Solar System - Smooth Pursuit Interactions using EOG glasses

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Abstract
Solar System implements smooth pursuit eye movement interactions on commercial smart glasses using electrooculography. The system requires no calibration and little to no training. We present a prototype implementation, describe initial user tests and show several application scenarios for hands-free eye gaze interactions.

Author Keywords
Eye tracking; gaze interaction; wearable computing.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Although the eye is one of the fastest and most accurate muscles in the human body, eye-based interactions are still far from being mainstream [1]. Many users find using eye movements for direct interactions wearying [5]. Eye movements for controlling the interface must be sufficiently different from regular eye movements so as not to be confused, which can lead to an interface that feels unnatural.

In recent years, however, researchers have found smooth pursuits can work well for direct eye interactions as following moving targets is a natural and intuitive eye behavior.

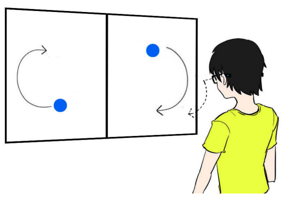

Figure 1: Solar System requires the user to track an orbiting cursor with the eyes to select an option whose icon is (optionally) rendered in the center of the orbit.

Figure 2: MEME: smart glasses with 3 electrodes to measure eye movements.

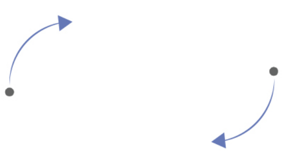

Figure 3: Orbits with different phases

Research so far has focused on using optical eye trackers to create smooth pursuit interfaces. Although there have been advances to make these devices smaller, they are often still quite obtrusive and have limitations in regard to battery power.

This paper contains the following contributions: (1) We assess the possibility of implementing a smooth pursuit interface similar to Orbits [2] using Electrooculography, (2) we describe the algorithm we use to create a prototype system on commercially available EOG glasses (J!NS MEME) and (3) we show the functionality of the system in an initial demonstration with three users. We also describe potential applications and use cases. Our system is calibration free and works on commercial, unobtrusive smart eyewear.

Related Work

Several researchers are exploring smooth pursuit for eye gaze interactions [3, 5, 6, 7]. In their 2013 paper, Vidal et al. [5] describe six usage scenarios for the technique. The Orbits paper by Esteves et al. [2] is the most closely related effort to this work as it utilizes circular movements to distinguish between prompts. However, Orbits focuses on interactions with a smart watch and uses a large and obtrusive optical eyetracking system. Špakov et al. [3, 7] introduce widgets for smooth pursuit similar to our cookbook application described below. A good resource about the fundamental mechanics of smooth pursuit eye movements is given by Robinson [4].

We are not aware of research that implements smooth pursuit interfaces using electrooculography on a consumer device. Other publications focus on optical eyetracking which is more expensive, requires more energy, is sensitive to sunlight, and often requires camera alignment before use.

Hardware

For our study, we use the J!NS MEME, an off-the-shelf pair of eyeglasses sold in Japan, which is able to measure eye movement using three electrodes in the nosebridge that are in contact with the skin (see Figure 2). When worn, the J!NS MEME is difficult to distinguish from a normal, unaugmented pair of eyeglasses. The device also incorporates an accelerometer and gyroscope. Data can be sent to a remote device over USB or wirelessly using Bluetooth. Calibration is not required, and the device fits most users with minimum adjustment to the nosepads.

We calculate the horizonal EOG value by subtracting the value returned from the left nosepad electrode (L) from the right (R). The vertical signal is calculated by subtracting the value from the bridge electrode (B) from the average of the two nosepad electrode. In practice, the horizontal signal tends to have larger magnitude than the vertical signal for the same amount of eye deflection; however, that difference is not a difficulty when comparing the relative motion of two systems.

Smooth Pursuit Detection Algorithm

Eye interfaces typically rely on the absolute position of the eye position relative to a given prompt. Recovering a static eye gaze point using EOG has significantly lower accuracy than with optical gaze trackers. However, with smooth pursuit interfaces, only relative movement is needed to select between prompts. Here, we focus on the phase of the repeated eye movements as the user tracks the cursors around the prompts.

