Environmental Controls Laboratory

(Electro-Oculography Application)

CleveLabs Laboratory Course System Version 6.0

Introduction

Spinal cord injury, cerebral palsy, and stroke are some examples of clinical problems which can have a large effect on upper extremity motor control for afflicted patients and may cause functional disability or handicap. Patients may have difficulty performing every day tasks at home or work. Patients can find it difficult to eat, drink, use a tool, or write. Another important activity that can be affected by the loss of upper extremity motor control is using a standard mouse for computer cursor control. Applications controlled by these inputs include word processing and computer-aided design (CAD) programs. Additionally, individuals without access to computers and the Internet are at a large disadvantage socially, economically, and intellectually. Therefore, the development of assistive computer interfaces is becoming increasingly important.

Figure 1. Clinical disorders such as a spinal cord injury can greatly affect functional tasks such as computer use.

Assistive computer interfacing techniques can enable computer cursor control for disabled populations. Since the upper extremity is disabled, a new control input source must be used for the cursor position and click controls that are typically found on a standard mouse.

The development of these assistive devices to restore computer access can have important benefits to society. First, they improve access to computers and the Internet for individuals suffering from movement disorders symptoms. By improving access, the proposed assistive technology should increase an individual's ability socially, economically, and intellectually. Assistive technologies can allow individuals to continue to work in their current jobs if a computer is a mandatory tool for their work, decreasing the overall economic impact on society.

In this laboratory session students will develop an algorithm to control the position of the dot on a screen and toggle its color based on the electro-oculography (EOG) signal. Students will learn how an approximately linear relationship exists between the position of the eye and the voltage of the EOG signal. They will then calibrate this relationship and implement it in a functional algorithm that can be extrapolated to computer cursor control.

Equipment required:

- CleveLabs Kit
- CleveLabs Course Software
- Five (5) snap electrodes
- Measuring Tape
- Microsoft Excel, MATLAB® or LabVIEW™

Background

The current standard handheld computer mouse device controls two major functions. First, the mouse translates the planar position of the mouse on a flat surface into the planar position of the cursor on the screen. This variable has two degrees of freedom including horizontal and vertical motion. Secondly, the standard computer mouse has an input for selecting items on the screen typically known as a click function.

When an individual loses upper extremity function, a new system needs to be developed that can take advantage of whatever remaining voluntary function they have to provide access to control a computer. For example, in the case of a stroke where only one upper extremity is affected, a patient may simply use their other hand to control a standard computer mouse. In another example, where a subject has had both arms amputated due to an accident they may be able to use their remaining voluntary shoulder movement to control the position of the cursor on the screen. As you can imagine, as the degree of disability of a person increases, the potential sites that can be used as inputs to control a computer mouse decreases.

For the purposes of this laboratory session, we will consider a severe case in which movement is severely limited. Consider the case of a high level spinal cord injury subject who has sustained an injury at the cervical level at approximately C3 or C4. In this case, the patient would have virtually no movement left from the neck down. Therefore, our potential input control options to restore computer access are extremely limited. Some potential sites that still remain under voluntary control include head movement and voice commands. Some commercially available systems currently exist and take advantage of this remaining control (Table 1). Other systems in the table are available for locked in subjects, such as spinal cord injury, who have very small motions still available in their arms.

Another potential source of voluntary control in these subjects is eye movement. You should have previously completed the laboratory session EOG I. You will use the knowledge gained in that lab session here. During this laboratory session you will learn how the horizontal and vertical position of the eye could be used to control the position of the cursor on the screen. Additionally, you will learn how blinks can be used to control the click features of a mouse.

Table 1. Existing Commercially Available Adaptive Computer Equipment

Company	Product	Method of Operation
Enablemart (vendor)	SAM Joystick	Joystick switch control moves cursor at a constant speed
Origin Instruments	Boost Tracer Head Mouse	Gyroscope senses head movement and transmits it to computer using radio frequency waves
Origin Instruments	The Head Mouse	Wireless optical sensor tracks a tiny, disposable target placed on the user's forehead or glasses
Commodio Inc.	Q Pointer	User can "point" at each object by voice, using a minimal vocabulary
Enablemart (vendor)	Big Keys LX	Large keys in order to locate and operate keys on a keyboard

Experimental Methods

Experimental Setup

This laboratory will use three channels to record both horizontal and vertical EOG from the subject. You should watch the setup movie included with the course software prior to starting.

