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EYE TRACKING SYSTEM INTERACTION BETWEEN HUMAN &COMPUTER WITH AND FUTURE PROSPECTS

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ABSTRACT

Eye tracking has a long history in the today's Technology, medical science and psychological department as a tool for recording and studying about the human visual behaviours. The Real-time gaze-based text entry can also powerful meaning of communication. There foe control the peoples with physical disabilities in the region. Following recent technological advances and the advent of affordable eye trackers, there is a growing interest in pervasive attention-aware systems and interfaces that have the potential to revolutionize mainstream human- technology interaction. In this chapter, we provide an introduction to the state-of-the art in eye tracking technology and gaze estimation. In this report shows the challenges involved in using a perceptual organ and the eye as the input modality. Examples of real life applications are reviewed, together with design solutions derived from research results. We also discuss how to match the user requirements and key features of different eye tracking systems to find the best system for each task and application.

KEYWORDS: Eye Tracking Technology and Gaze Estimation, Revolutionize Mainstream Human- technology Interaction

INTRODUCTION

Eye tracking system is a technique in which an individual's eye movements is measure by which the scholars knows where the individual person is looking for the object at any given time and the sequence in which their eyes are shifting from one location to another. Tracking eye's movements helps the HCI researchers or the scholars understanding visual and display-based information processing. The factors which may impact on the usability of system interfaces. In a such way eye-movement recordings provide the source of interface-evaluation data that can inform the design of improved interfaces. Eye movements can also be captured as discuss above and it may used as control all the signals to enable people to interact with interfaces directly without the need for input device like mouse or keyboard, which can be a major advantage for certain populations of users such as disabled individuals. Start this report with an overview of eye-tacking technology and some processes toward a details of eye tracking in HCI and its usability of research. The key component of the report is to provide a practical guide to inform researchers of the various eye-movement measures that can be taken, and the way in which these metrics can address questions about system usability. We conclude by considering the future prospects for eye-tracking research in HCI and usability testing.

EYE-TRACKING TECHNOLOGY

The History of Eye Tracking

There are different methods have been used to track eye movements in the use of eye-tracking technology was first pioneered in reading research over 100 years ago. Electro-oculographic techniques, for example, relied on electrodes mounted on the eye that measures the differences in between the electro potential so as to detect eye movements. Other historical methods required the wearing of large contact lenses that covered the cornea (the clear membrane covering the front of the eye) and sclera the white part of the eye that is seen from the outside, with a metal coil embedded all sides the edge of the eye lens; eye movements were then measured by fluctuations in an electromagnetic field when the metal coil moved along with the eyes.

CONCEPT OF EYE TRACKER

The **Concept of Eye Tracker is** used available today measure point-of-regard by the corneal-reflection/pupil-centre method such eye trackers usually consist of a standard computer connected with infrared camera mounted beneath display monitor, By which the image processing software to locate and identify the features of the eye used for tracking. In Some operations infrared light from an LED embedded in the infrared camera is first directed into the eye which create a strong reflections in target of the eye features to make them easier to track the objects. The infrared light enters the retina and a large proportion of it is reflected back and it making the pupil appear as a bright and a well defined disc is also generated by the infrared light appearing as a small but sharp shown in figure bellow Figure 1.

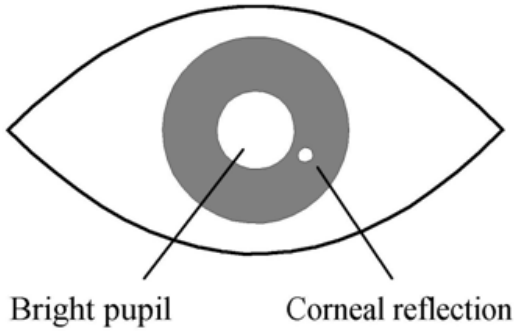

Figure 1: Corneal Reflection and Bright Pupil as Seen in the Infrared Camera Image

Once the image processing software has identified the centre of the pupil and the location of the corneal reflection, the vector between them is measured, and, with further trigonometric calculations, point-of-regard can be found. Although it is possible to determine approximate point-of-regard by the corneal reflection alone (as shown in Figure 2), by tracking both features eye movements can, critically, be disassociated from head movements. Video-based eye trackers need to be fine-tuned to the particularities of each person's eye movements by a "calibration" process. This calibration works by displaying a dot on the screen, and if the eye fixes for longer than a certain threshold time and within a certain area, the system records that pupil-centre/corneal -reflection relationship as corresponding to a specific x,y coordinate on the screen. This is repeated over a 9 to 13 point grid-pattern to gain an accurate calibration over the whole screen.

