Scan Paths Reduction in Eye Tracking Techniques

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Abstract   Nowadays, the eye tracking is gaining interest as an evaluation technique in a variety of areas and disciplines. Its use allows the study and analysis of the way in which a person visually explores a particular scene, interface or image. The use of this technique in the educational field has increasingly gained place and impact, highlighting its use in the evaluation of multimedia materials. It is interesting to know where and how the students focus their attention when studying the educational materials displayed on a screen. In particular, it is interesting to know the order of visual exploration that the student follows. In this way, for example, we can know, given a content consisting of text and images, whether the explanatory text is helpful or if the image on its own is enough. One of the representations obtained by applying eye tracking sessions is the scan path, which shows the order of points of attention (points of fixation) and the user fixation time on the scene. The main problem is the huge number of points on which a user fixes their attention while visually scanning the contents displayed, so these representations are complex and the analysis task is arduous. Thus, the objective sought is to reduce these scan paths and represent those data that can be more relevant to the researcher, such as transitions between the different areas of interest, or the scanning order of them. In this way, we can achieve a higher level of abstraction and a great deal of information easier to analyze for obtaining conclusions.

Keywords: eye tracking, eye tracker, scan path, heat map, blind spots map, fixation point, areas of interest

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1. Introduction

1.1. Approach

In the field of study of educational improvement different types of techniques are carried out. The aim is, on the one hand, from the perspective of teachers, to facilitate the task of teaching, and, on the other hand, from the point of view of students, to assist and facilitate the understanding of the study material.

Throughout the time new techniques have been developed and new technologies have appeared. This has allowed a great educational improvement due to the achieved results. One of these new techniques is eye tracking [9].

The motivation underlying the eye tracking technique is to monitor and record the way in which a person visually explores a particular scene, to determine in which areas, for how long, and in which order they fixes their attention [2].

Knowing how a user interacts, for example, with a specific educational computer system or with educational materials in digital form, we can see the strengths and weaknesses of this educational material and try to improve it and adapt it to the needs of analysis and understanding of the students [3,5,6,7,10,16].

For example, with this technique we can detect if in a particular educational software, the students avoid using a specific functionality due to the degree of complexity of use; this may lead to reduce the complexity of such functionality, adapting to the level expected by the students.

To detect all this, we can make use of an eye tracker, which is a special device that projects infrared rays to the user's eyes, which bounce off on their pupils and return to the device, which allows calculating with great precision the point where the user is looking at[12].

To facilitate the interpretation of the immense amount of data collected during a session of eye tracking, different computer programs are used. They can generate a series of animations and performances in order to graphically summarize the visual user behavior[1].
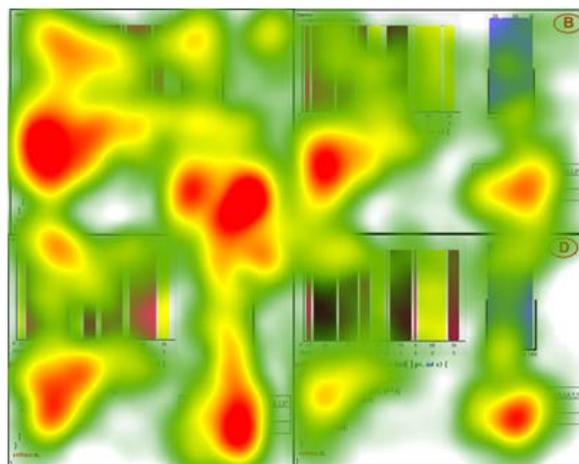

