A study of eye tracking technology and its applications

Conference Paper · October 2017

DOI: 10.1109/ICISIM.2017.8122153

CITATIONS
40

READS
7,279

3 authors:

Pramodini Punde
Sinhgad Institute of Business Administration and Computer Applications
16 PUBLICATIONS **47** CITATIONS
SEE PROFILE

Mukti Jadhav
Marathwada Institute of Technology
58 PUBLICATIONS **408** CITATIONS
SEE PROFILE

Ramesh Manza
Dr. Babasaheb Ambedkar Marathwada University
201 PUBLICATIONS **1,071** CITATIONS
SEE PROFILE

A study of Eye Tracking Technology and its applications

Pramodini A. Punde
MGMs Dr.G.Y.P.College of C.S.&I.T.,
Aurangabad, India

Dr. Mukti E. Jadhav
G.S.Mandal's M.I.T.College
Aurangabad, India

Dr. Ramesh R. Manza
Dr.B.A.M. University,
Aurangabad, India

Abstract—

We can measure the eye movement activity using eye tracking technology. Eye tracking gives us information about where do we look? What is ignored and how the pupil reacts to different stimuli. The eye tracking concept is basic but its process and interpretation can be very diverse and complex. ET measures the gaze points generated by our eye relative to the head. Eye trackers are availbble in either remote or mobile forms. It tracks and records where do we look and how we move the gaze. One can analyze, visualize and interpret this information with the help of software. We have gone through the common use of fingerprint analysis and applications, eye tracking also would be a great biometric tool for analysis in various applications. In this paper we discuss eye tracking technology and its various applications. Now days, ET is being employed in almost all field including psychology, human computer interaction, marketers, designers, academics, medical, research and many more.

Keywords—eye tracking; gaze; fixations; scanpaths

I. INTRODUCTION

Eye Tracking Technology:

Most of the knowledge about our external world is gathered by using our eyes. So vision is the most important of our senses. Where we fix our eyes (gaze), and how we move eyes is associated with where we pay attention to. Eye tracking uses sensor technology to follow an individual's gaze and eye movement. This enables the ET device to identify where our eyes are focused at exactly. It also determines our presence, attention, focus [1].

Literature Review:

In 1999, Kyualg Nam Kim and S.R.Ramakrishnan proposed a vision based eye gaze tracking method used for HCI. They proposed eye gaze as input mode for efficient computer interface. Eye movements were the focus of research in this area[2].

The general use of real time eye movement data was relatively less focused in Human Computer Interaction.Some work was done by Richard Bolt and presented many innovative uses of eye movement data. Researchers Ware and Mikaelian demonstrated an experiment for HCI, wherein simple operations like cursor positioning and target selection were performed. Recently, the Eye Tracking technology has flourished for more research in various fields.

Eye Tracking Method:

There are many techniques to track and record the eye movements. The most common technique used by modern eye trackers is Pupil Center Corneal Reflection (PCCR). It uses near-infrared camera or other optical sensor for tracking the direction of gaze. In this method a near infrared light is directed towards the pupil i.e. the center of the eyes that causes visible reflections in the cornea which are tracked by a camera. PCCR is most commonly used in remote non-intrusive eye trackers [3].

Eye tracker basically captures eye movement by using a light source that illuminates eye that causes visible reflections. It uses a high resolution camera to capture eye image to show these reflections. Then this eye image is used to identify the reflections of the light source on cornea and pupil. Then vector formed by angle between the cornea and pupil reflections is calculated and based on this information the gaze direction is calculated. The vector calculation methods include:

:

- Velocity based
- Dispersion Based
- Area of Interest

With the help of image processing, if the Line Of Gaze (LoG) or Line Of Sight can be estimated and the Point Of Regard (PoR) can be computed as the intersection of the LoG with the LoS with the object of space or scene.

