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Eye Tracking based Human Computer Interaction

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***Abstract*: With the evolution of Eye Tracking from a concept to reality, it is being explored scientifically these days in Human Computer Interaction in order to record the eye movements to determine the gaze direction, position of a user on the screen at a given time and the sequence of their movement. The threefold objective of this paper include introducing the reader to the key aspects and issues of eye-movement technology, practical guidance for developing an Eye tracking application, and various opportunities and underlying challenges to develop (Man and Machine Interfacing) MAMI systems using Eye tracking. We have uniquely integrated The Eye Tribe with Unity5.1.1 and through an experiment, we have also inferred that a subject with and without bifocal glasses show relatively similar fixation results if they have correct vision but the results differ with small error if the eye is corrected using lenses. Another experiment using Eye Tribe shows that gaze input requires less time as compared to the mouse input.**

***Keywords*: Eye Tracking, Unity, Eye gaze input, MAMI-Man and Machine Interface, HCI-human Computer Interface**

1. Introduction

Eye tracking systems bear enormous potential of tracking eye movements during emotion monitoring, reading, human activity recognition, the perception of advertising, visiting a website, HCI, driving assistance system, the sports cognition, drivers' fatigue detection systems, etc. We can also use an eye tracking system to implement an "eye mouse" and use it as control signals to enable users to interact with system interfaces directly without the need for input devices like mouse or keyboard, for ease of use of a computer for the disabled.The basic use of an eye tracking system is to record and analyze the constant motion of eyes of a user while looking at a screen before they stop and focus on a particular area. We use a non-invasive (remote) eye tracking device, The Eye Tribe, which has been recorded to be the smallest eye tracker in the world, measuring 20 × 1.9 × 1.9 cm. And also, the fact that this eye tracker does not require a separate power source, makes it even more portable. The Eye Tribe requires a USB 3.0 Super Speed port connection, which makes it compatible with most high speed computers and devices like smartphones, tablets. The Eye Tribe is compatible with Microsoft Windows 7 or newer and OSX along with a simple software development kit available for C++, C# and Java programming platforms. The main components of the Eye Tribe tracker consists of a camera and a high-resolution infrared LED, which can easily be deployed in a smartphone, computer etc. The device uses a camera to track the subject's eye movement. The camera tracks even the minutes of movements of the users' pupils, by taking the images and subjecting them to computer-vision algorithms. The "on-screen gaze coordinates" are determined via these algorithms which indicate the subject's point of vision on the screen during a task. Although the device works best indoors, but it also gives satisfactory results while working with Hardware, Camera sensors and different light settings in the working environment.

2. Eye movement metrics

Eye movements form the basis for the usability Research through eye tracking in Man and Machine Interfacing. Out of many eye movement measures, Fixation and Saccades are the most important ones.

- *Fixation:* Fixation is focusing the eyes at one particular point. Fixations, on an average last between 100-1000 ms, with the majority being between 200-500 ms, which depends hugely on the quality of information being processed and current cognitive load. Fixations are moments when the eyes appear to be relatively stationary that usual, taking input or "encoding" the information.
- *Fixation derived metrics:* Some other metrics derived from the fixation are Fixation duration, Fixations per area of interest, Number of fixations overall, Fixation spatial density, Repeated fixations, Time to first fixation, Percentage of participants fixating an area of interest.
- *Saccades:* "Saccades", also referred to as "Regressions" are the quick movements of the eye between two fixations, typically lasting for about 20 to 35 milliseconds. After each saccade, the eyes move to the next viewing position. Visual processing by the human eye is automatically suppressed during each consecutive saccade, which avoids blurring of the target text or image. Some Saccades derived metrics are mentioned below.