Figure 1. Heat map

Among these representations the heat maps (Figure 1), the blind spots maps (Figure 2), and/or the scan paths (Figure 3) are outstanding.
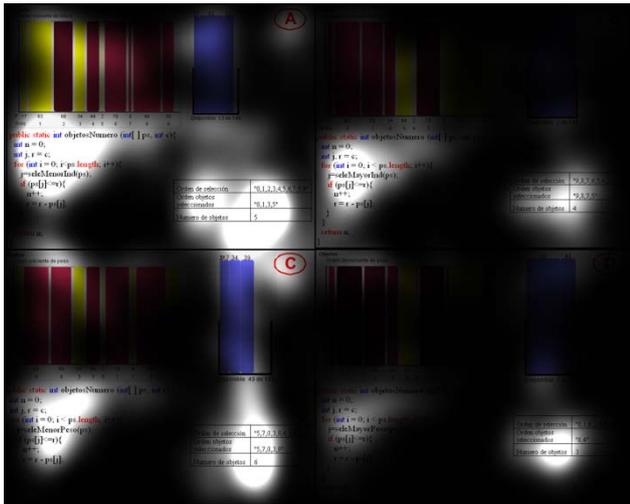

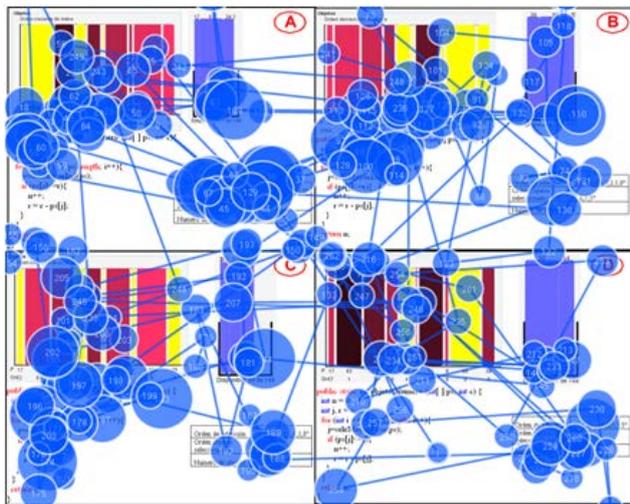**Figure 2.** Blind spots map

Figure 3. Scan path

The scan paths are the most used technique at the time of analyzing the results of an eye tracking session, as it is done in most studies related to educational improvement [13,14,15]. This is because, in such representations, not only can we observe the density (areas with the greatest number of fixations[1]), as displayed in the heat maps and blind spots maps, but also the order followed during the visual exploration.

The scanning order is something that can be very useful, for example, by knowing how many times a particular student has had to re-look at a specific area after exploring other/s, or to understand what is being queried in the first place before reaching to the area that contains the main element/s.

1.2. Purpose

The main problem of the scan paths lies in the huge number of fixations that a user performs to visually explore a particular scene; so this representation is

complex and it is difficult to clearly appreciate the order represented.

Thus, the purpose of this research is based on the hypothesis that it is possible to develop a software that allows us to simplify the scan paths, showing only those data which may be more relevant to the researcher or analyst.

Therefore, the objective of this work is to present the first versions of the method of reduction and abstraction of the information about the number of fixations that are collected in a scan path. This is obtained by decreasing the number of points represented in the scan paths, reducing them by zones and areas of interest. In a simple way, the final result would represent the transitions between these areas and the intensity of the fixation in them.

1.3. Document Structure

This document is divided into four main sections, plus the fifth section, the acknowledgments, and the last one, the references.

The first section is responsible for providing an overview of the field of study, as well as the objectives pursued in this research and the justification.

The second section refers to the background that has been considered and/or used in the development of this work, based on two tools: *Tobii Studio* and *iTrackEye*.

The third section contains the main part of the research, i.e., the resolution of the objectives, where the aspects that have been considered and the results are presented.

In the fourth section a series of conclusions about the work performed in this research are carried out, as well as possible future work lines (some ideas which we have been working in).

2. Background

This section describes the background of the present work. For this, it briefly describes two tools used to display and analyze the information obtained by applying the evaluation technique based on eye tracking: *Tobii Studio* and *iTrackEye*.