1. Your BioRadio should be programmed to the "LabEnviroControls" configuration.

2. You will need five snap electrodes for this laboratory. **NOTE: For this laboratory, you may want to attach all of the snap leads to the snap electrodes before you place the snap electrodes on the subject. It may be uncomfortable for the subject if you apply pressure to these electrode positions afterwards.** Properly prepare and clean the surface of the skin before applying any snap electrodes (Fig 2). Place one snap electrode above and one below the left eye. These electrodes will be used to measure vertical displacement of the eye. Place one snap electrode to the left of the left eye on the left temple and one to the right of the right eye on the right temple. These electrodes will be used to measure horizontal displacement of the eyes. Finally, place the last electrode between the two eyes, just above the bridge of the nose. This electrode will be used as a ground.

3. If you have not already, attach snap leads to all of the electrodes. Connect those snap leads to the harness input channels 1, 2, 3, and the ground using the picture below as a reference (Fig 2). Take all lead wires and run them behind the ear so the subject has an unobstructed field of vision.

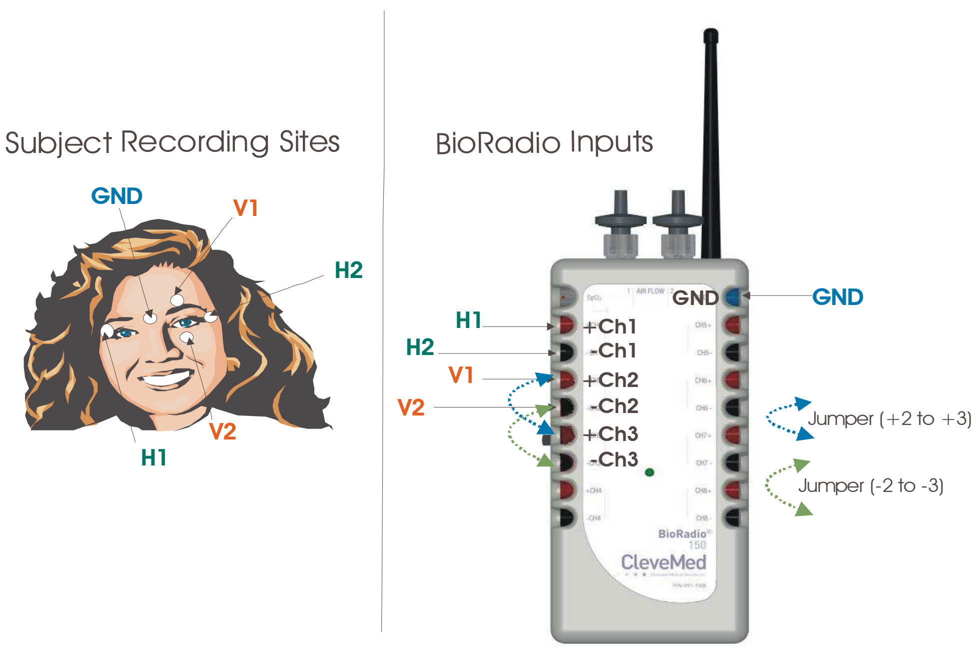


Figure 2: EOG electrode placements.

Procedure and Data Collection

For each of these experiments, it is very important that the subject keeps their head still while tracking objects. Only the subject's eyes should move to track the object.

1. Run the CleveLabs Course software. Select the "Environmental Controls" laboratory and click on the "Begin Lab" button.

2. Turn the BioRadio ON.

3. Click on the green "Start" button.

4. In this laboratory, you will monitor subject eye movement.

5. Click on the Raw EOG tab. You should see data scrolling across the screen. The first two channels are the horizontal and vertical DC value of the EOG. The third channel is the AC value of the vertical EOG. You many need to use a very small range (approximately 1uV) on the DC plot to see the changes when the eye moves.

6. First we will just examine the signal. Make sure that the time scale is set to 6 seconds. Then instruct the subject to keep their head still and look all the way up for 2 seconds and then all the way down for 2 seconds. This should give you some idea of the range of the vertical EOG DC signal. Readjust the range of the plot so you can see it well.

7. Now have the subject keep their head still and look all the way up for about a second, then straight ahead for about a second, and then all the way down for a second. Report a screen capture of this to show the different voltage levels.

8. Repeat steps 6 and 7 for the horizontal.

9. Instruct the subject to make several blinks and examine what happens to the vertical EOG AC plot. Capture a screen shot during the blinks. Save approximately 20 seconds of this data to a file called "blinking".

