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Head-Mounted Displays with Web-Technologies on Mobile Phones for E-Learning Scenarios: An Evaluation of Virtual Reality with WebGL

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Abstract

In this paper we describe the further research to enhance user cognition in e-learning scenarios with 3D web-technologies. This investigation is based on the previous findings with our research partner Bosch, which has been presented at Future of Education 2015 [1]. Our test framework has been extended to combine the powerful API WebGL on mobile phones with head-mounted displays. This technological setup has been recently described in public projects such as Googles Cardboard and Oculus Rift to generate a higher degree of immersion [2]. Compared to native VR applications (e.g. frameworks presented by Shailey and Hardy [3]) this web-based approach is accessible on any browsers without proprietary software or plugin. In the context of e-learning we assembled a browser-based user manual to affect user's perception in a surrounding virtual world. To evaluate the correlation between user cognition and technological dependencies we compared the WebGL-based visualization of monoscopic and stereoscopic views on head-mounted mobile phones. The A/B-test has been designed for a quantitative, empirical study to gather parameters of interaction, performance and visual quality. In summary the following results have been obtained:
1) The surrounding, stereoscopic view supports user's cognitive performance.
2) The interaction mechanisms are appropriate for panoramic views only.
3) The visual quality and size of viewport is limited in stereoscopic view.
4) The performance is negative affected in stereoscopic view.

These results complements WebGL as a cross-platform standard for 3D visualization - available on any browser without proprietary plugin - and support decision makers and developers in further Web-based VR e-learning applications with WebGL.

1. Introduction

Browser-based applications for e-learning have assumed a central role in knowledge transfer and education. The visual mechanisms of the user interface and the presentation of the content affect directly user's cognition and the efficiency of the content transfer. In this paper we present the further research in enhancing user's cognition with 3D web-technologies on mobile devices.
Modern web browsers that support cross-platform Web standards including WebGL and HTML5 have paved the way for new native approaches to visualize 3D in web applications without proprietary plug-ins such as Flash [4]. In comparison to existing solutions that depend on the Flash environment or a Java applet, WebGL is a contemporary standard that offers higher performance, better render quality and broad compatibility across all of the latest browsers available on mobile and desktop devices [5].
With our research partner Robert BOSCH GmbH we investigated a testing application for a digital manual which presents the object in 3D. To generate a higher virtual immersion and to increase user's spacial cognition the visual presentation of the e-manual has been extended for stereoscopic views. This methodology of a split-screen to generate a immersive 3D view has been described in projects, such as Googles Cardboard and Oculus Rift [2].

2. Methodology & Test setup

Different methodologies are applied to address both the perspective of educators, that are focusing on the aspect to design and generate content, and of the developers, that are focusing on the technological aspect. The feedback obtained describes both groups' tendencies to support either the use or omission of stereoscopic 3D view on mobile devices.
In the quantitative part of this investigation we wanted to gather data to support or reject the following hypothesizes:
H1: the available viewport in stereoscopic view is far smaller compared to monoscopic view.

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H2: The performance and frame rate of the stereoscopic application is slower compared to monoscopic view.
A second, qualitative test will evaluate the following claims:
H3: user's cognition is better supported with stereoscopic view compared to monoscopic view.
H4: the navigation and interaction is limited for panoramic views only.
The methodology for the above listed quantitative investigations is based on a A-B variation test based on between-subject design. The qualitative part is based on a field study combined with the think-aloud-method.

