Capturing and Visualizing Eye Movements in 3D Environments

Thies Pfeiffer, Cem Memili, Patrick Renner

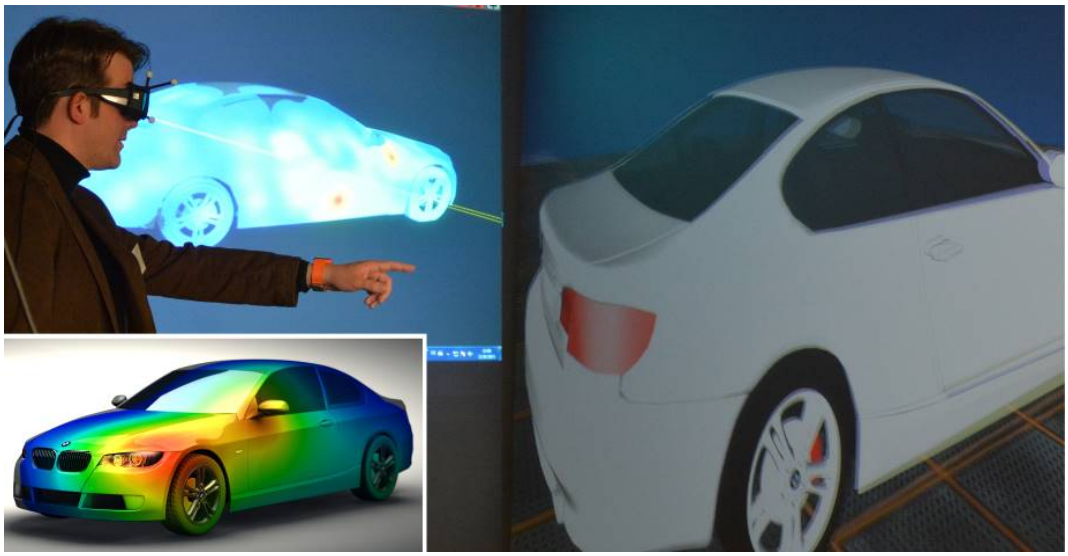

Figure 1: The presented approach is able to map fixations to 3D models of the environment and create 3D heatmaps in real-time. The example shows a 3D gaze recording in an immersive virtual environment (person to the left inspecting 3D object on the right). Real-time heatmap generation is shown in the left background (wrong colors due to photography of a projection screen). Lower left corner shows a rendering of the created 3D heatmaps.

1 Introduction

Visual attention can be a viable source of information to assess human behaviors in many different contexts, from human-computer interaction, over sports or social interactions, to complex working environments, such as to be found in the context of Industry 4.0. In such scenarios in which the user is able to walk around freely, mobile eye-tracking systems are used to record eye movements, which are then mapped onto an ego-perspective video. The analysis of such recordings then requires large efforts for manually annotating the recorded videos on a frame-by-frame basis to label the fixations based on their locations to the target objects present in the video. There are several problems scientists are faced:

- Manual annotations are cumbersome and error prone. The time required for the annotation of the data renders many studies unfeasible.
- The annotated material consists of 2D videos of a 3D environment, which is an abstraction and the results are difficult to integrate. In particular, it is difficult to create appropriate visualizations for the collected data.

Published at SAGA Workshop 2015, proceedings archived under DOI: 10.2390/biecoll-saga2015_0.
Individual article archived under DOI: 10.2390/biecoll-saga2015_3

2 Our Contribution

First, we present a method to record eye movements in 3D scenarios and annotate fixations with corresponding labels for the objects of interest in real-time [2]. For this purpose, we rely on computer-vision methods for the detection of the camera position and orientation in the world. Based on a coarse 3D model of the environment, representing the 3D areas of interest, fixations are mapped to areas of interest. As a result, we can identify the position of the fixation in terms of local object coordinates for each relevant object of interest.

Second, we present a method for real-time creation and visualization of heatmaps for 3D objects [1]. Based on a live-streaming of the recorded and analyzed eye movements, our solution renders heatmaps on top of the object surfaces. The resulting visualizations are more realistic than standard 2D heatmaps, in that we consider occlusions, depth of focus and dynamic moving objects.

Third, we present a new method which allows us to aggregate fixations on a per object basis, e.g. similar to regions/areas of interest. This allows us to transfer existing methods of analysis to 3D environments.

We present examples from a virtual supermarket, a study on social interactions between two humans, examples from real-time gaze mapping on body parts of a moving humans and from studying 3D prototypes in a virtual reality environment.

3 Discussion

The presented work covers the full workflow from recording to aggregating, analyzing and visualizing data on visual attention over multiple participants. The toolchain is designed in such a way, that the results can be gathered in real-time, during the recording of the study. This not only significantly reduces the time required for the conduction of the studies. It also increases the quality of the recordings, as problems can be detected already during the recording session. The annotation is also objectified and thus random errors by human annotators are eliminated.

ACKNOWLEDGMENTS: This research was supported by the Cluster of Excellence Cognitive Interaction Technology 'CITEC' (EXC 277) at Bielefeld University, which is funded by the German Research Foundation (DFG).

References

1. Pfeiffer, T., & Memili, C. (2015). GPU-accelerated Attention Map Generation for Dynamic 3D Scenes. In T. Höllerer, V. Interrante, A. Lécuyer, & J. E. S. II (Eds.),Proceedings of the IEEE VR 2015 (pp. 257–258). IEEE.
2. Pfeiffer, T., & Renner, P. (2014). EyeSee3D: a low-cost approach for analysing mobile 3D eye tracking data using augmented reality technology. Proceedings of the Symposium on Eye Tracking Research and Applications, 195–202.

Published at SAGA Workshop 2015, proceedings archived under DOI: 10.2390/biecoll-saga2015_0.
Individual article archived under DOI: 10.2390/biecoll-saga2015_3