User Experiences with Augmented Reality Aided Navigation on Phones

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ABSTRACT

We investigate user experiences when using augmented reality (AR) as a new aid to navigation. We integrate AR with other more common interfaces into a handheld navigation system, and we conduct an exploratory study to see *where* and *how* people exploit AR. Based on previous work on augmented photographs, we hypothesize that AR is used more to support wayfinding at static locations when users approach a road intersection. In partial contrast to this hypothesis, our results from a user evaluation hint that users will expect to use the system while walking. Further, our results also show that AR is usually exploited shortly before and after road intersections, suggesting that tracking support will be mostly needed in proximity of road intersections.

INDEX TERMS: H.5.1. Artificial, augmented and virtual realities.

1 INTRODUCTION

Previous studies show that augmented photos enhance map-based navigation systems. Chittaro *et al*. [1] demonstrate that augmented photos allow users to take correct decisions at road intersections faster than a map. While walking, users rely on audio instructions and glances at the map. Hile *et al*. [2] highlight an "*80/20 rule*", where 80% of the time is spent on the map and 20% (*"at critical points in the path*") on augmented photos. Yet, as also discussed by Hile *et al*. [2], photos do not always match the appearance of the environment due to its variability, and are rarely taken exactly from the user's position.

In contrast, *Augmented Reality* (AR) anchors information to the live video from a camera. Feiner *et al*. [3] presented the first AR system for navigating a university campus. Since then, a large number of head-worn AR navigation systems have been developed. Recently, handheld AR navigation systems also appeared, such as MARA[1] or Wikitude Drive[2]. Since photos enhance navigation, we believe AR can do at least as well – if not better – due to the closer match between the view on the display and the environment. However, AR requires highly accurate tracking of the device's pose, which is not always achievable in uncontrolled environments.

Differently from augmented photos, there is a lack of studies on *where* people use AR, *e.g*. only at road intersections or anywhere, and *how* people use AR, *e.g*. standing still or walking. This knowledge can inform the design of AR interfaces and also define the necessary improvements for tracking technology. In this work, we discuss results and observations from an exploratory study in which participants used a map-based navigation system enhanced with AR to navigate through an outdoor route.

[1] http://research.nokia.com/research/projects/mara

[2] http://www.wikitude.org/drivebeta

Figure 1. Screenshots of our system. (Left) Map, glyphs and textual instructions. (Right) Arrow-based Augmented Reality view.

2 IMPLEMENTATION

We developed a multimodal navigation system (Figure 1). Like in other navigation systems, we use a *forward-up map* that shows the user's position and the path to be followed. We also provide hints as *glyphs* and, for eye-free usage, as *audio instructions*. All new instructions are notified by the phone vibrating. We also integrate an *AR interface*. We augment the environment with virtual arrows that indicate the direction the user should follow; when the arrow is not visible, we guide the user in turning the camera towards it. Like in our previous work [4], tilting motions trigger transitions between map and AR: tilting the phone down shows the map, tilting it up transitions to AR. Our system runs interactively on a smartphone. We use GPS to track position, and accelerometer and compass for orientation. In contrast to most commercial systems, if a user is standing still we fuse sensors and vision tracking for a more stable orientation tracking [5].

3 USER STUDY

We conducted an exploratory study on a real-world navigation task, looking at where and how participants exploit map and AR interfaces. In line with previous work on augmented photos, we hypothesized that AR, despite being available everywhere, is mainly used while standing still at road intersections (decision points). Nine people (age 25–33, M = 28.1) participated in the experiment. Three had previous AR experience (p1, p2, p4), but no-one was familiar with AR navigation systems. Three of them were smartphone owners (p2, p6, p8), five were regular users of navigation systems (p1, p2, p4, p6, p8). Participants navigated a path of 1.67 km (Figure 2). The GPS *dilution of precision* was mostly excellent during the study, and only rarely moderate.

After briefing participants on the experiment, we walked them to the starting point of the path while they practiced with the system. We reminded participants to avoid shortcuts and to use the device freely (not feeling forced to use it continuously). We video recorded participants throughout the task. No-one exited the path. After the task, we collected subjective feedback through a

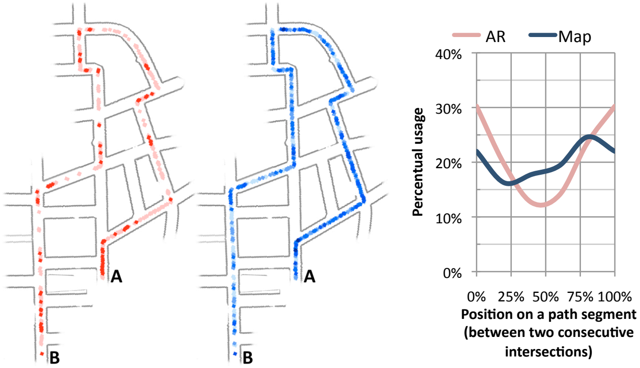

Figure 2. Where AR (left) and map (middle) interfaces were used on the path A–B. Darker colors mean that more participants used the interface at the same location. (Right) Average usage of AR and map between consecutive road intersections.

semi-structured interview. A researcher coded all *usage sessions* from the video recordings (sequences of video frames in which participants looked continuously at the phone's screen). For each usage session we then extracted the corresponding software log. Following, we present our analysis of the software logs extracted.