- *Gaze:* Also referred to as “dwell”, “fixation cluster” and “fixation cycle”, Gaze is usually the sum of all fixation durations within a prescribed area. It is best used to compare attention distributed between targets. It can also be used as a measure of anticipation in situation awareness if longer gazes fall on an area of interest before a possible event occurring.
- *Gaze duration:* Averaging the spatial location of a series of consecutive fixations within an area of interest along with the cumulative duration gives the Gaze duration. It generally includes multiple fixations and relatively shorter time period for the short saccades between these frequent fixations

3. Description of approach

We have developed a basic application for interface and object selection using The Eye Tribe eye tracker instead of the webcam (inbuilt in the system) in order to achieve "mouse input" using the eye gaze input. This eye tracking system helps us to perform a generic task like selecting one out of several objects displayed on the CRT screen using physical input. Eye movement-based input techniques in Man and Machine Interfacing represent a change in input from objects for the user to actuate by specific commands (eyesmovements) to passive equipment (Eye Tracker) that simply senses parameters of the user’s body. The approach followed in described in the next section.

A. Calibrating the camera

To perform Calibration locally, we have used game development Engine and interfaced The Eye Tribe eye tracker along with it, first time ever in the world such that the first scene to which the user is subjected, is the calibration scene of the Eye Tribe server in Unity itself. After making the left and right eye visible on the screen, we have calculated the distance of the user from the screen. The Eye Tribe recommends the user to be at distance of 45cm to 75cm within the range of the device. Later we have calculated the angles of the left and right eye relative to the screen space. This enhances the existing eye detection algorithms by mapping this calculated angle to the field of view of the eye. The size of the fovea of the human eye varies between 1-2° of the visual field indicating that if we stand at a certain distance from an object, the area covered by the fovea will be a projection of the size of the fovea in a 1-2° degree angle.When we move the fovea in order to place it on areas we are interested in we do not need to place it exactly centred and on top of the area as the projected area becomes larger and hence, covers more, the further away an object is. Thus, in our algorithm we aim to shift the on screen angle of vision by scaling it in a way that becomes a projection on the area covered by the fovea. Random calibration points and calibration rating depending on the performance of the user makes this system even more reliable.

B. Obtaining Gaze coordinates

Next we have controlled the navigation of the scene Camera according to the stream of the gaze data received by the server. We have also mapped the scene Camera to 3:2 aspect ratio and tilted the camera according to the eye angle. Then, after mapping the gaze indicator in our scene we have applied a collision detection mechanism which detects the on screen collision of gaze fixation with any object displayed n the CRT screen.

C. Validating Gaze data

To remove any burring or faults in the raw data received by the Eye Tribe server, we have incorporated a gaze data validation Algorithm that maintains and analyzes a frame history of Gaze frames at the run time. Since, the human does not remain stationary for long, we have used updating methods so that the raw gaze coordinates can be converted to smoothed gaze coordinates by performing necessary operations on those acquired raw gaze coordinates.

D. Mapping with unity

To achieve usable data, we need to map gaze points into Unity because the obtained gaze points have origin in the top left corner, unlike Unity which uses lower left as the origin. Thus, it is mandatory to convert a screen point to a Unity point. This has been achieved in our lab for the first time, for the sake of accuracy of the data. As soon as we obtain the Unity

4. Eye tracking experiments

Following experiments have been done in our lab to demonstrate differences in search patterns of users under different conditions.

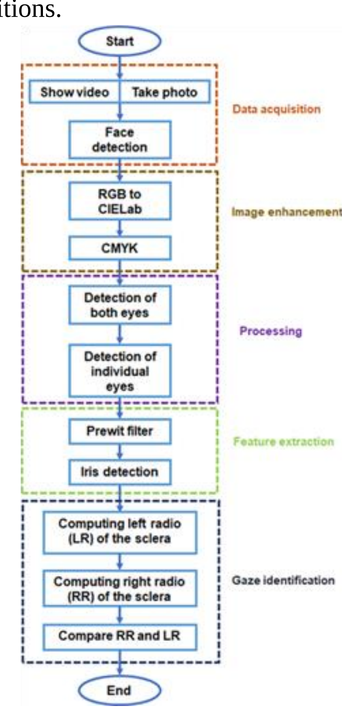

Fig. 1. Flowchart showing the successive action while developing the eye tracking system

