A Path-based Attention Guiding Technique for Assembly Environments with Target Occlusions

Patrick Renner*, Jonas Blattgerste† and Thies Pfeiffer‡
Cluster of Excellence Cognitive Interaction Technology
Bielefeld University

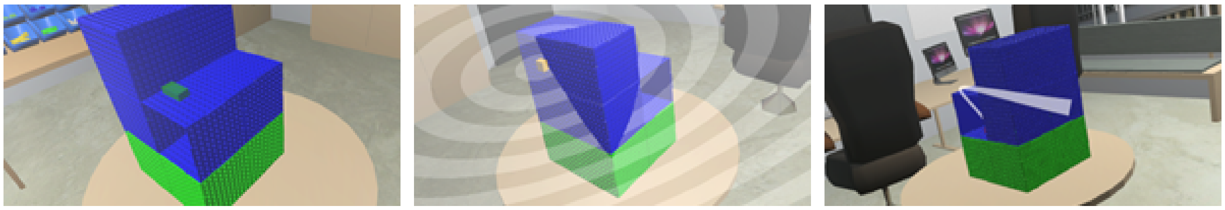

Figure 1: The different attention guiding techniques which were evaluated: 3D in-situ highlight (left), SWave (concentric waves moving towards the target, middle), proposed 3D path guiding the user towards the target (right).

Abstract

An important use-case of augmented reality-based assistance systems is supporting users in search tasks by guiding their attention towards the relevant targets. This has been shown to reduce search time and errors, such as wrongly picked items or false placements. The optimization of attention guiding techniques is thus one area of research in augmented assistance.

In this paper, we address the problem of attention guiding in domains with occluded targets. We propose and evaluate a variant of a line-based approach and show that it improves upon two existing approaches in a newly designed evaluation scenario.

Keywords: Attention guiding, simulated augmented reality, evaluation.

Index Terms: H.5.2 [Information Interfaces and Presentation (e.g. HCI)]: User Interfaces—Miscellaneous

1 Introduction

The localization of objects in an environment is an essential task relevant for many work processes. In tasks with up to 300 picks per hour, each second counts and even small optimizations have a huge effect. In the work proposed here, we are focusing on manual assembly places, yet the techniques will also scale up to scenarios in logistics with large warehouses or picking and packing work places.

Various approaches of attention guiding for AR glasses have been developed in the past and were compared in different scenarios (e.g. [2], [7]). The first step of assembly tasks is usually to find and pick the relevant parts which are to be assembled. The simplest form of signaling the correct target is probably to highlight it, e.g., in form of an in-situ outline, as suggested by Feiner et al. [3]. Such a highlight is thus only visible when the AR display at least partially overlaps with the target object. We will use the highlighting approach as a minimum baseline in our evaluation, as it provides only the absolutely necessary assistance information in our scenario, without any active guiding of the user.

Especially in the area of navigation, arrows are a widely used means of guiding the user towards the correct location [2]. A well-known technique of giving path-like information was suggested by Biocca et al. [1]. Their Omnidirectional Attention Funnel could reduce search times, task load and the error rate in comparison to audio cueing and highlighting. In previous research, we compared different techniques, including highlighting and in-view 2D arrows [6]. The fastest performance was achieved using an in-situ direct line towards the target. The targets, however, were arranged in 360° around the user with no occlusions. In a second study [5], a variation of the Attention Funnel, arrow-based guidance and a new approach called SWave based on concentric circles were evaluated. In their scenario, they found comparable good performance for arrows and SWave, surpassing that of Funnel and image-based approaches.

In the present paper, we will add to this line of research an assembly task scenario with an environment with target occlusions. This important and common challenge is, to the best of our knowledge, underrepresented in scientific research so far. For this scenario we have designed our own variant of a line-based guiding technique based on Catmull-Rom splines. We compare this with the classic highlighting [3] approach and the recently published SWave approach [5], which showed similar performance as the standard arrow-based approach in their comparison.