EYE TRACKING AS A RESEARCH AND USABILITY-EVALUATION TOOL

Why Study Eye Movements in HCI Research?

What a person is looking at is assumed to indicate the thought "on top of the stack" of cognitive processes (Just & Carpenter, 1976). This "eye -mind" hypothesis means that eye-movement recordings can provide a dynamic trace of where a person's *attention* is being directed in relation to a visual display. The Measurement other aspects of eye movements like, It can reveal the *amount* of processing being applied to objects at the point-of-regard. In the process of inferring information from eye-movement recordings involves the HCI researcher defining "areas of interest" over certain parts of a display or interface under evaluation, and analyzing the eye movements which fall within such areas. In this way, the visibility, meaningfulness and placement of specific interface elements can be objectively evaluated and the resulting findings can be used to improve the design of the interface. For example, in the scenario where the participants asked to search an icon, longer-than-expected gaze on the icon before the eventual selection would indicates lacks meaningfulness and the probably needs to be redesigned. Detail descriptions of eye-tracking metrics and interpretation is provided in the following sections mention in the report.

Previous Eye-Tracking Research

Mainstream psychological research has benefited from studying eye movements as they can provide an insight into problem solving, reasoning, mental imagery, and search strategies (e.g., Ball, Lucas, Miles, & Gale, 2003; Just & Carpenter, 1976; Yoon & Narayanan, 2004, Zelinsky & Sheinberg, 1995). The eye movements a window shows onto so many aspects of cognition, therefore a rich opportunities for the application of eye-movement analysis as a usability research tool in HCI and related disciplines such as human factors and cognitive ergonomics. Although eye-movement analysis is still very much in its infancy in HCI and usability research, issues that are being increasingly studied include the nature and efficacy of information search strategies on menu-based interfaces (e.g., Altonen, Hyrskykari, & Räihä, 1998; Byrne, Anderson, Douglas, & Matessa, 1999; Hendrickson, 1989), and the features of websites that correlate with effective usability (e.g., Cowen, Ball, & Delin, 2002; Goldberg, Stimson, Lewenstein, Scott, & Wichansky, 2002; Poole, Ball, & Philips, 2004). Eye trackers have, additionally, been used more broadly in applied human factors research to measure situation awareness in air-traffic-control training (Haul and, 2003), to evaluate the design of cockpit controls to reduce pilot error, and to investigate and improve doctors' performance in medical procedures (Law, Atkins, Kirkpatrick, & Lomax, 2004; Mello-Thoms, Nodine, & Kundel, 2002). The commercial sector is also showing increased interest in the use of eye-tracking technology in areas such as market research, for example, to determine what advert designs attract the greatest attention and to determine if Internet users look at banner advertising on websites.

Eye-Movement Metrics

The main measurements used in eye-tracking research are fixations (described previously) and saccades, which are quick eye movements occurring between fixations. There are also a multitude of derived metrics that stem from these basic measures, including gaze and scan path measurements

Eye Fixation: Eye Fixations can be interpreted quite differently depending on the context. In an encoding task for

e.g., browsing a web page on the web higher *fixation frequency* on the particular area can be indicative of greater interest in the target, such as a photographs in the news reports, or it can be a sign that the target is complex in some way and more difficult to. However, these interpretations may be reversed in a search task: A higher number of single fixations, or clusters of fixations, are often an index of greater uncertainty in recognizing a target object. The *duration* of a fixation is also linked to the processing-time applied to the object being fixated (Just & Carpenter, 1976). It is widely accepted that external representations associated with long fixations are not as meaningful to the user as those associated with short fixations (Goldberg & Kotval, 1999). Fixation-derived metrics are described in Table 1.