- Experiment to Illustrate gaze patterns of different users with and without bifocal glasses It is generally agreed that under normal conditions, human eye movements have increased visual attention. Also, wearing bifocal eye glasses might result in an irregular eye Gaze data. Therefore, we performed an experiment on thirty subjects, where 10 of them belong to the category of people (called A) who regularly wear spectacle and have an uncorrected eye of about -4 to -6 power. The other 10 belong to the category of people who do not wear spectacle at all (called B) and have 6/6 correct eye vision. The third category of people is those who wear spectacles just while reading or viewing screen (called C). The following graph shows True and False for fixation and non-fixation respectively. It also shows the average gaze x and y coordinates of the eye of the users. This graph shows that wearing of the spectacle does not cause the device to lose accuracy and precision while recording the input gaze data but the variation in the average values of x and y gaze coordinates among A type users is due to the fact that they have uncorrected eye vision and they find it difficult to locate the target on screen without spectacles. So, in A type user, general observation is that they fixate their eye off target for a longer duration. Whereas, in case of both B and C type users, we do not observe much deviation from the target with or without specs. Only A type users find it difficult to locate the target without spectacles on the screen.
- Experiment to Illustrate faster searching through eye gaze input rather than mouse input The system tracks the computer user's movements with a video camera and translates them into the movements of the mouse pointer on the screen. This experiment was performed on 20 subjects. It includes tracking a red coloured ball among many other balls present in the environment and click on it using mouse or fixate eyes on the red coloured ball after the colours disappears from the ball(that is after 5 seconds of the commencement of the experiment). The following graph shows that more number of subjects successfully performed the task in less than 1 or 2 seconds when the input mode was eye gaze and more number of people successfully completed the task in 4 seconds on an average when the input mode was mouse. This is due to the fact that while looking on the screen, if the user does not have to control the mouse for sending the input, its attention remains undivided and the user can follow the target with complete attention. While in case of mouse input mode, the attention of the user gets divided in following the target and also making the mouse pointer reach the target and click it. This increases the response time of the user. Also, more number of users resulted in losing the task while using mouse as input which is also a result of many factors like divided attention, laziness, slow response time, slow system processor etc. All these limitations can be overcome by using eye gaze input in Real Time systems. Thus, for disabled users, an eye tracking interface may be an indispensable form of communication (e.g., eye typing). In a more general interactive setting, however, there is some debate as to whether it makes sense to overload a perceptual organ (the eye) by a motor task (e.g., mouse like pointing

5. Results

In this paper, we have overcome many limitations of the traditional eye trackers and their applications like Calibration issues, practical problems while developing an eye tracking system. We also performed two experiments depicting that there does not exist much difference in the accuracy of the Eye Tribe while taking eye gaze inputs of the user wearing or not wearing glasses. The Eye Tribe has a sampling rate of 30 Hz and 60Hz mode and an accuracy of 0.5degree to 1 degree. The spatial Resolution of the device is 0.1 degree (RMS) and Latency less than 20ms at 60Hz. The operating range lies between 45cm-75cm on an average and provides a tracking area of about 40cmX30cm at 65 cm distance at 30 Hz. The recommended screen size is about 24 inches and outputs Binocular gaze data. Thus, with such high latency as claimed by the Eye Tribe and also proved via the Search Task experiment makes this device highly accurate and advisable to use as eye gaze input. The eye-gaze input system led to a faster pointing time as compared with mouse input, especially for older adults. This result demonstrates that an eye-gaze input system may be able to compensate for the declined motor functions of older adults when using mouse input. Also, during the task where we tested the accuracy of the Eye Tribe, we used two types of data, one with glasses and the other without glasses. So, accuracy of the Eye Tribe in our Lab without the spectacle came out to be 50.3% while without spectacle it was reported to be 47.96%. This indicates an error rate of roughly 2%, which is assumed to be quite good and acceptable.