2 Design of a Spline-based Attention Guiding Technique

The attention guiding techniques described before were mostly evaluated in environments where targets were not occluded by other objects but located in front of the users or around them. In these cases, the user does not have to actually navigate as re-orienting is sufficient to reach the target. For more complex environments, we developed a new guiding technique which does not only visualize where the target is located, but also explicitly shows the way for navigating to it. Our approach is similar to map-based navigation applications, which are often visualizing a path to guide the user. A difference is that in such applications the path is often depicted in 2D, whereas the complexity of our setup requires a path in 3D. Our guidance technique is displaying a spline which starts in front of the user and ends at the target location as shown in Figure 1, right).

The basic idea of showing how to approach to the target is similar to the Omnidirectional Attention Funnel [1]. However, there are substantial differences. Firstly, the gates of the Attention Funnel are arranged along a Hermite curve instead of an actual path. Thus, it does not support showing the way to an occluded target. Instead, the curve would lead the user towards/through the occluding object. In our approach, the path is calculated in real time using a 3D mesh of waypoints around the relevant area. We can guarantee that the

*e-mail: prenner@techfak.uni-bielefeld.de
†e-mail: jblattgerste@techfak.uni-bielefeld.de
‡e-mail: tpfeiffer@techfak.uni-bielefeld.de

path does not pass through occluding objects by only allowing connections between waypoints if there is no geometry between them. Currently, the waypoint mesh is designed manually for a specific scenario. However, it is also possible to calculate the waypoint mesh based on sparse voxel octrees. A second difference to the Omnidirectional Attention Funnel is the change from gates to a simple spline-based path. In recent studies [5], it was shown that for small FOVs, the gates can be confusing.

The path is computed as follows: It starts 30 cm in front of the user's head position, in the middle of the AR FOV. A 3D grid of waypoints is arranged around the 3D target area. In a pre-processing step, rays are cast between all waypoints. If a ray does not hit any geometry, the corresponding waypoints are connected. During runtime, for each frame the best path starting from the waypoint closest to the beginning of the spline to the target spot is computed using an A* algorithm. The waypoints on the path are connected by Catmull-Rom splines. The implementation always choosing the closest waypoint at the beginning leads to a path jumping over to the next waypoint after a certain movement of the user. The idea behind this was to ensure that users see a stable path which does not drift from one waypoint to the other.

3 Evaluation Study

To evaluate whether the proposed path-based attention guiding technique improves over previous techniques in the context of complex environments with target occlusions, we compared it to a highlight guidance and the SWave guidance as described in the following:

3D Highlight The highlight was chosen as a very basic guiding technique (Figure 1, left). The idea is to visualize the target spot where to place a brick by projecting a 3D box with the corresponding size, orientation and color.

SWave As originally introduced in [5], the SWave (Spherical Wave-Based Guidance) technique is realized using a sphere which is centered at the head position of the user (Figure 1, middle). The radius of the sphere is permanently updated to match the distance to the target spot. Moving waves are rendered using a GPU shader directly on the sphere. This way, the guiding technique serves as an in-situ visualization having the waves converging to the 3D target position but also has in-view aspects as the waves are always visible.

3.1 Study Design

The experiment was conducted in an assembly scenario extending the work of Funk et al. [4]. We extended the target assembly structure in a way to include several opportunities for occlusions: The structure was shaped like an 'L' including two caves (Figure 1), one on the left and one on the right side. Potential placement targets for new bricks could thus be located in directly visible locations, behind the construction, to the sides and within the caves. The whole scenario was modeled in VR using the AR simulator described in [6]. The assembly of bricks was realized using the controllers of the HTC Vive. Participants could grasp and release virtual bricks. Whenever a brick was moved near the target area, small green spheres appeared to highlight the position where the brick should be placed.