2.1. Tobii Studio

Tobii Studio[2] is the software required for the creation of projects (sessions or experiments) of eye tracking. This software is provided by the manufacturer of the model of the *Tobii*[3] eye tracker.

Each project can have one or more test; and, in turn, each test can have various multimedia elements, to be shown to the user and on which to carry out the analysis of eye tracking.

In addition to designing of the eye tracking sessions, *Tobii Studio* incorporates the functionality to display the results of a project of eye tracking.

Tobii Studio generates the representations commonly used when applying these types of techniques (heat maps, blind spots map, and scan paths). However, we cannot

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[1]A fixation refers to a point in which the user has fixed his attention during a certain time [12].

[2] Tobii Studio Website. Available at: http://www.tobii.com/en/eye-tracking-research/global/products/software/tobii-studio-analysis-software/.

[3]Tobii Website: http://www.tobii.com.

make changes over these representations, for example, to simplify the scan paths and adapt them to the needs of the researcher (what is intended in this research).

Currently, the latest version of this software and with which we are going to work is 3.3. Moreover, it is important to note that this is proprietary software, so its use is subject to payment of a license.

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2.2. *iTrackEye*

iTrackEye [11] is an application created by the CHICO research group of the College of Computer Science Engineering of Ciudad Real at the University of Castilla-La Mancha, and will be the starting application on which we are going to work in this investigation. The aim is to add to this application the necessary functionalities to support the objective mentioned in the introduction section (the reduction of scan paths, as well as the identification and detection of visual patterns).

This application allows us to import the data generated by *Tobii Studio* (stored in a .tsv file[4]), and performs a series of proprietary representations, always included within the three static representations commonly used when applying the technique of eye tracking (heat maps, blind spots map, and scan paths).

Initially, *iTrackEye* was created to be used on mobile devices (more specifically, for iPad), but it is currently under development to convert it into a multiplatform application (specifically, giving web support to the features included).

In this respect, *iTrackEye* is in a process of continuous improvement, to which new functionalities are added adapting to new needs and to emerging challenges.

3. Scan Path Reduction Method

Figure 4. Scan path represented by *iTrackEye*

As has been previously commented, *iTrackEye* is an application which has underlied the implementation of the

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[4]Tab-Separated Values: file type with simple text formatthat stores data in a tabular structure, in which each value is separated from the next by a tab character.

functionalities for the simplification of scan paths. Figure 4 shows, as an example, the default representation of the scan paths carried out by *iTrackEye*.

3.1. Scan Paths Reduction

As can be seen in Figure 4, the number of fixation points represented is a problem when analyzing this representation because, while it is relatively easy to see the areas of greatest density, to follow the order of the fixations is a difficult and almost impossible task.

In many cases, the interest of the researcher or analyst in these representations is not to follow point to point where a specific participant has been fixed their attention, but to see the order followed between different areas of interest.

An area of interest (hereafter, AOI) is a zone that the researcher defines as important. For example, in Figure 4, we can see a title, an image, and an explanatory text(in total, three principal elements), the AOIs may be, for example, each of these principal elements.

Thus, the functionality that it is intended to incorporate allows simplifying the representation, based on these AOIs, reducing the number of fixation points generated in these areas. This reduction will present two variants:

1. One point complete reduction.
2. Partial reduction by zones.

3.1.1.One Point Complete Reduction

In this type of reduction, all fixation points of an AOI carried out during the same period (that is to say, the fixations performed before moving to another AOI or move out of the current) are reduced to a point. In this way, it is possible to see only the order of transition between AOIs.

Thus, Figure 5 shows the result of applying this new functionality of the *iTrackEye* application. In the figure it can be seen how, starting from the same example shown in Figure 4, a significant reduction in the number of fixation points (from more than two hundred represented points to only eight) can be obtained.

Figure 5. One point complete reduction in *iTrackEye*

It is important to note that, in this type of reduction, what interests more is not to know how long the user has been looking at a specific area, but only the transition between areas. Therefore, the diameter of each fixation point (which in other representations is related to the time

of fixation at that point), remains constant at each of the represented points.