4 Results

System usage averaged 21.2% (σ=12.6) of the total task time. On average, 28.7% (σ=22.5) of it was AR usage and 71.3% (σ=22.5) map usage. The average duration of a usage session, in which AR was used, was 4.8 seconds (σ=2.3). Sessions, in which AR was not used, lasted on average less (1.8 seconds, σ=0.6). The latter sessions include usage of map, text instructions and glyphs. Figure 3 shows the usage time for each participant (p1-p9).

Previous AR experience. System usage varied strongly between participants. Participants with previous AR experience (*p1*, *p2* and *p4*) exploited AR throughout the path (57.1% of system usage, σ=8.5); all other participants used AR only a few times (14.5% of system usage, σ=7.5). Participants with previous AR experience justified the usefulness of AR for cases in which the turn to take was unclear (*p1*, *p2*), or when the signs with the street names were not visible (*p4*). For the other participants, the map was sufficient (*p6*, *p9*) and more familiar (*p5*), it gave a better overview of the path (*p3*), or the arrow visualization was not stable enough (*p8*).

Where AR was used. Figure 2 shows where participants used AR and map interfaces. While map interfaces were used almost uniformly throughout the path, the AR interface shows less usage on straight path segments. We also look in detail at where participants used AR and map interfaces over path segments (a path section between consecutive road intersections). Both AR and map usage increases when approaching an intersection. Yet, while map usage mildly increases at intersections, AR usage shows a steeper curve with more usage just before an intersection (decision on the turn to take) and shortly after it (confirmation of being on the correct street).

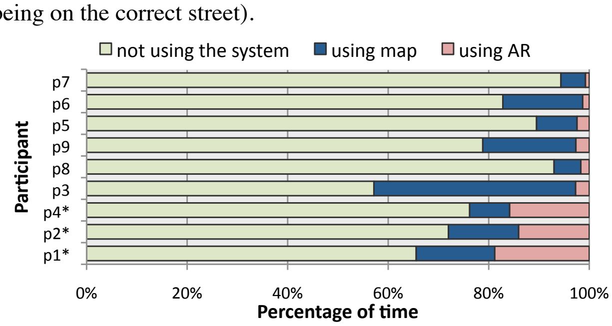

Figure 3. Percentage of usage time for each participants (* indicates a participant with previous AR experience).

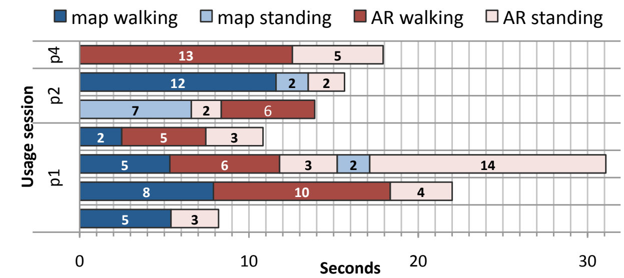

Figure 4. All single usage sessions in which a participant stopped walking and used the system while standing still (timings in seconds).

How AR was used. Both map and AR interfaces were used almost only while walking. The few cases of usage while standing still are presented in Figure 4. The system was usually used from a still position only after a failed attempt to use it while walking. Usage while standing still is probably only plausible at difficult intersections, if the user does not succeed in making a decision on the fly while walking. In the observed cases, the interface used for making or confirming the final decision was always AR.

Affordance. During usage while walking, tracking relied on inaccurate sensor data. Participants interpreted unintentional misplacements of the arrows as intentional instructions. For example, a participant interpreted a left-turn arrow with positional offset as an instruction to cross the street and turn left onto the opposite pavement. Participants interpreted errors in the orientation of the arrow as instructions to leave the pavement and walk on the street, or to move back from the street onto the pavement. Comments hint that the affordance of AR arrows increased expectations on the accuracy of the visualization.

5 Conclusion

In contrast to augmented photos, AR prompts usage while walking. AR was rarely used while standing still, usually after a failed attempt to make a decision while walking. Supporting a walking user with more accurate tracking is thus important, but as continuous, accurate tracking is a known hard problem, a more applicable solution might be to inhibit usage while walking at the interface level. In general, our results show that users exploit AR mostly in proximity of road intersections: these are therefore the most important locations to support with accurate tracking. This can for example be achieved by feeding a vision-based panorama tracker [5] with pre-recorded panoramas. Tracking accuracy must also be clearly communicated by the visualization, *e.g.* showing confidence intervals. Our results show that AR can be integrated into a handheld navigation system. Yet, they also show that AR still needs more added value before it can, for inexperienced users, overtake other more common interfaces. We are positive that providing accurate tracking specifically at road intersection will enhance the value of AR and prompt more AR usage.

Acknowledgements. This work was supported by the Christian Doppler Laboratory for Handheld Augmented Reality.

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