ESTER

Eye-Tracking Science Tool and Experiment Runtime

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Abstract. We introduce ESTER, an interactive 3D real-time (Eye-tracking) Science Tool and Experiment Runtime for investigating visual attention by means of the aggregation and representation of three-dimensional gaze paths and positions.

Keywords: eye-gaze tracking, stereoscopic imaging, 3D visualization, real-time, user studies.

1 Introduction

3D visualization is widely recognized as a crucial aspect in communication of spatial information. The widespread usage of 3D graphics engines and the development of 3D formats consequently results in a variety of systems ranging from information visualization systems to computer-aided design (CAD) tools as well as computer games and entertainment. However, the success and further progress of 3D applications inherently depends on visualizing content in a user-centered way. User-Centered Design is an approach to user interface design in which the needs, wants, and limitations of users are given extensive attention. Our consideration is focused on analyses and investigations of 3D interfaces, which assist the user in perceiving spatial information as effectively and efficiently as possible [3]. A necessary requirement to achieve this aim is the provision of a visual experiment creation tool to investigate the visual attention of users interacting with virtual three-dimensional objects and scenes.

2 Eye-Tracking in Stereoscopic Projected Virtual Scenes

Stereoscopic projection is a well-established technology that exploits the fact that our visual system consists of two eyes [10]. Recently, 3D visualization using stereoscopic projection is gaining increased attention [2, 10]. In addition, the usage of eye-tracking systems facilitates the correct detection of eye positions and furthermore the calculation of 3D gaze positions in a virtual scene, whereby we can effectively simulate the real-world experience of depth perception in virtual worlds [11].

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However, the detection of the gaze position in three-dimensional virtual environments still lacks methods and techniques to process and depict information about the visual attention of the user.

Researching attention-based 3D visualizations as well as perceptual bias towards stereoscopic 3D visualizations in human-computer interaction requires interactive computer systems [9]. To this end, an extensible component-oriented software framework was implemented to record and give feedback about the visual attention of the user [4]. The framework was developed based on standard components: OpenSceneGraph [5] and wxWidgets [8]. Additionally, the framework uses a modern approach to extensible component-based software engineering in C++, by using an implementation of the OSGi standard [7], the Open Service Platform [1].

The Eye-tracking Science Tool and Experiment Runtime (ESTER) is developed based on this software foundation. On the one hand, ESTER visualizes a three-dimensional scene in an interactive real-time environment (see Fig. 1) and renders the virtual world stereoscopically using NVIDIA 3D Vision [6] shutter glasses. On the other hand, a stereoscopic eye-gaze tracking setup is used to detect the intersection points of gaze rays of the user with the observed virtual world [11]. To achieve this, the visual attention and eye movements are recorded with up to four cameras for high accuracy and tolerance of head motion.

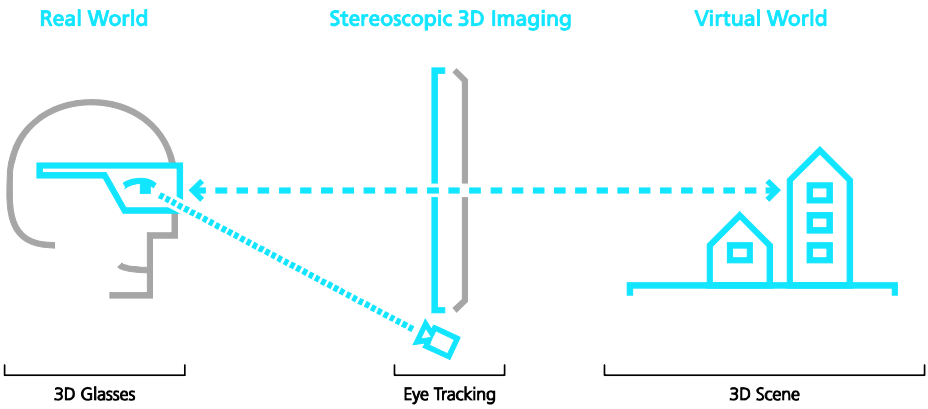

Fig. 1. Conceptual structure of ESTER for stereoscopic and eye-tracking based 3D visualizations of virtual scenes

2.1 Science Tool

The software framework ESTER provides a graphical experiment creation environment for scientists as well as interface and interaction designer. The features in ESTER have been designed to address many of the research needs that have been encountered when working with three-dimensional scenes in interactive environments. This ranges from simple experiments in which a static scene is shown that is explored by the user, to more sophisticated experiments in which the user interacts with virtual three-dimensional worlds.

The creation of experiments is achieved by an intuitive hierarchical experiment interface, which features building conceptual blocks (see Fig. 2). The functionality of the editor window supports the realization of simple as well as complex experimental procedures. Furthermore, custom JavaScript code can be added to extend experiments when required. Additionally, the editor window of ESTER provides a built-in 3D visual stimulus creation to compose primitives, textures, and lights into a virtual scene, with support for a multitude of import data formats. As a science tool for creating eye-tracking experiments, ESTER supports a variety of eye-tracking devices, performing camera set-up, calibration, and validation. ESTER also contains a real-time preview window that visualizes the currently selected three-dimensional scene as it is presented during the experiment. (see Fig. 2).