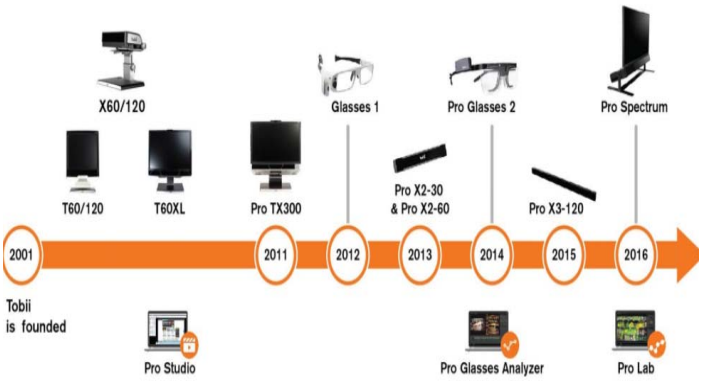

Fig. 1 Eye tracker types [7]

The modern eye trackers can be available as small and tiny as a pencil case and are getting more flexible and compact than the earlier eye trackers those were very large and cumbersome. Because of its flexibility, eye trackers are gaining popularity in almost all fields. Any research domain can get benefits from the collective quantitative evidences

978-1-5090-4264-7/17/$31.00 ©2017 IEEE

captured with method without making the participants uncomfortable. We can get quick results with meaningful visualizations and statistical data from an eye tracker. Eye trackers measure visual attention, interest and has become a popular tool for research in almost all fields for example cognitive linguistics, Psychology, Medicine, Marketing, Engineering, education, gaming and also in enhancing HCI by using eye movements for navigation and control.

Eye tracking is used as a powerful research tool, now is more accessible and is growing in popularity. Researchers from varied fields and disciplines such as Sports Scientists, Cognitive Psychologists, reading researchers, usability analysts, psycholinguists, electrical engineers, neurophysiologists and many more have a vested interest in eye tracking for a variety of reasons. The growth of eye tracking in recent years has gone through many challenges in designing an eye tracking experiment and analyzing the data.

Now days the laptops, tablets, smart phones with 3G, 4G technology are very commonly used. We have gone through the popularity and use of touch control in various devices. Similarly, eye tracking technology is also going to take off a big way.

The reason behind this is all smart phones have high resolution cameras. This can be combined with eye tracking technology to get data about the user's vision when the user is performing his routine task. As eye tracking is growing quickly in popularity knowledge about it has become more accessible than ever, creating a vast ocean of information.

Eye Tracker Types:

The following two types of eye trackers are available in the market:

- Remote Eye Trackers/ Screen Based
- Head Mounted Eye Trackers/ Mobile

A. Remote or Screen Based Eye Trackers:

These types of Eye Trackers require the respondents/ participant to sit in front of a screen to interact with the stimuli or screen based content. Remote ET systems track the eyes within certain limits called headbox, but the eye movement freedom is sufficiently large and the respondents feel unrestricted. Following are the characteristics of remote Eye Tracker:

- Records eye movement at a distance
- There are no attachments to respondent
- Computer or screen mounted
- Respondent sits in front of ET
- Observations of any screen-based stimulus material, offline stimuli can be recorded

B. Head-mounted or mobile Eye Tracker:

These are fitted near the eyes and allow respondent/ participant to move freely. These are used if your study needs to perform tasks in a natural environment. On the other hand, glasses might shift during the recording [4] Following are the characteristics of mobile Eye Tracker:

.

- Records eye movement from a close range
- Mounted on a lightweight eyeglasses
- Respondent can walk around freely

The eye trackers are available in the market from following organizations:

- Tobii
- SMIVision
- EyeLink
- Interactive Minds
- Imotions
- Mirametrics
- EyeTech

II. EYE TRACKER METRICS

We can get following metrics from an eye tracker and the information that we get from an eye tracker can be analyzed for various applications [4].

Fixations and Gaze Points:

The main metrics used in eye tracking are fixations and gaze points.