10. Click on the Spectral Analysis Tab. Then click on the frequency plot. Select the channel to process to be channel 3. We will not see anything interesting if we complete a spectral analysis of the first two channels since it is a DC signal. You can try it if you want later.

11. Turn on the frequency plot. Set the data collection interval to 500ms. Then instruct the subject to blink quickly but precisely 5 times in a row. Examine what happens to the estimated peak frequency when they do this a few times. Write this number down for later use in the application.

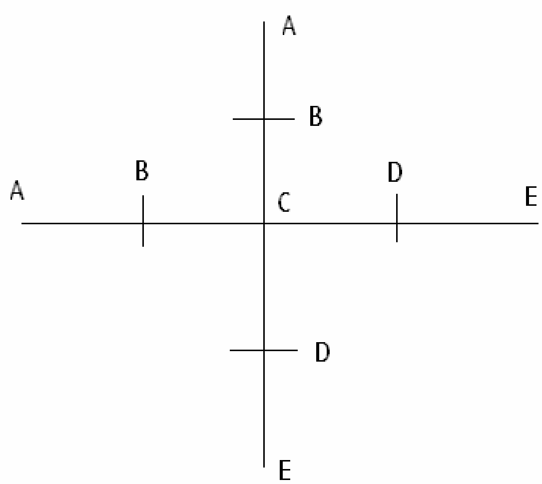
12. Click on the processing and application tab. In this application you will be using the EOG signal to move a dot around on the screen and also change the color of the dot.

Imagine a spinal cord injury patient with a high level injury that leaves them paralyzed from the neck down. They would have no way to use a computer as we do with a mouse. In order to give them access to controlling a computer, we need to make use of whatever function they have left for control. One function that remains under their control is their eyes. Therefore, for this laboratory you can imagine that moving the dot around on the screen is analogous to moving the mouse and that changing the color of the dot is analogous to clicking the mouse.

13. Turn on the Dot Control Switch and then set the control type to manual. Then use the manual controls to see how the eye control plot should work. A value of 1 on the up/down switch corresponds to all the way at the top of the box, where as a value of –1 corresponds to all the way at the bottom with 0 in the middle. It is similar in the left to right switch. The color switch toggles the color of the dot from red to blue. The horizontal and vertical values can be seen in the horizontal and vertical values to the left of the plot. These values will be important to monitor later when the plot is actually under eye control.

14. Now that you understand how the values on the plot work, turn the eye control plot off.

15. You need to setup a grid in front of the subject to look at. The grid can be seen in the plot below with each letter being 1 foot apart. One way you can setup this grid is by using a tape measure. Use the tape measure to mark off five increments that are 1 foot apart. You should have 4 total feet. Hold the tape measure horizontal at eye level in front of the subject at a distance of about 1 foot away. The center of the tape measure or yardstick should be aligned with the subject's nose.



16. The letters on the plot above correspond to the letters in the "Location for Collection" drop down menu in the EOG calibration section. The tape measure should currently be horizontal so you are starting with the horizontal axis. Set the "Axis for Calibration" to be horizontal. Then select the location to be A. Instruct the subject to focus on location

A on the tape measure without moving their head. When you are sure they are looking at A, click on the collect data switch. The horizontal EOG DC value will be filled in under –2.00ft column and horizontal row of the Eye Voltage Data matrix.

17. Repeat for positions B-E on the horizontal axis.

18. Now turn the tape measure vertical and line up position C with the subjects eyes. The tape measure should still be about one foot away from the subject. Collect data for each of the vertical positions to fill in the rest of the Eye Voltage Data matrix. Once again it is important that the subject keeps their head still and only moves their eyes.

19. After you have collected all the data in the Eye Voltage Data matrix, you will see how there is a fairly linear relationship between eye position and voltage. In the Linearization Check box, set the axis to plot to H (horizontal) and click on the create plot switch. This will plot the raw data and the linear fit as well as show the mean squared error between the two. **BE SURE TO WRITE DOWN THE NUMBERS IN THE MATRIX BEFORE GOING ONTO THE NEXT STEP. ONCE YOU CAPTURE A SCREEN SHOT THE NUMBERS WILL BE RESET TO ZERO. YOU WILL NEED THESE VALUES FOR A FUTURE PROCEDURE.**

20. Create a screen shot of plots for both the horizontal and vertical axis.

21. Now you should be convinced that there is a linear relationship between eye voltage and eyes position. You are now going to calibrate the signal to control the position of the dot. Turn on the Dot control switch.

