, or playing an audio file from the computer.

History of ALS

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many diseases that can alter a person's life by slowly taking away the ability to move and communicate. To date, a cure for this disease has not been found, but many different products have been and are being created to assist patients to overcome the hurdles of this disease, allowing them to continue participating in society. When ALS causes a person's muscular system to stop working, one of the few things left unaffected are the eyes.

This paper begins by describing the history of ALS, followed by a section that explores eye-tracking systems and current technology used by ALS patients. A comparison between the existing technologies and the proposed system is presented and, finally, results and conclusions.

Amyotrophic lateral sclerosis (ALS) (Fang, Kamel, Sandler, & Ye, 2008; Vivekananda, Johnston, McKenna-Yasek, Shaw, Leigh, Brown, & Al-Chalabi, 2008; Fallis & Hardiman, 2009; Mackenzie, Rademakers, & Neumann, 2010; Sutedja, van der Schouw, Fischer, Sizoo, Huisman, & Veldink, 2001; Scarmeas, Shih, Stern, Ottoman, & Rowland, 2002; Brooks, Miller, Swash, Munsat, & World Federation of Neurology Research Group on Motor Neuron Diseases, 2000; Shatunov et al., 2010) is a "progressive neurodegenerative disease that affects nerve cells in the brain and the spinal cord" that usually affects people between the ages of 40 and 70. In the 1860s, Jean Martin Charcot, a French neurologist, discovered the disease while studying spinal cords (Vivekananda et al., 2008). The disease originates in the spinal cord, inside one of the lateral regions, home for muscle controls and nerve cells.

When a person has ALS, the muscles do not receive any "nourishment," which would usually come via a signal to the nerve cells. Eventually, the muscles start to atrophy until neurons are completely damaged. The loss of neurons in the muscles makes it easier for the brain to lose control of "initiating" muscle movement (Vivekananda et al., 2008). ALS can start with a certain muscle group within the body but will eventually break down all of them. Because of this, affected people may not be able to move their limbs or even hold an object. Patients are usually unable to move, diminishing their overall lifestyle (Fang et al., 2008; Vivekananda et al., 2008; Fallis & Hardiman, 2009).

In the late 1870s, scientist Louis Javal first noticed that eye movement was not smooth but rather had many pauses and fixations (Fallis & Hardiman, 2009). He studied people reading books and concluded that the eyes see several visual images combined together at once, which causes them to move in an unsmooth sweep. Nearly a century later, in the 1950s, Alfred Yarbus discovered relations between fixation and the interest in an object (Fallis & Hardiman, 2009; Sutedja et al., 2001; Scarmeas et al., 2002). His studies, which took many years, concluded that eyes have a predetermined thought process based on objects they have seen before. Eyes basically record what they have seen before that attracts them the most. A person's eyes will tend to first look at something that attracts them, which was recorded by the eye and brain at an earlier time. Eyes will have an order of elements and know how often a person tend to look at them, making the objects pop out to the eyes the next time they see them (Fang et al., 2008; Vivekananda et al., 2008; Fallis & Hardiman, 2009; Norloff, 2017).

In the 1970s, the concept of eye tracking spread worldwide, and scientists were making significant improvements in recording eye movements. More measurements were being

accurately obtained and recorded, which allowed scientists to better understand how the eye works. This led to the “strong eye-mind hypothesis” in 1980 (Fallis & Hardiman, 2009).

This hypothesis stated that there is no delay time between when the eye sees an object and when the brain processes the information. This was a major finding, since many people did not believe that it could be true. Studies showed that the hypothesis was correct, and there is “no lag between what is fixated and what is processed” (Fang et al., 2008).

In 2001, a Swedish “garage startup,” Tobii, was one of the first companies in the world to transform eye-tracking studies into products to market globally (Fallis & Hardiman, 2009). Shortly after its startup, Tobii created the world’s first plug-in eye-tracking system that could track eye movement and behavior. The product was used worldwide by scientists to continue studying eyes. By 2005, Tobii once again created the first computer with a built-in eye-tracking camera, for the assistive technology market (Tobii, 2018). These products eventually led to the creation of other products, such as eye-tracking glasses and eye-controlled communication devices. Tobii is still the largest eye-tracking technology company in the world today (Tobii, 2018).