6. Eye tracking applications

Virtual reality environments can also be controlled by the use of eye movements. The large three-dimensional spaces that users operate in often contain far-away objects that have to be manipulated. Eye movements seem to be the ideal tool in such a context, as moving the eyes to span long distances requires little effort compared with other control methods. We have developed one such application integrating and The Eye Tribe Eye tracker that aims at controlling mouse cursor using Eye Tracking. The portion of the interface becomes active when it is gazed upon. Such a system may prove useful in training the players for playing football or basketball virtually, on the screen. This might also be deployed for analyzing the gaze patterns of the player on the virtual field and help the coach to train the player better by improving his/her attention by fixating closely on the target on the field. This system might prove to be a boon for the differently able people, who can control the motion of cursor through their eyes, read a pdf file, browse a website or even play games Eye movements can be measured and used to enable an individual actually to interact with an interface. Users could position a cursor by simply looking at where they want it to go, or "click" an icon by gazing at it for a certain amount of time or by blinking. The first obvious application of this capability is for disabled users who cannot make use of their hands to control a mouse or keyboard.

7. Challenges faced during eye tracking

Eye trackers, in their infancy are quite sensitive instruments and have difficulty in tracking participants who have interrupted normal path of reflection, such as subjects with hard contact lenses, bifocal or trifocal glasses, and glasses with super-condensed lenses. Gaze tracking has long been considered as an alternative or potentially superior pointing method for computer input. Surveys also reveal problems tracking users who have large pupils or if their eyelids obscure some part of their pupil and thus, making it difficult for the eye tracker camera to identify the pupil movement. Also, calibration once done does not remain fruitful for much longer time and should be repeated at regular intervals due to head movements and other adjustments. Subject should be made to perform pre-defined tasks so that their eye movements can be properly attributed to standard metrics and actual cognitive processing can be done. Distractions (e.g., colourful or moving objects around the screen or in the testing environment) should also be eliminated, as these will inevitably contaminate the visual processing and hamper the eye-movement data. Lastly, eye tracking generates huge amounts of data and that too very precisely, so filtering and analyzing it holds utmost importance which will help us to minimize chances of errors through manual processing of such large data. Also, we may also acquire a lot of false data while tracking unless the Eye tracker is integrated with the game or application. Thus, we must pay close attention to what data we have obtained and how to process it, in order to generate desired results.

8. Opportunities and future work

Eye movements provide objective data on how subjects perceive the world and how they react when subjected to different kinds of stimuli, which can be put to use for Researches in Psychology. Eye tracking devices combined with physiological data such as brain imaging can help identify how the information is processed in the brain. Eye tracking can be used to analyze visual development and link it to developmental aspects of neurological functions, neurological diseases and brain damage. Also, Reading patterns can be cross referenced with different demographics of people and therefore provide insight into how they gather information. Human computer interaction allows users to input information in a more natural way into their computers. Eye tracking can be used as a control medium, like moving the cursor and clicking on icons on the screen, as well as creating adaptive user interfaces, where the computer reacts to the eye gaze of the user and create an interactive environment. Eye tracking is great for coaches who want to train their players on effectively gathering information from the field through simulations. Batsmen's eye movements monitor the moment when the ball is released, make a predictive saccade to the place where they expect it to hit the ground, wait for it to bounce, and follow its trajectory for 100−200ms after the bounce. Learning to analyze an environment quickly can be a valuable skill in air traffic control, radar control, medical X-ray examinations, video surveillance, industrial process control, driving, army or police field work, surgical training and others. Teaching this skill through simulations using an eye tracker can eliminate the time-consuming process of only learning it with experience.

9. Conclusion

In order to make user interact with computer naturally and conveniently by only using their eye, we provide an eye tracking based control system. The system combines both the mouse functions and keyboard functions, so that users can use our system to achieve almost all of the inputs to the computer without traditional input equipment. The system not only enables the disabled users to operate the computer the same as the normal users do but also provides normal users with a novel choice to operate computer. According to our TAM questionnaire analysis, the participants considered our eye movement system to be easy to learn. Meanwhile, participants show their interest in using the proposed eye control system to search and browse information. They are looking forward to see more of our research results on the use of eye tracking technique to interact with the computer.

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