Figure 1: Screenshot from test application with stereoscopic view

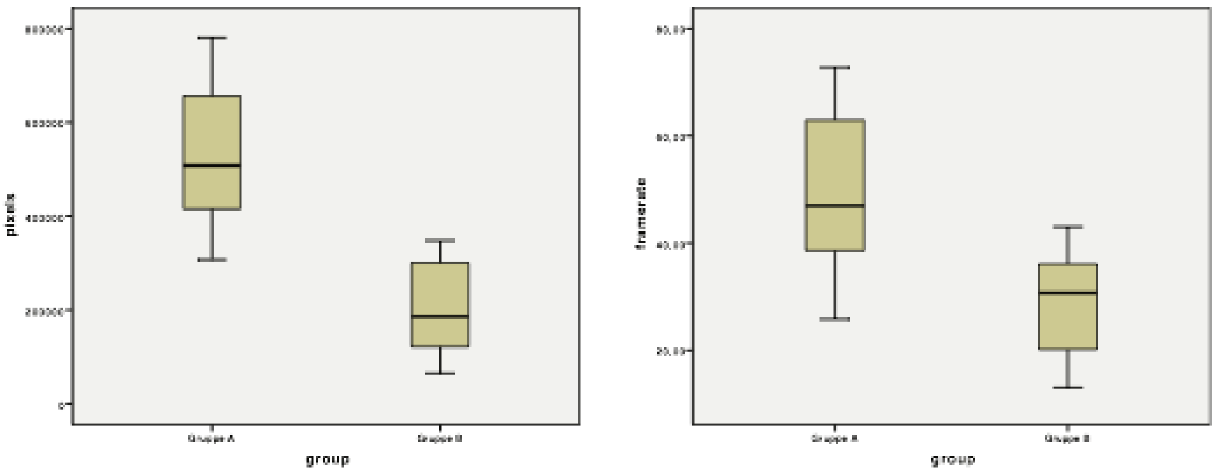
Two test applications have be assembled for a variation test, focusing on the visual aspects of both a 3D monoscopic and 3D stereoscopic output. 3D content is rendered with WebGL and includes shaders specially developed for photo-realistic outputs. The framework Three.js has been extended with a module for a high-performance and accelerated loading process. The loader handling module sets up a stream to the model database and pipes packages of model records. Products that are part of the visible browser view-port get loaded and rendered in an asynchronous stream pipeline immediately. Thus, the user can view and interact without high pre-loading delay. Figure 1 shows a screenshot from stereoscopic view.
The analysis for the quantitative gathered data has been conducted with SPSS, as mentioned from Urban [6].
In the qualitative part, according to Chi's eight function steps [7], the first step to analyze interview material is to transcribe it. Similar methodology is also found in Strauss' more complex theoretical method [8], as well as in the work of Mayring [9]. After segmenting the sampled protocol, a coding scheme is chosen. Generally this coding is intended to reduce the amount of transcribed data and reduce the number of statements derived from them [10].
Specific phrases from the transcript are assigned to keywords from the chosen coding scheme. In order to find tendencies that block or promote the establishment of stereoscopic, three-dimensional visualizations in e-learning scenarios, two main coding categories formalize both pro and contra statements. Finally, to detect consistencies between categories they can be visualized as representations of sets, which allow for the shaping of otherwise abstract results [10].

3. Results

The study's results provide not only a view into the technological aspects, but also establish a number of reasons why this visual setup for an innovative e-learning approaches is still at the very beginning. The following findings from the quantitative part can be formulated:
- first, to generate a stereoscopic view the display has therefore to be split into two parts: one per eye. In our quantitative test we tested 80 (each group 40) different viewport sizes on mobile devices with the following result: the available viewport is only about 39% in stereoscopic view compared to monoscopic view. As mentioned above the main reason can be found in in split-screen. Additionally there are interspaces around each frame, visible in figure 1. With this finding the hypothesis H1 can

be confirmed. Figure 2.1 visualizes the frequency of occurrence of each group in boxplot-format: group A with monoscopic view provides a higher amount of pixels (respectively screen size) for each frame compared to stereoscopic view.

- second, according to the frame rate measured on different mobile devices (n = 80; each group n = 40) the median of the stereoscopic view, with fps 28.7 ± 8.8, is far lower compared to monoscopic view, with fps 49.0 ± 13.7. Thus, the render speed and performance of the stereoscopic application is low. Regarding use-case scenarios for VR e-learning applications this technological result, which limited the potential target devices and target group, has to be considered. Hypothesis H2 can be confirmed. Figure 2.2 visualizes the frequency of occurrence of each group: the frame rate in group A



with monoscopic view higher compared to stereoscopic view.

Figure 2: group A with monoscopic view, group B with stereoscopic view. (left 2.1) measured amount of pixels per viewport; (right 2.2) measured frame rate.

The following findings from the qualitative test can be highlighted:

- the probands accomplished the wayfinding and navigation tasks in stereoscopic view more successful compared to monoscopic view. This result supports the visualization of content in immersive 3D views. Hypothesis H3 is supported.
- there have been significant difficulties in interaction and usability for the probands. Navigation and orientation in 3D space caused problems. The mechanisms in 3D space are appropriate for panoramic views only. This finding supports hypothesis H4.

4. Conclusion

The listed findings from this empirical test serve as first tendencies as to whether stereoscopic 3D should be omitted or implemented in e-learning web applications. Regarding the support of WebGL on major browsers and the technological aspects from the A/B testing, such as performance and available viewport size, it's important to bring these dependancies into context with the specific target group. Educators and decision makers need to balance between these aspects to support their audience. In stereoscopic view the complexity of 3D models, visualization and navigation is limited. These findings have been confirmed with the technological aspects of render performance, viewport size and proband's reaction. As a positive aspect the support of the visual cognition has to be highlighted. In our empirical evaluation stereoscopic view supports wayfinding and navigation tasks.

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