

User Awareness of Tracking Uncertainties in AR Navigation Scenarios

Frieder Pankratz

Andreas Dippon

Tayfur Coskun

Gudrun Klinker*

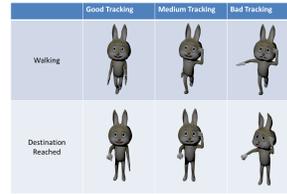
Fachgebiet Augmented Reality
Technische Universität München, Fakultät für Informatik
Boltzmannstraße 3, 85748 Garching b. München, Germany



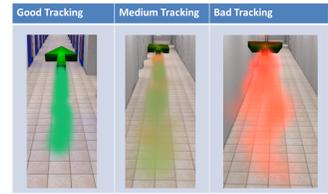
(a) User during the Evaluation



(b) *Select Door* scenario with simulated smartphone



(c) Virtual Character Visualization



(d) Flying Spirit Visualization

Figure 1: Evaluation setup (a, b) and two example visualizations (c, d)

ABSTRACT

Current Augmented Reality navigation applications for pedestrians usually do not visualize tracking errors. However, tracking uncertainties can accumulate so that the user is presented with a distorted impression of navigation accuracy. To increase the awareness of users about potential imperfections of the tracking at a given time, we alter the visualization of the navigation system. We developed four visualization and error visualization concepts and used a controlled Mixed Reality environment to conduct a pilot study. We found that, while error visualization has the potential to improve AR navigation systems, it is difficult to find suitable visualizations, which are correctly understood among the users.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

Pedestrian navigation only using Augmented Reality visualizations requires robust and accurate tracking in large environments. Such tracking often is difficult to impossible to maintain.

Usually in situations, where the tracking becomes bad, the visualization is either completely disabled or stays frozen while the camera is moving. Some systems [2, 6] address the issues of error propagation and how meaningful AR visualizations can be achieved while suffering from large tracking and registration errors. For pedestrian navigation using only AR navigation hints, continuous updates of the visualizations are crucial. Taking tracking issues and the need for continuous updates into consideration, a wrong visualization could lead to a distorted impression of navigation accuracy, guiding the user in a wrong direction or making turns at a wrong intersection. User awareness of the current tracking quality thus is imperative.

To address this issue, we developed different visualizations for the tracking quality. We investigated whether these visualizations were able to raise the awareness of the user about the accuracy of the current tracking situation.

*e-mail:(pankratz | dippona | coskun | klinker)@in.tum.de

2 RELATED WORK

With the recent advances in smartphone technology the use of AR visualizations for pedestrian navigation has become an active research field for indoor and outdoor navigation, e.g. [4, 5].

Mulloni et al. [5] state that the visualization must be able to communicate the current tracking accuracy to the user. Moeller et al. [4] argue that the system should be able to inform the user about ambiguous self-localization estimates, especially when these errors could lead to wrong navigation instructions.

MacIntyre et al.[3] introduced different visualizations depending on the level of error. While this gets quite close to our approach, they chose to change the AR visualization towards a situational description in the case of increasing tracking error.

3 TEST ENVIRONMENT

We implemented a highly controllable mixed reality system to simulate an AR navigation system. This way, we can assure a uniform tracking behaviour for every user to yield comparable results.

We created an immersive virtual environment reflecting the physical surroundings at our university to decrease the mental load of the users as they were all familiar with the environment. Both MR visualization devices, a Vuzix Wrap 920AR HMD and a generic smartphone were equipped with infrared markers to be tracked with an ART infrared tracking system.

The dynamic error during runtime was estimated using an optical square marker tracking system (standard deviation of 0.86 mm positional, 0.00094 degree rotational error) and sampled from a suitable gaussian distribution which has a scaled variant of the uncertainties as parameters. A static offset representing the registration error was added to the error of the tracking system. For good tracking the registration error was zero. For medium tracking the values were chosen so that the navigation target would be shown between two possible targets (1.25m). In the case of bad tracking, the navigation target would be shown at an adjacent target (2.5m).

