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Visualisation and Analysis of Multiuser Gaze Data: Eye Tracking Usability Studies in the Special Context of e-Learning

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I. Problem Statement

The motivation for my dissertation derives from my master thesis (for reference see [1]) where I have applied the usability method of eye tracking within the context of e-learning. During this work I have been recurrently confronted with the issue, that the cumulative visualization of recorded eye movements (of several test users) is significantly affected by lack of clarity. Current visualization methods of gaze data may lead to unspecific interpretation in form of ambiguous or inconsistent results during the final analysis process. It is not infrequent that inappropriate visualizations mislead researchers and provoke false conclusions of academic as well as economic studies. The most common visualization methods for cumulative gaze data are *heatmaps* as well as *gaze plots* – for further reference see state-of-the-art works from [2,3]. The former is suitable for an overview of eye movements' intensities, density as well as the general distribution of the learner's visual attention. However, this visualization method neglects fundamental information for example about the temporal distribution (order of fixation/saccades), general traceability of gaze, (cumulative) start as well as end of learner's visual explorations and additional information about visual transitions between areas of interest (AOI). The second considers most of the above mentioned aspects, however cannot be fully applied due its insufficient form of representation for multiuser-gaze data. In Figure 1 an exemplary gaze plot for a single user is shown. In contrast Figure 2 represents a gaze plot of 10 test users for the same visual stimulus. Both figures clearly show that there is an imminent need for cumulative gaze plot visualization for multi-user gaze data.

The second topic of my PhD concerns the linking of eye tracking studies' results to e-learning technologies. Eye tracking research has been largely adapted to marketing or human-computer-interaction in general - however it has not been commonly used for learning technologies or e-learning applications in particular. Furthermore the reliability of existing eye tracking studies (within both and economic settings) may be impaired due to ambiguous interpretation. It is a general issue that the analysis process of these eye tracking results is not carried out by basic guidelines or (internationally approved) standards. An aim of my dissertation is to develop a practical framework respectively a set of guidelines for the interpretation process in order to minimize ambiguity during analysis of gaze data. As a side effect this framework should contribute to the improvement of the learning technologies' quality.

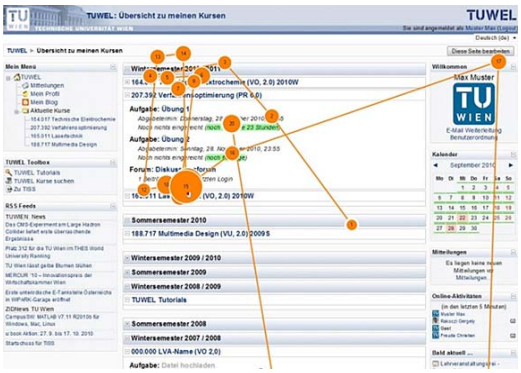

Figure 1: single-user gaze plot

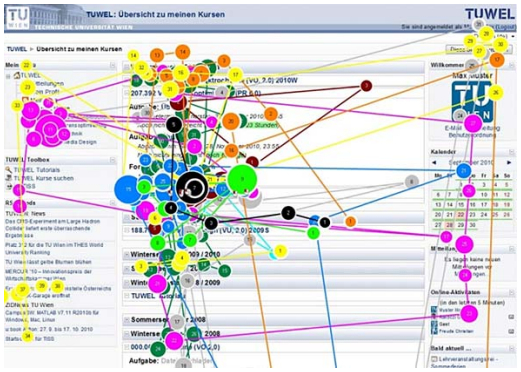

Figure 2: Ambigious gaze plot for multi-user gaze data

Eye movements and subsequently the visual attention of learners highly depend on the user interface as well as on the usability of modern learning technologies. As shown in academic research the learner's visual exploration, navigation and problem solving strategies form a crucial part of the learning process itself. A better understanding and subsequently an effective mapping, monitoring or supervising of learners' eye movements by various methods of eye tracking may lead to an improved learning process.

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However this effect can only be achieved if learning technologies are developed and designed according to guidelines that are based on a learn-supportive fundament. In my opinion eye tracking research in the context of learning technologies may lead to new insights that are characterized by a learner-centered design - in particular supporting hereby the visual perception of learners.

II. Research Question

The first challenge within my PhD is to implement an eye tracking visualization method that covers the following fundamental criteria:

1. Visible temporal order, precise spatial position and orientation of (cumulative) fixations/saccades
2. Intensity, duration and density of eye movements
3. Minimizing occlusions of overlapping gaze data
4. Clearly visible start as well as ending points of learners' visual exploration
5. Clearly visible transitions between AOIs

For the second part of my PhD the following research questions have to be answered:

- What patterns of eye movement signalize difficulties of navigation within e-learning environments?
- Which eye tracking metrics are mostly suitable for designing and analyzing e-learning technologies?
- By what guidelines can visual attention (during learning with e-learning technologies) be improved?
- How do visual learning elements correlate with learners' visual exploration strategies?
- Are there crucial factors for designing a visually efficient e-learning environment? Etc.

III. Research Methodology

My research during my PhD basically consists of three major steps. The first step includes the conceptual development as well as implementation of a visualization method of multi-user gazeplot. The development is based on commonly adopted strategies such as clustering algorithms, methods for retrieving gaze path, classification of relative differences among eye movements as well as generalization due to convex hulls. As an example the two methods of [4] *mean-shift algorithm* as well as *distance-threshold algorithm* that were specifically developed for eye tracking measures - enable an effective clustering of heavily scattered eye movements. Further useful approaches and strategies for implementation can be found in [5]. As the implementation platform Tobii analysis SDK is applied. Further development tools are Tobii Studio and MatLab.

Within the second step of my dissertation I plan to carry out some small-size eye tracking tests and a large-scale user study with approx. 40 participants. These empirical investigations will be carried out iteratively and in academic settings. As visual stimuli e-learning tools will be used.

The third step will be the development of a novel correlation framework between eye tracking metrics and e-learning. As stated before there is hardly any research on this interdisciplinary topic. Initial work is done by [6] opposing usability guidelines to design processes of e-learning modules. A similar correlation framework for web usability and eye tracking was developed by [7], however this work's metrics can't be directly applied to e-learning setting. This gap will be also investigated within my PhD.

IV. Contribution to the Research Area

Two results of my dissertation may be seen as a contribution to academic research. The first result will be a software tool for visualization of multi-user gaze data that could be further used in eye tracking research as currently there is no such tool. With this innovative approach new insights may be gained in various research fields.

The second result will be a novel correlation framework consisting of practical guidelines for designing and implementing learning technologies. The guidelines will be derived from eye tracking studies conducted within my PhD project. The framework should act as a contribution to a better understanding of the correlation between specific visual patterns and the design of effective learning tools. This part of the PhD project will be elaborated in a more practical way and should be a new and useful guide for all e-learning practitioners – not only for e-learning authors, lecturers or course designers of e-learning, but also for system providers of advanced learning technologies. In this way, students using those e-learning systems considering my correlation framework will benefit from a (visually) more intuitive as well as user-optimized interface.

Acknowledgment and Advisor's Contribution

My doctoral thesis is part of the work conducted by the Teaching Support Center of Vienna University of Technology. My PhD advisor Dr. Margit Pohl supports my work by giving regular feedback on academic methodology, direction of work as well as on partial results. The eye tracking equipment itself is provided by Dr. Margrit Gelautz (Interactive Media Systems Group), whereas the e-learning expertise is supported by the Teaching Support Center of Vienna University of Technology.

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