Table 1: Fixation-derived Metrics and how they Can be Interpreted in the Context of Interface Design and Usability Evaluation. References are given to Examples of Studies that have Used Each Metric

Eye-movement Metric	What it Measures	Reference
Number of fixations overall	More overall fixations indicate less efficient search (perhaps due to sub-optimal layout of the interface).	Goldberg & Kotval (1999)
Fixations per area of interest	More fixations on a particular area indicate that it is more noticeable, or more important, to the viewer than other areas.	Poole et al.(2004)
Fixations per area of interest and adjusted for text length	If areas of interest are comprised of text only, the mean number of fixations per area of interest should be divided by the mean number of words in the text. This is necessary to separate out: (i) a higher fixation count simply because there are more words to read, from (ii) a higher fixation count because an item is actually harder to recognise.	Poole et al.(2004)
Fixation duration	A longer fixation duration indicates difficulty in extracting information, or it means that the object is more engaging in some way.	Just & Carpenter (1976)
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.	Mello-Thoms et al. (2004); Hauland (2003)
Fixation spatial density	Fixations concentrated in a small area indicate focussed and efficient searching. Evenly spread fixations reflect widespread and inefficient search.	Cowen et al.(2002)
Repeat fixations (also called "post-target fixations")	Higher numbers of fixations off-target after the target has been fixated indicate that it lacks meaningfulness or visibility.	Goldberg & Kotval (1999)
Time to first fixation on-target	Faster times to first-fixation on an object or area mean that it has better attention-getting properties.	Byrne et al.(1999)
Percentage of participants fixating an area of interest	If a low proportion of participants is fixating an area that is important to the task, it may need to be highlighted or moved.	Albert (2002)
On-target (all target fixations)	Fixations on-target divided by total number of fixations. A lower ratio indicates lower search efficiency.	Goldberg & Kotval (1999)

Saccades: No encoding takes place during saccades, so they cannot tell us anything about the complexity or

salience of an object in the interface. However, regressive saccades (i.e., backtracking eye-movements) *can* act as a measure of processing difficulty during encoding (Rayner & Pollatsek, 1989). Although most regressive saccades (or "regressions") are very small, only skipping back two or three letters in reading tasks, much larger phrase-length regressions can represent confusion in higher-level processing of the text (Rayner & Pollatsek, 1989). Regressions could equally be used as a measure of recognition value, in that there should be an inverse relationship between the number of regressions and the salience of the phrase. Saccade-derived metrics are described in Table 2.

Table 2: Saccade-derived Metrics and how they can be Interpreted in the Context of Interface Design and Usability Evaluation. References are given to Examples of Studies that have Used Each Metric

Eye-movement Metric	What it Measures	Reference
Number of saccades	More saccades indicate more searching.	Goldberg & Kotval (1999)
Saccade amplitude	Larger saccades indicate more meaningful cues, as attention is drawn from a distance.	Goldberg et al. (2002)
Regressive saccades (regressions)	Regressions indicate the presence of less meaningful cues.	Sibert et al. (2000)
Saccades revealing marked directional shifts	Any saccade larger than 90 degrees from the saccade that preceded it shows a rapid change in direction. This could mean that the user's goals have changed or the interface layout does not match the user's expectations.	Cowen et al.(2002)

Scanpaths: A scanpath describes a complete saccade -fixate-saccade sequence. In the search option or task, an optimal scan path is viewed as being a straight line to a desired target botton with relatively short fixation duration at the target or the destination. Scanpaths can be analysed quantitatively with the derived measures described in Table 3.

Table 3: Scanpath-derived Metrics and how they can be Interpreted in the Context of Interface Design and Usability Evaluation. References are given to Examples of Studies that Used Each Metric

Eye-movement Metric	What it Measures	Reference
Scanpath duration	A longer-lasting scanpath indicates less efficient scanning.	Goldberg & Kotval (1999)
Scanpath length	A longer scanpath indicates less efficient searching (perhaps due to a sub-optimal layout).	Goldberg et al. (2002)
Spatial density	Smaller spatial density indicates more direct search.	Goldberg & Kotval (1999)
Transition matrix	The transition matrix reveals search order in terms of transitions from one area to another. Scanpaths with an identical spatial density and convex hull area can have completely different transition values – one is efficient and direct whilst the other goes back and forth between areas, indicating uncertainty.	Goldberg & Kotval (1999); Hendrickson, (1989)
Scanpath regularity	Once ªcyclic scanning behaviourº is defined, deviation from a ªnormalº scanpath can indicate search problems due to lack of user training or bad interface layout.	Goldberg & Kotval (1999)