4 VISUALIZATION

We defined the following three categories of visualizations:

- *Discrete Information:* navigation hints are shown in discrete steps starting at the user and ending at the destination
- *Continuous Information:* navigation hints are shown continuously starting at the user and ending at the destination

- *Guiding Information*: a virtual entity leads the user to a destination and shows only the next few meters of the path from the user towards the destination

For *Discrete Information* we use 3D arrows placed on the floor every 2 meters pointing along the path to the target. The error visualization changes the color and shape of the arrow. With increasing error the color shifts from green to red and the arrow changes its shape by decreasing the length of the shaft and the arrowhead continuously morphing from a cone to a rectangle and to an inverted cone. In the case of *Continuous Information* we developed a line visualization that starts at the user and is placed on the floor along the path. As an additional hint, a small number of particles are flying periodically towards the target on the line. With increasing error the color of the line and the particles changes from green to red. We developed two systems with *Guiding Information*. The first, called *Flying Spirit*, is a 3D arrow flying from the user to the target, leaving a short trail of particles along its path. The arrow restarts from the user's position when it gets too far ahead. The error visualization of the arrow is similar to the arrows on the floor. The particle trail changes its compactness and color. The second approach on guiding information is similar to the idea of the *AR Puppet* [1]. A virtual avatar, a human-like bunny character, leads the user. The character walks along the path. It stops in front of the target pointing at the target with its finger. If the user falls too far behind, it stops moving, turns towards the user and waves its hand until the user catches up. The error visualization alters the way the character is walking and pointing at the target.

5 EVALUATION

We created different navigation tasks for each user. In each task the user has to follow the navigation hints until the system stops automatically. At that point, a number is shown above each target in the display. The participant has to name up to three numbers sorted by certainty of which target is the correct one. The tasks were created by using the following independent variables: Simulated Output Device (HMD, Smartphone), Scenario (Select Door, Select Hallway), Visualization (2D Arrows, Flying Spirit, Line, Character), Error Visualization (On, Off), Error Value (low, medium, high), Distance to Target (3m, 6m). The error values correspond to good, medium and bad tracking. As there is no difference between *Error Visualization On* and *Off* in the case *Error Value = low*, 160 tasks resulted. Target doors and hallways were selected at random for each pair of tasks. A pair consists of two tasks where all parameters are equal except the distance parameter. We divided the tasks into four groups to 40 tasks each, based on the combinations of *Simulated Output Device* and *Scenario*. The 40 tasks within a group were permuted for each user. To decrease learning effects and user fatigue, we permuted these four groups by alternating the *Scenarios*. We provided each participant with additional information about the system and the visualizations before the tasks started. We then let the users familiarize with their surroundings in the virtual world. Before the evaluation tasks started, two training tasks, similar to the later given tasks, had to be solved. Following the training phase, the real tasks were executed. The participants were finally asked to fill out a short questionnaire containing demographics and ratings for the visualizations and the corresponding tracking error. The overall time per evaluation was about 45 minutes.

6 RESULT ANALYSIS

The eight (6 male, 2 female) participants had an average age of 28 (from 20 to 33). We split the 160 tasks of each user into three groups for analysis: 32 tasks with *Error Value low* which served as a control group, 64 tasks with *Error Visualization Off* and 64 tasks with the *On* setting. The control group serves to check that the navigation hints are perceived correctly when there is no error, where we expected nearly 100% hit rate. This was confirmed with

a hit rate of 98.8% between all users. For the other two groups, our hypothesis was that the correct target number is named more often within the three answers, if the *Error Visualization* is *On*. Based on the result of a two-tailed t-test we cannot reject the corresponding null hypothesis ($p = 0.08$). Yet, the participants found the error visualization somehow useful (avg. 2.25, 0 (not useful) to 4 (useful)). They reported that the location of the visualization was more important than the appearance and that they based their answers on that principle. In the *high* error case most users only named one target. This mainly explains the much higher hit rate at the *medium* error case compared to the *high* error case. From the interviews we noticed that only two users rigorously considered the appearance of the visualizations for their decisions. Their hit rates were much higher with the *Error Visualization* activated. The results also showed that the distance did not have influence on the differences of the hit rates. The simulated devices also did have no influence on the results. From the four visualizations, the users considered the error visualization of the virtual character the most helpful, as it is the only visualization that shows a range of targets.

7 DISCUSSION

The evaluation showed that users who perceived the error visualizations as we intended, had a much higher awareness of the tracking error and were therefore able to select the correct targets more often. A major issue of our implementation was that there was no change of the target location. As long as the users are able to clearly select a target, many will tend to select that target, no matter how the visualization changed. The visualization should rather disperse in the vicinity of the destination to point towards a short range of possible targets. This would probably also highly increase the intuitive understanding of the navigation system. With that in mind we propose the following design guideline for creating error visualizations in AR navigation: **The change in the visualization has to be so severe, that the user is presented with several possible targets instead of just one.**

8 CONCLUSION

Even if the evaluation of error visualizations for AR navigation systems could not verify a significant improvement of user awareness when selecting a target by using error visualization, we got much positive feedback about the visualizations of tracking errors during the interviews. Overall we believe that error visualization bears the potential to increase awareness of tracking errors. Yet, the magnitude of change in the visualization needs to be increased. We therefore postulate a design guideline about creating error visualizations for AR navigation systems.

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