Figure 1 demonstrates the Solar System concept. Two options are displayed on a screen. A cursor orbits each of the options. The cursors' movements are rendered out of phase with each other. We detect the user's smooth pursuit

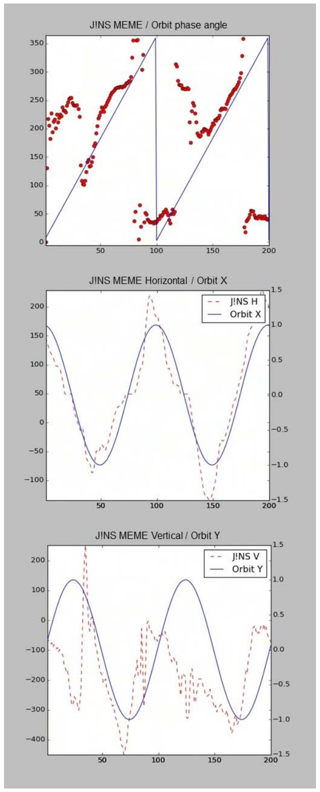

Figure 4: Calculated phase angle value and Sensor value from J!NS MEME with reference Orbit values

eye movements in the EOG data and compare them to the cursors' positions to determine which of the two the user is tracking.

More specifically, we first establish a center of rotation by averaging the vertical and horizontal EOG signals over a small window of time. After the center is established, we calculate the angle of motion relative to that center for each incoming EOG sample. We compare those angles to the angles of the two prompts and select the one with the highest correlation.

Signal Level Evaluation

Figure 4 demonstrates the signal calculated from the EOG data. As can be seen, the phase of the data is easy to detect and correlate with the motions of the orbiting cursors on the screen. Note that while we present the method using only two choices with a 180 degree phase difference, more choices could be distinguished by using smaller phase differences or varying the speed of the cursor movement. In addition, different shapes of cursor movement can be used. For example, one cursor could be moving in a square pattern while another moves in a circular pattern. The process of selecting which prompt is being tracked remains the same; simply choose whichever prompt's motion has the highest correlation with the EOG data.

Architecture

For portability, we implemented the detection process to work in web browsers. As the data from J!NS MEME is sent over Bluetooth by default, we modified the data transfer method so that the receiving machine can forward the J!NS MEME data over a socket, and the data be compared to the cursor movement rendered in the web browser. The detection process occurs in real time which allows an interface designer to apply it to many scenarios.

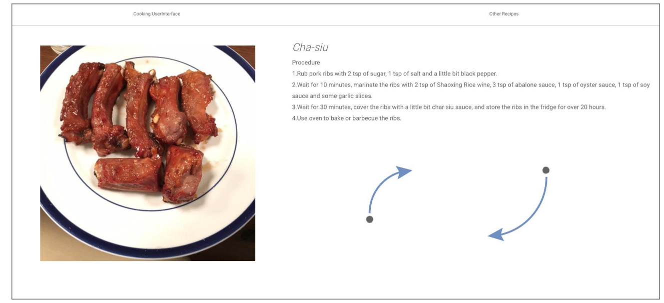

Figure 5: Example user interface for cooking.

Application Scenario

We did a proof-of-concept with three users using Solar System. The initial test displayed two different cursors traveling clockwise and 180 degrees out of phase (see Figure 3). All users could select either cursor intentionally.

Figure 5 demonstrates one of the scenarios in which Solar System might be used. While cooking from a recipe, the chef's hands are often covered in food. Solar System allows the chef to turn the pages of a cookbook without touching it. Here, we have used the cursors with two different phases previously described so that the cook can select a recipe and navigate between the next and previous steps for food preparation. The chef can prepare dishes and cut or cook foods for the recipe while reading and interacting with the cookbook hands-free.

Future Work and Conclusion

We are extending our experiments and preparing some rigorous performance tests. We are interested in how fast selection can occur using the MEME as well as the minimum visual angle a rotating cursor can subtend and still be distinguishable in the EOG data. Additionally, we wish to investigate how many cursors can be distinguished simultaneously by varying phase, speed of rotation, and shape of movement.

We are also investigating different application scenarios. Any situation requiring hands-free interaction, such as soldering, maintenance work, circuit testing, and assistive interfaces, is potentially interesting.

We have presented an implementation of smooth pursuit eye gaze interaction on commercial electrooculography glasses. Visualization of the data and testing in an initial application scenario suggest that the method is viable.

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