Feasibility of Electroculography as a Command Interface for a High Tetraplegia Neural Prosthesis

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Abstract:
Following high cervical spinal cord injury, few voluntary actions remain for the control of a neuroprosthetic for restoration of arm function. One of the remaining actions following such an injury is eye gaze direction. This study explores the use of eye gaze direction, measured using the electroculargram (EOG), as a command source for controlling the position of the arm in a typical workspace. Using the EOG with a robot arm as a proxy to a stimulated paralyzed arm, the feasibility of such a command source is demonstrated.

1. INTRODUCTION
A cervical level spinal cord injury can result in significant loss of function and impact both the injured individual as well as their family and care givers. Neural prosthetics offer a potential solution to this loss of function and may enable a greatly enhanced level of self-dependence [1,2]. With a high level injury, the amount of function which must be restored is substantial, while the number of voluntary actions available to serve as command inputs is markedly limited. The problem comes down to one of controlling the position and orientation of the hand in space with the remaining voluntary actions which are limited to the head, neck, and face due to the injury level. Despite the significant loss of many voluntary actions, a number of potential command sources remain by which the user can produce the three dimensional control signals necessary to restore arm function [3]. One of these actions is eye gaze direction, which can be determined by measuring the electroculargram (EOG) of the eye. This study is an investigation of this potential command interface and it’s applicability as an input to a neural prosthetic for high tetraplegia.

1.1. Electroculography
The electroculargram is the electrical signal produced by the potential difference between the retina and the cornea of the eye [4]. This difference is due to the large presence of electrically active nerves in the retina compared to the front of the eye.

2. METHODS
In this study, the EOG signal of both eyes was measured. The right eye was used to measure both horizontal as well as vertical eye gaze directions, while the left eye EOG was only measured in the horizontal plane. To measure the dipole across each eye, the electrodes were placed around the orbit of each eye. The horizontal plane electrodes were positioned on the sides of the bridge of the nose and the temples. The vertical electrodes were placed roughly above and below the midline of the eye as it was
fixated on a distant point. These positions are shown in figure 1. The reference electrode was placed at the base of the neck on the crest of the C7 vertebra.

To study the applicability of using EOG signals to command a paralyzed arm stimulated with FES, the subject commanded the motion of a small industrial robot arm. The arm was mounted inverted, next to the subject’s shoulder (fig. 2). This served as a stand-in for a paralyzed arm activated using FES. The robot itself was programmed to behave similar to a natural arm in terms of speed and bandwidth. This allowed for the system to approximate a user with an ideal neuroprosthesis while permitting for experiments to be conducted using intact subjects.

The recorded signals were collected and interpreted by a custom controller created using Simulink and xPC Target. The command algorithm was a constant velocity gated ramp which detected signal amplitude greater than a specific threshold (half maximum recorded signal) determined during initial user calibration. When eye gaze in a particular direction was above threshold, the robot arm would move in that direction. Depth was controlled by crossing the eyes. A switch, activated by the back of the subject’s head was used to indicate a voluntary motion and enable gaze tracking to reduce the effects of natural saccades and general glances.

3. RESULTS
The signals used to calibrate the system are illustrated in figure 3. The system was able to classify and implement commands from a set of 19 pre-determined commands presented to the user (fig. 4).
4. DISCUSSION AND CONCLUSIONS
Using the described system, subjects were able to efficiently move the robot arm around a workspace that would be available to an individual with an FES actuated paralyzed arm. This command source affords a means of controlling a neuroprosthetic arm that is both intuitive as well as unobtrusive. An additional benefit of this method of capturing user intent is that, being a biopotential recording, it may be readily implanted to reduce the amount of worn equipment. By using a manual head switch to indicate command intent, combined with gross eye gaze direction measured using EOG, a complete user interface can be developed for commanding the action of a stimulated paralyzed arm.

References

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