    Start with the horizontal plane. Position A should correspond to the left hand side of the Command/Control plot and position E should correspond to the right side. In other words, you need to develop an equation that normalizes the values from A to E in the horizontal row of the Eye Voltage Data matrix from 0 to 1. You can do this with an equation that is setup in the following form:

    > Control Value = current eye voltage * sensitivity + offset
    >
    > We can utilize a sensitivity coefficient with a linear relationship in our algorithm since you previously showed that the EOG signal varies linearly with eye position.
    >
    > Your goal is to ensure that the control value for both the horizontal and vertical position of the eye falls between 0 and 1.
    >
    > First, based on the typical EOG voltages that you recorded for the horizontal eye movements, set the horizontal sensitivity to a number that, when multiplied by those voltages, would produce values close to between 0 and 1. Now examine the digital indicator labeled “horizontal value” which is located just below the “Eye

Control" switch. This is the current horizontal eye control value. This value should at least be on the order of 10's now that you are multiplying the raw eye voltage by your sensitivity. If it is not, adjust your sensitivity until it is.

Finally, adjust the horizontal offset until the value is between 0 and 1

22. Repeat for the vertical axis.

23. Now instruct the subject to look left, right, up, and down. If the dot is completely off the screen you may want to click on the "Center Dot" button to reset the dot to the middle position. This can occur since the subject may have moved their head from the original calibration condition.

24. If the dot moves far off the screen when they look back and forth, your sensitivity values are too high and need to be readjusted. If the dot isn't moving at all, then the sensitivity is too low and needs to be increased. Continue to adjust the sensitivity and offset values until the subject can effectively control the position of the dot on the screen.

25. Now have the subject look up, down, left, and right. The dot should move accordingly.

26. Now that we have the dot moving in space correctly we will learn how to change the color of the dot by blinking. Earlier you examined what happened to the estimated peak frequency when the subject blinked 5 times in a row. If you cannot remember these values, go back to the frequency domain plot and try it again. Set the maximum frequency peak to be just above this value and the minimum peak frequency to be just below this. You may have to tune these to get this to work. The estimated peak frequency is calculated over the last data collection interval. The last six peak frequencies are stored in memory. The number of past samples control refers to the number of past samples that must be in your specified frequency range to toggle the color of the dot. When a past sample is within the range, the green LED next to it turns on. For example if you set this value to 3 and the dot was blue, if the past 3 values are in your specified range then the dot will toggle to red. If the past 4 values were, the dot will toggle quickly to red, but then back to blue because two sets of 3 went by. With practice and tuning of the frequency range, the subject should be able to toggle the color of the dot back and forth.

Discussion Questions

1. Describe any difficulties that you encountered in calibrating the EOG signal to control the position of the dot on the screen. Describe any other methods that could be used to improve this algorithm.

2. Describe any problems you had with training the subject to toggle the color of the dot by blinking. How long did it take to train the subject? What methods could you employ to improve this algorithm?

3. Propose some other novel algorithms or input sources that could be used to restore computer cursor control function for an individual with a high level spinal cord injury.

4. While blinking may be useful to control the click feature of the mouse, it could be a potential source of noise for controlling the position of the dot. Therefore, it should be filtered out of the signal. Using MATLAB or LabVIEW, import the data from the "blinking" data file that you created. Then create a filter that could be used to remove blinking from the EOG signal.

References

1. Croft, RJ, RJ Barry. Removal of ocular artifact from the EEG: a review. Neurophysiol Clin 2000: 30: 5-19.

2. Enderle, JD, Blanchard, SM, and Bronzino, JB. Introduction to Biomedical Engineering. Academic Press, San Diego, 2000.

3. Guyton and Hall. Textbook of Medical Physiology, 9th Edition, Saunders, Philadelphia, 1996.

4. Kandel ER, Schwartz JH, Jessel, TM. Essentials of Neuroscience and Behavior. Appleton and Lange, Norwalk, Connecticut, 1998.

5. Rhoades, R and Pflanzer, R. Human Physiology. *Third Edition.* Saunders College Publishing, Fort Worth 1996.

6. Sadasivan PK, D Narayana Dutt. ANC Schemes for the Enhancement of EEG Signals in the Presence of EOG Artifacts. Computers and Biomedical Research, 29, 27-40 (1996).