Spatial coverage calculated with convex hull area	Scanpath length plus convex hull area define scanning in a localised or larger area.	Goldberg & Kotval (1999)
Scanpath direction	This can determine a participant's search strategy with menus, lists and other interface elements (e.g. top-down vs. bottom-up scanpaths). ªSweepº denotes a scanpath progressing in the same direction.	Altonen et al. (1998)
Saccade/fixation ratio	This compares time spent searching (saccades) to time spent processing (fixating). A higher ratio indicates more processing or less searching.	Goldberg & Kotval (1999)

Blink rate and pupil size: Blink rate and pupil size can be used as an index of cognitive workload. A lower blink rate is assumed to indicate a higher workload, and a higher blink rate may indicate fatigue (Bruneau, Sasse, & McCarthy, 2002; Brookings, Wilson, & Swain, 1996). Larger pupils may also indicate more cognitive effort (Marshall, 2000; Pomplun & Sunkara, 2003). However, pupil size and blink rate can be determined by many other factors, such as ambient light levels, so are open to contamination (Goldberg & Wichansky, 2003). For these reasons, pupil size and blink rate are less often used in eye tracking research.

Technical Issues in Eye-tracking

Experimenters looking to conduct their own eye-tracking research should bear in mind the limits of the technology and how these limits impact the data that they will want to collect. For example, they should ensure that if they are interested in analysing fixations, that the equipment is optimised to detect fixations (Karn, Goldberg, McConkie, Rojna, Salvucci, Senders, Vertegaal, & Wooding, 2000). The minimum time for a fixation is also highly significant. Interpretations of cognitive processing can vary dramatically according to the time set to detect a fixation in the eye-tracking system. Researchers are advised to set the lower threshold to at least 100ms (Inhoff & Radach, 1998).

Researchers have to work with limits of accuracy and resolution. A sampling rate of 60hz is good enough for usability studies, but inadequate for reading research, which requires sampling rates of around 500hz or more (Rayner & Pollatsek, 1989). It is also imperative to define areas of interest that are large enough to capture all relevant eye movements. Even the best eye trackers available are only accurate to within one degree of actual point-of-regard (Byrne et al., 1999). Attention can also be directed up to one degree away from measured point-of-regard without moving the eyes (Jacob & Karn, 2003).

Eye trackers are quite sensitive instruments and can have difficulty tracking participants who have eye-wear that interrupts the normal path of a reflection, such as hard contact lenses, bifocal and trifocal glasses, and glasses with super-condensed lenses. There may also be problems tracking people with very large pupils or “lazy eye”, such that their eyelid obscures part of the pupil and makes it difficult to identify. Once a person is successfully calibrated, the calibration procedure should than be repeated at regular intervals during a test session to maintain an accurate point-of-regard measurement.

There are large differences in eye movements between participants on identical tasks, so it is prudent to use a within-participants design in order to make valid performance comparisons (Goldberg & Wichansky, 2003). Participants should also have well-defined tasks to carry out (Just & Carpenter, 1976) so that their eye movements can be properly

attributed to actual cognitive processing. Visual 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 eye-movement data (Goldberg & Wichansky, 2003). Lastly, eye tracking generates huge amounts of data, so it is essential to perform filtering and analysis automatically, not only to save time, but also to minimise chances of introducing errors through manual data processing.

EYE TRACKING AS AN INPUT DEVICE

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 (Jacob & Karn, 2003). However, intention can often be hard to interpret; many eye movements are involuntary, leading to a certain "Midas Touch" (see Jacob & Karn, 2003), in that you cannot look at anything without immediately activating some part of the interface. One solution to this problem is to use eye movements in combination with other input devices to make intentions clear. Speech commands can add extra context to users' intentions when eye movements may be vague, and vice versa (Kaur et al., 2003).

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 (Jacob & Karn, 2003). Eye movement interaction can also be used in a subtler way, for example, to trigger context-sensitive help as soon as a user becomes confused (e.g., performs too many regressions) while reading text (Sibert et al., 2000). Other researchers (e.g., Ramloll, Trepagnier, Sebrechts, & Finkelmeyer, 2004) have used gaze-based interaction to help autistic children learn social skills by rewarding them when they maintain eye contact while communicating.