Several years ago, the Eyegaze Edge company created the first ALS eye-tracking system to help patients live normal lives while battling their disease (Norloff, 2017). Eyegaze Edge is a system that can help an ALS patient control lights, surf the Internet, take classes, play music, and much more. It is simply a computer with an eye tracker built into the screen. A patient moves his or her eyes to complete everyday tasks because they cannot do it physically. This allows patients to not feel totally helpless, giving them control over their lives in ways previously impossible. These devices allow for speech synthesis, quick communication shortcuts for phrases. This program is also customizable. This is something similar to the product that we are planning to develop.

Current Technologies vs the Proposed System

Researching ALS eye-tracking products reveals only a few schools engaging in projects related to eye tracking. An extensive commercial and academic literate review has been conducted (see References) and reveals no optimal system to help ALS patient communicate. To meet this need, this paper describes a novel eye-tracking system that is small, portable, easy to use, and affordable.

The goal is to develop a successful, user friendly, customizable eye-tracking system for ALS patients. It should use an open source code and be able to be connected to any PC/laptop computer. The ultimate goal is to create customizable software that can be used by anyone needing assistance for eye tracking. We plan to create this project to help ALS patients to facilitate communication while having the option to continue using their own voice. We wish to see ALS patients continue fitting in society with this assistive technology.

Current products in the ALS community have an initial price of \$5,000 to \$10,000. With a significant cost, these machines are also large and cumbersome, causing discomfort while in use. They are heavy and can cause claustrophobia because they force users to have their

heads in an enclosed space. These are not the only negative effects of current technology; they also require extensive calibration that can quickly exhaust the user, making these machines less enjoyable and problematic. The product we have developed is a fraction of the price, less than \$200, while being easy to initially set up and calibrate with a short five-minute tutorial. This allows for the user to easily use the integrated GUI that performs functions by only eye movement.

At first, the proposed system was based on eye-tracker hardware from Tobii. Our research group purchased Tobii eye-tracker hardware without software and then wrote original code to enable it to work with any computer.

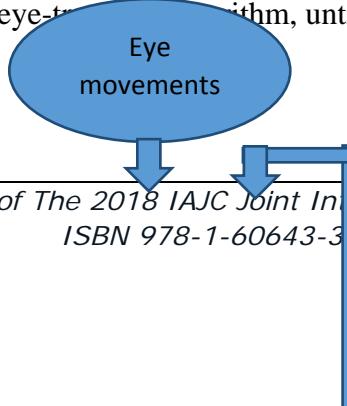
Design Methodology

To accomplish mouse movement from the eye tracker, a script was created to slightly move the mouse and used the Tobii to move the mouse where the user is looking. To generate a user-friendly GUI interface, a program using Microsoft Visual Studio was developed to create buttons that would activate when the user/patient looked at them for a predefined period of time. The program would play a sound file, depending which button was pressed.

This software can move the mouse cursor on a Windows machine based on the reading from the Tobii eye tracker. The Tobii software that the eye-tracking sensor uses does not directly move the mouse cursor to where the user is looking. Instead, it allows users to move the mouse cursor to where they are looking by either pressing a button or by physically moving the mouse. The user can set up a button on the keyboard so that the mouse cursor will jump to the location of where the user is looking when pressing that button. Likewise, if the mouse is moved even slightly, the cursor will jump to where the user is looking.

Both of these options are not suitable for ALS patients because requiring them to move or press an object physically may not be possible. Circumventing this issue requires that the mouse constantly move on its own so that the cursor would always jump to the location the user is looking. As it turns out, using AutoHotKey, a simple script can be written to complete this task. This way, no other movement aside from the eyes is necessary to move the mouse cursor on a Windows machine.

Figure 1 illustrates the process of eye tracking. First, the eye should move. Once movement is detected, the eye-tracking software is initialized. If initialization fails, the system tries to perform this task until it is successful. Then the core of the process (eye detection) occurs. Many factors should be considered, including eye color and darkness, which determine how easily the software can detect the eye. Glasses also affect the eye detection process. If the proposed system cannot detect the eye, a message will appear after predefined trials to detect the eye. Once the eye is successfully detected, a calibration should take place followed by activation of a continuously eye-tracking algorithm, until the user/patient unplugs the system.