Gaze Point:

The basic units of measuring the eye movements are gaze points, one gaze point is one row captured by the ET device.

Fixation:

A fixation is a cluster denoted by a series of gaze points which are to be close in time and range. Fixation is a period in which our eyes are fixed at a particular object in a stimulus. Typically fixation duration is 100 to 300 milliseconds.

Smooth pursuit:

It is an eye movement that allows eyes to closely follow a moving object i.e. voluntarily shift gaze. For example, imagine watching clouds in the sky. Here, our eye movements are quite opposite as our eyes follow moving objects steadily t i.e. clouds.

Saccades:

Saccade refers to a rapid eye movement which redirects the visual axis to a new location. The rapid eye movements between fixations are referred to as saccades. For example while reading a book our eye movements are not smooth across the line but instead our eyes jump and pause generating a number of saccades. Typically saccades are measured in angle velocity. On an average, saccades span 7 to 9 characters along a line that contains text. This can be used to study reading behavior as early or expert readers.

Scan paths:

The scanpath was first defined by David Noton and Lawrence Stark in 1971. The sequence of fixation-saccade-fixation is referred to as scanpath..

Heat maps:

The static or dynamic or static aggregations of gaze points and fixations generate the distribution of visual attention are represented through a heat map. Heat maps serve

978-1-5090-4264-7/17/$31.00 ©2017 IEEE

as an excellent method for visualization; it shows maximum attention area of the stimulus.

Fig. 2 Heat Maps

Heat maps use easy to read color coded scheme. A high number of gaze points are indicated by Red area and shows an increased level of interest, yellow and green area point toward less visual attention.

Area of Interest:

Area of interest (AOI), are subregions of a stimulus object displayed on screen defined by user. Metrics to separate AOIs are evaluated with the performance of two or more specific areas in the same picture, website or any program interface.

Fixation Sequence:

Fixation sequence can be generated based on fixation position and time information. It depends on where a respondent looks and for how long. We can build an order of attention where the respondent looked first, second and so on. This parameter is used in research as it reflects salient elements in the display or in an environment that catch much attention. AOIs that respondents look at first are visually more salient and hence are of more interest.

Respondent count:

This metric allows to extract more information about the number of respondents had gaze direction towards a specific AOI. Higher respondent count indicate that fixations and gaze points are driven by some external aspects in the stimulus

Time Spent:

Time spent specifies the amount of time that respondents have spent on a specific AOI. It often indicates motivation and conscious attention because long prevalence at a region points to a high level interest.

III. APPLICATIONS OF EYE TRACKING

Eye tracking technology is going to take off a big way as we have gone through the touch control/ sensor technology. The ET technology can be used in almost all fields. Eye tracker device gathers various metrics discussed above. This data can be analyzed and used for many applications. The most commonly used eye tracking applications are discussed below:

Scientific and Academic Research:

The ET is widely used in academic and scientific research fields. It is applying the most of eye tracking technology for cognitive, developmental, experimental and media applications almost in medical, neuroscience, and psychology [5] [6].

Market Research:

With the innovations in ET technology, it is possible to measure attention to specific brands, products or theit key messages. It is also used to understand the ease or difficulty in store navigation.

In past few years, use of ET technology for market research has become important. Many of leading brands use ET tools to evaluate their products, designs, shopping behavior of their customers, advertising the products to optimize the overall customer experience. The wearable eye trackers enable the researchers to understand the entire shopper's experience in a real or simulated store [7].

Neuroscience and Psychology:

Human beings visualize in their minds first and then expectations get shape the way we see the world. If we see a picture of a living room, we most likely assume or know where we expect the television set. If it is at another location, we might be baffled and gaze around the "scene semantics and our 'rules' how we imagined living room should look are violated.