Some techniques alter a display depending on the point of regard. Some large-display systems, such as flight simulators (e.g., Levoy & Whitaker, 1990; Tong & Fisher, 1984) channel image processing resources to display higher quality or higher resolution images only within the range of highest visual acuity (i.e., the fovea) and decrease image processing in the visual range where detail cannot be resolved (the parafovea). Other systems (e.g., Triesch, Sullivan, Hayhoe, & Ballard, 2002) take advantage of the visual suppression during saccades to update graphical displays without the user noticing. Yet another rather novel use is tracking the point-of-regard during video-conferencing, and warping the image of the eyes so that they maintain eye contact with other participants in the meeting.

FUTURE TRENDS

Future developments in eye tracking should centre on standardising what eye-movement metrics are used, how they are referred to, and how they should be interpreted in the context of interface design (cf. Cowen et al., 2002). For example, no standard yet exists for the minimum duration of a fixation (Inhoff & Radach, 1998), yet small differences in duration thresholds can make it hard to compare studies on an even footing (Goldberg & Wichansky, 2003). Eye-tracking technology also needs to be improved to increase the validity and reliability of the recorded data. The robustness and accuracy of data capture needs to be increased, so that point-of-regard measurement stays accurate without the need for

frequent re-calibration. Data-collection, -filtering and -analysis software should be streamlined so that they can work together without user intervention. The intrusiveness of equipment should be decreased to make users feel more comfortable, perhaps through the development of smaller and lighter head-mounted trackers. Finally, eye-tracking systems need to become cheaper in order to make them a viable usability tool for smaller commercial agencies and research labs (Jacob & Karn, 2003). Once eye tracking achieves these improvements in technology, methodology, and cost, it can take its place as part of a standard HCI toolkit.

CONCLUSIONS

Our contention is that eye-movement tracking represents an important, objective technique that can afford useful advantages for the in-depth analysis of interface usability. Eye-tracking studies in HCI are beginning to burgeon, and the technique seems set to become an established addition to the current battery of usability-testing methods employed by commercial and academic HCI researchers. This continued growth in the use of the method in HCI studies looks likely to continue as the technology becomes increasingly more affordable, less invasive, and easier to use. The future seems rich for eye tracking and HCI.

GLOSSARY

- **Eye tracker:** Device used to determine point-of-regard and to measure eye movements such as fixations, saccades, and regressions. Works by tracking the position of various distinguishing features of the eye, such as reflections of infrared light off the cornea, the boundary between the iris and sclera, or apparent pupil shape.
- **Eye tracking:** A technique whereby an individual's eye movements are measured so that the researcher knows where a person is looking at any given time, and how their eyes are moving from one location to another.
- **Eye-mind hypothesis:** The principle at the origin of most eye tracking research. Assumes that what a person is looking at indicates what they are currently thinking about or attending to. Recording eye -movements can, therefore, provide a dynamic trace of where a person's attention is being directed in relation to a visual display such as a system interface.
- **Fixation:** The moment when the eyes are relatively stationary, taking in or "encoding" information. Fixations last for 218 milliseconds on average, with a range of 66 to 416 milliseconds.
- **Gaze:** An eye tracking metric, usually the sum of all fixation durations within a prescribed area. Also called "dwell", "fixation cluster", or "fixation cycle"
- **Point-of -regard:** Point in space where a person is looking. Usually used in eye tracking research to reveal where visual attention is directed.
- **Regression:** A regressive saccade. A saccade that moves back in the direction of text that has already been read.
- **Area of interest:** An area of interest is an analysis method used in eye tracking. Researchers define areas of interest over certain parts of a display or interface under evaluation, and analyse only the eye movements that fall within such areas.

- **Saccade:** An eye movement occurring between fixations, typically lasting for 20 to 35 milliseconds. The purpose of most saccades is to move the eyes to the next viewing position. Visual processing is automatically suppressed during saccades to avoid blurring of the visual image.
- **Scanpath**: An eye-tracking metric, usually a complete sequence of fixations and interconnecting saccades.

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