3.1.2. Partial Reduction by Zones

For its part, this type of reduction reduces the number of fixation points by AOIs and by zones within these AOIs (taking also into account the durations of fixations). That is, within an AOI the fixation points are grouped by zones of a fixed dimension. In this way, we can see the order of fixations (simplified) performed within the same AOI and, of course, between AOIs.

Thus, Figure 6 shows the result of applying this new functionality of the *iTrackEye* application. Again, starting from the example of Figure 4 a reduced number of fixation points (from more than two hundred represented points to around of one hundred and fifty)is observed.

Figure 6. Partial reduction by zones in *iTrackEye*

In this case, the reduction is less than in the previous type, because within each AOI all the fixations performed are taken into account, and not just one, as it happens in the other reduction type.

In this type of reduction, we are interested to know how long the user has been looking at a particular area, so that the diameter of each fixation point is calculated according to all the fixation points that are grouped in the zone of the fixation point represented.

Also, the coordinates of each fixation point represented are calculated from the average of the coordinates of the fixation points grouped in this zone.

4. Conclusions

The scan paths in the field of the study of the educational improvement have always been a reference in terms of quality and understanding the results obtained by the technique of eye tracking. However, this type of representation, from the beginning, has had the problem of the large amount of data represented, making the task of analysis so difficult and, sometimes, impossible to perform.

The objective of this research, based on simplifying the scan paths, has been successfully achieved, as observed in the previous section of results. In fact, this simplification has more than optimal results, having achieved two types of reductions or new representations.

On the one hand, thanks to the complete reduction, we can see the order followed between the different AOIs; this can help, for example, to understand why a specific AOI is visited, or the existing relationships when consulting different AOIs in a certain order.

Additionally, thanks to the partial reduction, not only the order followed between the AOIs can be observed but also within the same AOI (where the points represented are grouped by areas). Also, it can analyze over which elements of each AOI the participant has been fixed more, besides knowing the intensity of fixation (the fixation time) over each one.

Therefore, it can be concluded that the problem that has always existed with scan paths has been softened through these new representations implemented in the *iTrackEye* application [11]. Also, in this way, a remarkable improvement in the effective analysis of these scan paths has been obtained: this technique will allow achieving better results and significant conclusions in studies of educational resources, content, procedures, and techniques through the technique of eye tracking.

4.1. Future Work Lines

As of now, having achieved the challenge of simplifying the representations of scan paths, a large amount of new ideas arise about how to use the data from these simplifications to improve the analysis of the results, or even create new types of analysis that help to know certain characteristics previously unidentifiable, but latent in this type of representations.

One of these new ideas comes from a study conducted at the University of Padova (Italy), related to the generation and/or identification of visualization patterns [4].

Currently, the CHICO research group of the College of Computer Science Engineering of Ciudad Real at the University of Castilla-La Mancha is devoted in full research in this area of detection and representation of visualization patterns, taking as a basis the representations resulting from the scan paths.

The identification and/or detection of visualization patterns allow, on the one hand, the observation of which visualization patterns has followed a particular participant (understanding the order of the visual scanning), and, additionally, determining whether the participants have followed a pattern in particular in its fixings at a given time or after a particular action (that is to say, the identification of similarities in the visual exploration behavior among them and other relations).

For example, returning to the previous section and based on the example of Figure 4, suppose that the areas of interest defined are each of the three principal elements existing (title, image, and explanatory text) and a defined pattern is to fix their eyes, according to the following order, in the areas of interest of the elements image, explanatory text, and title again. Having defined both, a researcher can see if a participant or group of participants follow at some time this pattern (and the researcher can calculate percentages of coincidences, among other things).

It is noteworthy that, again, the *iTrackEye* application takes a special role, as it is the application that we are using to make the implementation of this new functionality, where the first promising results have already been achieved.