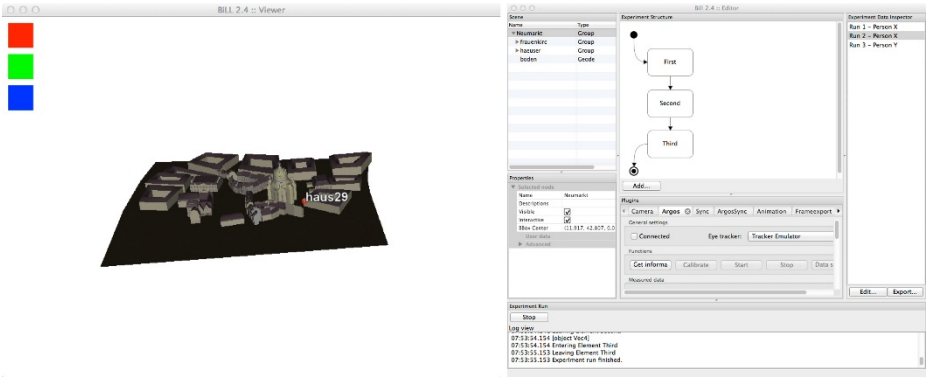

Fig. 2. Preview window of ESTER showing a virtual 3D scene (left) and Editor Window of ESTER showing the active experiment's configuration

2.2 Experiment Runtime

In order to improve visual analysis of gaze data in stereoscopically displayed virtual scenes, we propose a set of eye-gaze visualization techniques: *planar-depicted*, *object-based*, and *spatial-focused*. By providing different kinds of depicting eye-gaze data, visual attention can be depicted in different ways whereas a combination of these techniques has the potential to considerably facilitate usability studies in interactive 3D applications.

Comparable to the visualization of 2D eye-tracking data, ESTER provides a visualization method, which is a 2D planar representation of 3D fixation data (see Fig. 3 left). This kind of visualization can be used to analyze the visual attention of the user in principle due to the ambiguous representation, which results from 3D data depiction on a 2D layer.

To investigate a subject's attention towards individual scene elements, an object-based visualization method is integrated. This technique highlights objects that are focused using a representative color (see Fig. 3 center). This visualization technique is especially helpful to a supervising experimenter, because it allows the rapid identification of objects that are currently looked at by the subject.

With the spatial-focused visualization technique, we introduce a new gaze visualization of eye-tracking data for facilitating detailed inspection of visual attention of virtual worlds (see Fig. 3 right). Fixation data is visualized as spheres in the virtual world and allows the depiction of fixation locations in spatial coordinates. Compared to the previous techniques, the spatial-based attention visualization is the most complex approach due to the transformation of real eye fixation and saccades into virtual world coordinates. Thereby, the virtual depth position of user fixations are recordable and presentable.

Fig. 3. Visualization techniques of eye-gaze position data in the stereoscopically presented virtual environment: planar-depicted (left), object-based (center), and spatial-focused (right).

3 Conclusion and Discussion

In this paper, we present a science tool and experiment runtime for designing eye-tracking experiments using eye-gaze visualizations in interactive real-time environments. The system allows the evaluation of gaze data in stereoscopically displayed virtual scenes. First results indicate the high potential for facilitating usability studies of 3D user interfaces for HCI researchers and practitioners. However, visual gaze analysis of virtual worlds is still in an early stage and therefore offers much potential for further development. Using this system, interaction and interface designer can investigate 3D visualizations and interfaces relating to expectations concerning usability. This is achieved by the real-time representation of the visual attention inside the virtual scene and the evaluation of gaze behavior by recording and playing back the registered eye movements of subjects for usability studies.

4 Future Work

Prospectively, the hardware setup and the software framework comprising ESTER will be used for all steps required in regular user studies – from preparation, to live data recording, and finally data play back and analysis. Additionally, it is necessary to systematically compare the efficacy of the planar, object-based and spatial visualization technique to analyze their relative efficiency. Therefore, several parameters of the visualization methods have to be estimated in empirical studies. Furthermore, the creation of user studies using ESTER as a design tool and experiment runtime has to be validated by empirical studies of the system itself. Also, the improvement and optimization of the visualization techniques in the con-text of the evaluation of user data is needed. For example, it is highly desirable to represent

data from several users at once for comparison purposes. In addition, possibilities to combine various auxiliary data, such as fixation duration, pupil radius, or viewing directions, have to be investigated.

References

1. Applied Informatics, http://www.appinf.com/index.html
2. Bourke, P.: Omni-Directional stereoscopic fisheye images for immersive hemispherical dome environments. In: Computer Games, Multimedia and Allied Technology, pp. 136–143 (2009)
3. Jokela, T., et al.: The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In: Proceedings of the Latin American Conference on Human-Computer Interaction, pp. 53–60 (2003)
4. Kammer, D., et al.: A component-oriented framework for experimental computer graphics. Elsevier - Comput. Stand. Interfaces 34(1), 93–100 (2012)
5. Kuehne, B., Martz, P.: OpenSceneGraph Reference Manual v2.2. Skew Matrix Software and Blue Newt Software (2007)
6. NVIDIA, http://www.nvidia.com/object/3d-vision-main.html
7. OSGi Alliance: OSGi Service Platform Release 4, Version 4.1. OSGi Alliance, San Ramon, CA, USA (2007)
8. Smart, J., et al.: Cross-platform GUI programming with wxWidgets. Prentice Hall (2006)
9. Stellmach, S., et al.: 3D Attentional Maps: Aggregated Gaze Visualizations in Three-dimensional Virtual Environments. In: Proceedings of the International Conference on Advanced Visual Interfaces, pp. 345–348. ACM, New York (2010)
10. Su, C.-H., et al.: A real-time robust eye tracking system for autostereoscopic displays using stereo cameras. In: IEEE International Conference on Robotics and Automation, Proceedings, ICRA 2003, vol. 2, pp. 1677–1681 (2003)
11. Weber, S., et al.: Eye tracking in real world and virtual environments: Algorithms for determining gaze position in 3D space. In: Proceedings of the17th European Conference on Eye Movements (2013)