The task in each condition was to place 40 LEGO DUPLO bricks at different positions on the assembly structure. We collected the time participants needed to place each brick by keeping track of the clicks on the Vive controllers.

3.2 Results

24 participants took part in our experiment. They were aged between 18 and 33 (average = 23.88, sd = 3.31) and 13 of them were female.

Looking at the time which was needed to find the correct location and placing one brick (Figure 2), the 3D highlight was the slowest technique. Participants needed on average 5.72 s (sd: 1.23). The 3D Path performed best with on average 4.38 s (sd: 1.13). In between, using the SWave technique participants needed 5.03 s (sd: 1.28) for placing one brick. An ANOVA revealed a significant difference between the guiding techniques ($F(2,21) = 7.3$, p<.01). Tukey's honest significance post-hoc test showed that the 3D path performed significantly better than the 3D highlight (p<0.001).

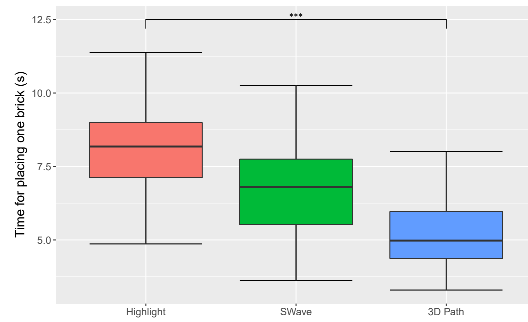

Figure 2: Time needed to place a brick using the different techniques.

4 Discussion and Conclusion

When participants used the 3D highlight for finding the location for placing a brick, there was a tendency to take the longest time and also to make most head movements. This was expected, as (in most cases) they had to walk and look around to be able to find the location. The other two techniques support navigating to the target, with some restrictions in SWave. Indeed both techniques performed better than the baseline. However, the SWave technique did not help participants as much as the 3D Path.

Thus, the results of the evaluation show that in a complex environment, explicitly guiding the user's attention by visualizing a 3D path to the target outperforms simple 3D highlights as well as the SWave technique which recently was shown to be a promising technique for simpler environments.

In a follow-up study, we plan to improve the 3d path guiding technique by automatizing the waypoint mesh and on addressing other aspects of the overall pick-and-place process, namely the correct placement of the parts in case of more complex aggregates.

References

[1] F. Biocca, A. Tang, C. Owen, and F. Xiao. Attention Funnel: Omnidirectional 3d Cursor for Mobile Augmented Reality Platforms. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '06, pages 1115–1122, New York, NY, USA, 2006. ACM.

[2] S. Feiner, B. MacIntyre, T. Höllerer, and A. Webster. A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment. *Personal Technologies*, 1(4):208–217, 1997.

[3] S. Feiner, B. Macintyre, and D. Seligmann. Knowledge-based Augmented Reality. *Commun. ACM*, 36(7):53–62, July 1993.

[4] M. Funk, T. Kosch, S. W. Greenwald, and A. Schmidt. A Benchmark for Interactive Augmented Reality Instructions for Assembly Tasks. In *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia*, MUM '15, pages 253–257, New York, NY, USA, 2015. ACM.

[5] P. Renner and T. Pfeiffer. Attention Guiding Techniques using Peripheral Vision and Eye Tracking for Feedback in Augmented-Reality-based Assistance Systems. In *3D User Interfaces (3DUI), 2017 IEEE Symposium on*, pages 186–194. IEEE, 2017.

[6] P. Renner and T. Pfeiffer. Evaluation of Attention Guiding Techniques for Augmented Reality-based Assistance in Picking and Assembly Tasks. In *Proceedings of the 22nd International Conference on Intelligent User Interfaces Companion*, pages 89–92. ACM, 2017.

[7] B. Schwerdtfeger and G. Klinker. Supporting Order Picking with Augmented Reality. In *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality*, ISMAR '08, pages 91–94, Washington, DC, USA, 2008. IEEE Computer Society.