At a first glance we have been able to take advantage of this improved procedure of eye tracking reduction. A second thought takes us to envisage a set of diverse research fields and we can mention innovative areas of research in education, such as learning design and presentation strategies, where the use of this eye tracking technique can improve the production of high-quality educational materials and procedures and make a more effective use of some resources already produced.

Acknowledgement

References

[1] Bojko, A. 2013.Eye Tracking the User Experience: A Practical Guide to Research (1st ed.). Rosenfeld Media, NY, USA.

[2] Hassan, Y., and Herrero, V. 2007. Eye-Tracking en Interacción Persona-Ordenador. In Journal of No Solo Usabilidad, nº 6.

[3] Hyönä, J. 2010.The use of eye movements in the study of multimedia learning. In Journal of Learning and Instruction, nº 20, 172-176.

[4] Mason, L., Tornatora, M. C., and Pluchino, P. 2013. Do fourth graders integrate text and picture in processing and learning from an illustrated science text? Evidence from eye-movement patterns. InJournal of Computers & Education, nº 60, 95-109.

[5] Mayer, R. E. 2010. Unique contributions of eye-tracking research to the study of learning with graphics. InJournal of Learning and Instruction, nº 20, 167-171.

[6] Molina, A. I., Redondo, M. A., Lacave, C., and Ortega, M. 2014. Assessing the effectiveness of new devices for accessing learning materials: An empirical analysis based on eye tracking and learner subjective perception. InJournal of Computer in Human Behavior, nº 31, 475-490.

[7] Navarro, Ó., Molina, A. I., Lacruz, M. and Ortega, M. 2015. Evaluation of multimedia educational materials using eye tracking techniques. In 7th World Conference on Educational Sciences (Athens, Greece, February 05 - 07, 2015). WCES-2015.

[8] Molina, A. I., Redondo, M. A., Ortega, M., and Lacave, C. 2014. Evaluating a graphical notation for modeling collaborative learning activities: A family of experiments. In Journal of Science of Computer Programming, nº 88, 54-81.

[9] Nielsen, J., and Pernice, K. 2009. Eyetracking Web Usability (1st ed.). New Riders, SF, USA.

[10] Ozcelik, E., Arslan-Ari, I., and Cagiltay, K. 2010. Why does signaling enhance multimedia learning? Evidence from eye movements. InJournal of Computer in Human Behavior, nº 26, 110-117.

[11] Patón, J. D., Ortega, M., Molina, A. I., and Redondo, M. A. 2015. iTrackEye: Aplicación iOS para iPad basada en el tratamiento de los datos resultantes de Eye Tracking. In 1ªConferência Ibero-Americana de Ambientes de Aprendizagem Futuros (Porto, Portugal, October 01 - 02, 2015). CIAAF 2015.

[12] Poole, A., and Ball, L. J. 2005. Eye Tracking in Human-Computer Interaction and Usability Research: Current Status and Future Prospects. Chapter in C. Ghaoui (Ed.): Encyclopedia of Human-Computer Interaction. Idea Group, Inc., PA, USA.

[13] She, H.-C., and Chen, Y.-Z. 2009. The impact of multimedia effect on science learning: Evidence from eye movements. In Journal of Computers & Education, nº 53, 1297-1307.

[14] Tai, R. H., Loehr, J. F., and Brigham, F. J. 2006. An exploration of the use of eye-gaze tracking to study problem-solving on standardized science assessments. In International Journal of Research & Method in Education, nº 29, 185-208.

[15] Tsai, M.-J., Hou, H.-T., Lai, M.-L., Liu, W.-Y., & Yang, F.-Y.2012. Visual attention for solving multiple-choice science problem: An eye-tracking analysis. In Journal of Computers & Education, nº 58, 375-385.

[16] van Gog, T., and Scheiter, K. 2010. Eye tracking as a tool to study and enhance multimedia learning. In Journal of Learning and Instruction, nº 20, 95-99.