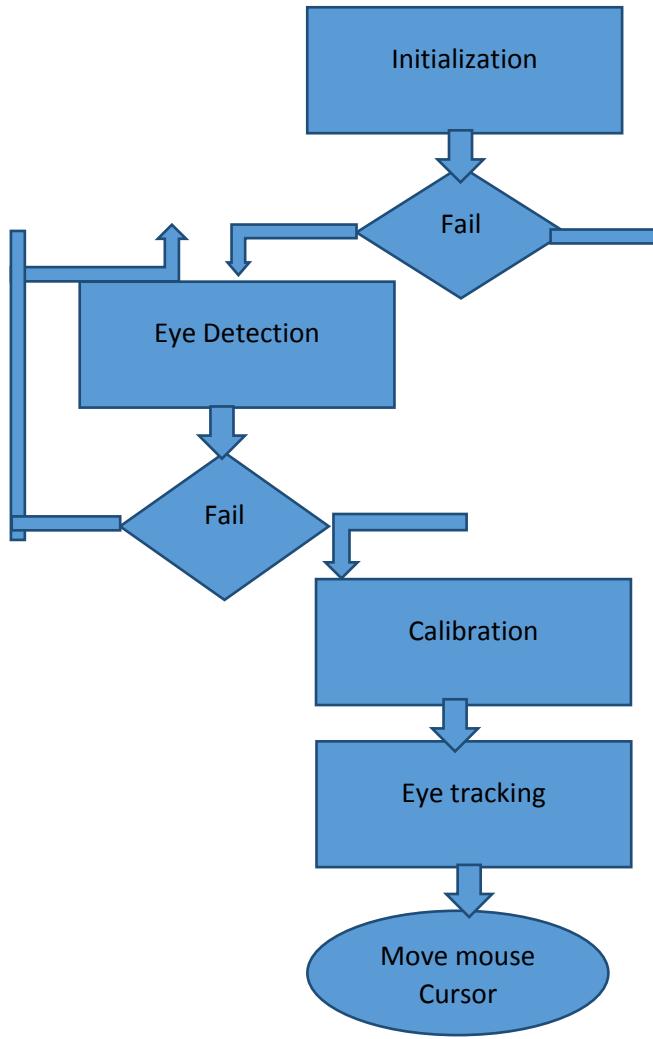


Figure 1. Eye tracking process.

Proposed System Advantages

In testing the system, the eye tracker successfully tracking each person's pupils with the mouse moving exactly where the user looked. The system is meant to be an affordable, easy-to-use alternative to current ALS assistive technologies. As previously mentioned, these devices are expensive, complicated, and tiresome for the patient to use. In addition, lack of insurance support limits access to current technology. This is why the proposed system can compete with existing systems. It is compact and sits in a laptop on the bedside table, eliminating the possibility of claustrophobia, and patients can sit comfortably while using the Visual Voice system. Most pre-existing programs use a standard voice or electrical signals to communicate while the proposed system can use the patients' personal voices, as long as they record them prior to losing the function of talking. The search team can allow them to integrate phrases directed to loved ones or request assistance to provide an enjoyable and personalized experience.

Risk

Because the eye tracker uses infrared imaging to detect eye movement, safety was a major consideration. Looking at the user safety manual for the eye tracker, we were able to find warnings about infrared use, as well as some of the compliance standards. One such standard is IEC/EN 62471:2008, which places devices into risk groups based on level of exposure. This standard includes devices using infrared light. A device placed into the low, medium, or high risk groups must have specific wording in the safety manual. However, the Tobii eye-tracker manual does not include warnings related to the standard; apparently, the device is exempt.

Some risks are important to consider while using the device. The first is for epileptics due to the computer screen and lights; they should exercise caution and stop usage if the device causes discomfort. The second risk is related to the infrared imaging, as it can affect medical equipment sensitive to infrared light. The final warning is related to magnetic fields, as the device could interfere with pacemakers within a six-inch distance.

Conclusion

ALS, commonly known as Lou Gehrig's disease, is one of many diseases that can alter a person's life by slowly taking away the ability to move and communicate. To date, a cure for this disease has not been found, but many products have been and are being created to assist patients overcome the hurdles of this disease, allowing them to continue participating in society. When an ALS patient's muscular system stops working, one of the few things left unaffected is the eyes.

Our goal is to utilize an off-the-shelf sensor and develop software that allows a patient to navigate a basic computer screen by eye movement. There are also several commands that will allow patients easy access by just hovering over them with their eyes. This system will have potential in the marketplace by furthering accessibility for patients with ALS and other muscle degenerative diseases.

In the future, this software will be tested by ALS patients at Charles T. Sitrin Health Care. Study feedback will determine improvements or changes to the software.

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