To get deeper insights and information into cognitive processes, attention, learning and memory eye tracking is useful to analyze the sequence of gaze patterns in the field of Neuroscience and psychology. Another aspect of research is done as to how we encode and recall faces how we encode and recall faces and where do we look to extract the emotional state of others. Eye tracking provides insights into reading performaces, word processing, particularly how eye movements are affected during reading by the emotional contents of text [8].

Psychology Research:

In the field of psychology, researchers can measure and correlate visual attention with other measures to study how brain works. The research in visual attention can be applied to normal populations and for specific subjects that have different behavioral patterns or different kind of mental disorders

Medical Research:

ET technology in combination with other conventional research methods or biometric sensors can be helpful in diagnosis of diseases such as Autism Spectrum Disorder (ASD), Schizophrenia, Alzheimer's, Obsessive Compulsive Disorder (OCD), Attention Deficit Hyperactivity Disorder (ADHD), and Parkinson's disease. For an instance it can be used to detect drowsiness or support many other fields for medical and monitoring purpose.

Usability Research:

The emerging field that us ET technology is usability and user experience. One most suitable example is Website testing. Here attention to main points/contents of the website, communication and Call to Attention (CTA) can be measured. The website owner may lose revenue if it is difficult to find a certain product on a website. Therefore if that website could be improved to easily find a product, the revenue would be

978-1-5090-4264-7/17/$31.00 ©2017 IEEE

increased. Same applications can be used in mobile Apps on Tablets and smart phones [9].

Packaging Research:

There is huge investment in designing packages of products. This is enhanced with ET technology especially for fast moving consumer goods. This makes sure that the package of a product has catchy messages and gets visual attention on the shelves as compared to other products. Eye tracking is used here for understanding the customers' preferences and designing the packages [10].

PC and Gaming Research:

ET technology is introduced to HCI and gaming to enable game designers to better understand gaming experience and accordingly control the experience and increase realistic approach. In the coming time it is even possible to personalize the games development by using player's eye movements. [11].

Human Factors and Simulation:

Use of ET in automotive research has used ET for a long time to capture driver's visual attention or drowsiness both with respect to navigation and dashboard layout [12].

Ophthalmology:

In this field, on-screen vision studies are conducted for medical researches and also for investigating eye diseases. The result of this study assist in understanding the human eye and vision and also developing innovative approaches to diagnosing disease [13]. The ET solutions in ophthalmology are:

- Perimetry
- Vision testing and Screening
- Direction of the eye misalignment (Strabismas)
- Oculomotor Functions
- Refractive Surgery
- AMD (Age related macular degeneration)

Result Analysis:

The above discussed applications are the most commonly used within ET research. However, ET is not limited to these and can be even more powerful when used in combination with further biometric sensors. In our further research, we will be using ET technology and methods to classify early glaucomatous changes from the eye tracker data. For example, we used DOVES database that provides us with more than 30,000 fixations. The database contains eye data, fixation data for 29 subjects. The fixation data for a subject is shown below [14]:

X-Position	481.35	274.6	316.3	296	783	673	609.29	542.79
Y-Position	373.76	377.1	243.6	441.1	507.9	257	333.53	362.05
Duration	187	52	65	38	203	208	103	121

Table 1: Fixation data for a subject

This fixation data when accessed through MATLAB produces following output:

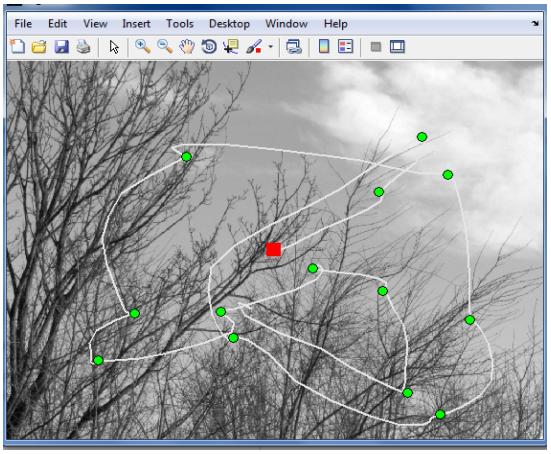

Fig. 2: Computed Fixations for a subject

In above figure, the red square shows the first fixation and green dots show the computed fixations. With the study of above mentioned applications, we propose that the eye tracking data can be analyzed for various problems. We will be using eye tracking metrics, scanpaths and fixations to identify glaucomatous changes in high risk groups. Glaucoma is leading cause for irreversible blindness in developing countries such as India. Early detection of Glaucoma is important to save the vision loss due to Glaucoma. Here, we propose that eye tracker metrics analysis may help us to detect early glaucomatous changes in high-risk groups. Whenever we look at any scene, many eye movement metrics are captured, saccadic eye movements are generated. Saccade is a change in gaze position by a rapid sweep, followed by fixations where the eye is stable. Scan path is the sequence saccades-fixations-saccade. We can collect this eye movement data as a part of person's daily routine activities and analyze this data for early detection of Glaucoma.

IV. CONCLUSION

In this paper we studied eye tracking technology, its method and applications in various fields. A single technology can have a wide scope of applications. Now days the laptops, tablets, smart phones with 3G, 4G technology are very commonly used. We have gone through the popularity and use of touch control in various devices. Similarly, eye tracking technology is also going to take off a big way. The reason behind this is all smart phones have high resolution cameras. This can be combined with eye tracking technology to get data about the user's vision when the user is performing his routine task. As eye tracking is growing quickly in popularity

knowledge about it has become more accessible than ever, creating a vast ocean of information. Here is a wide scope for analyzing huge data generated from an eye tracker and applied for solving a specific problem. Here, we propose to study early glaucomatous changes in high risk groups with the help of eye tracker data.

REFERENCES

[1] http://www.eyetracking.com/

[2] Vision based eye gaze tracking for HCI, R.S. Ramakrishna, IEEE SMC 99 Conference proceedings

[3] https://imotions.com/blog/eye-tracking-work/

[4] Eye Tracking Pocket Guide copyright 2016

[5] Low cost eye tracking technique for visual scan path detection in the diagnosis of special learning disorders in children, Sumathi V, M. Monicasubhashini, Himabindu. J, IJCSET, August 2011, Vol.1 Issue 7, 424-428

[6] A case study of using eye tracking techniques to evaluate the usability of e–learning courses, Liu, Mingzhuo, Zhu, Zhiting

[7] www.tobiipro.com

[8] Reading performance Using Eye Tracking to Assess Reading performance in Patients with Glaucoma: A Within-Person Study, Nicholas D. Smith, Fiona C. Glen, Vera M. Mönter, and David P. Crabb, Hindawi Publishing Corporation Journal of Ophthalmology Volume 2014, Article ID 120528, 10 pages http://dx.doi.org/10.1155/2014/120528

[9] Identifying Web Usability Problems from Eye-Tracking Data, Claudia Ehmke, Stephanie Wilson British Computer Society,People and Computers XXI – HCI Proceedings,2007.

[10] Consumer Purchasing Based on Packaging Structural Design/Product Visual Display in a Retail Environment, Thackston, Katie, Pham, Andy, Galvarino, Josh]

[11] Eye Tracking in Human-Computer Interaction and Usability Research: Current Status and Future Prospects Alex Poole and Linden J. Ball, Psychology Department, Lancaster University, UK

[12] OculomotorET Biometric Authentication via Oculomotor Plant Characteristics, proceedings of the IARP/IEEE International Conference on Biometrics, March 29 - April 1, 2012 New Delhi, India

[13] www.smivision.com

[14] DOVES: Adatabase of visual eye movements, Van de Linde, I.Rajshekar, U. Bovicj, A.C. Cormack, L.K.(2009). Spatial Vision, 22(2): 161-177. URL:http://live.ece..utexas.edu/research/doves.

.

978-1-5090-4264-7/17/$31.00 ©2017 IEEE