Map Torchlight: A Mobile Augmented Reality Camera Projector Unit

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Abstract
The advantages of paper-based maps have been utilized in the field of mobile Augmented Reality (AR) in the last few years. Traditional paper-based maps provide high-resolution, large-scale information with zero power consumption. There are numerous implementations of magic lens interfaces that combine high-resolution paper maps with dynamic handheld displays. From an HCI perspective, the main challenge of magic lens interfaces is that users have to switch their attention between the magic lens and the information in the background. In this paper, we attempt to overcome this problem by using a lightweight mobile camera projector unit to augment the paper map directly with additional information. The "Map Torchlight" is tracked over a paper map and can precisely highlight points of interest, streets, and areas to give directions or other guidance for interacting with the map.

Keywords
Mobile augmented reality, projector phones, magic lens interfaces.

ACM Classification Keywords
H.5.1 Multimedia Information Systems: Hypertext navigation and maps.

Figure 1: Prototype of a Map Torchlight unit in use. The castle of the City of Münster, Germany, is highlighted with a frame of white light (marked in the figure with a yellow circle). By clicking the center of the 4-way button on the phone the user can access detailed information about the castle history on the phone screen.

Introduction

In many mid- to large-sized cities, large-scale public maps are ubiquitous. They help to facilitate orientation and provide information to tourists, but are also helpful to locals who may need to look up an unfamiliar place while on the go. See-through interfaces such as magic lens interfaces or tool glasses [2] can combine the advantages of a large-scale paper-based maps with the advantages of a dynamic projection [9]. The paper map provides static general interest geographical features and information about them, while the dynamic display shows additional information chosen by the user, such as information on events, customized public transport routes, or personal interests. However, there is a cost of switching visual attention between the background map and the device display to access the additional information. In previous tests, we found that users tend to keep visual attention on the device display and take less benefit from the large-scale background map than they could otherwise. This disadvantage is especially severe when the task requires the acquisition of overview knowledge [7]. Camera projector units have the potential to overcome this switching cost, because they integrate static content from the paper map with dynamic content from the projector on a single display. Initial research on mobile projection interfaces was conducted by Raskar et al. [6] followed up by Beardsley et al. [1] and Cao et al. [4]. Blask et al. [3] explored the interaction with a wrist-worn projection display by simulating the mobile projector with a steerable projector in a lab. The recent work of Hang et al. [5] investigates the advantages and disadvantages of interacting with map applications using mobile projection. Beyond previous work, we present a lightweight combination of a *mobile camera device* with a mobile projector. Using the camera to determine the position of the mobile camera projection unit with respect to the background, we enable a pixel precise augmentation of the background content, such as a paper map, with additional information. No additional tracking infrastructure is needed, such as a fixed camera based tracking system (Vicon) in [4]. We try to combine the properties of the systems presented above and developed a lightweight, small, wireless prototype that can be used in a mobile

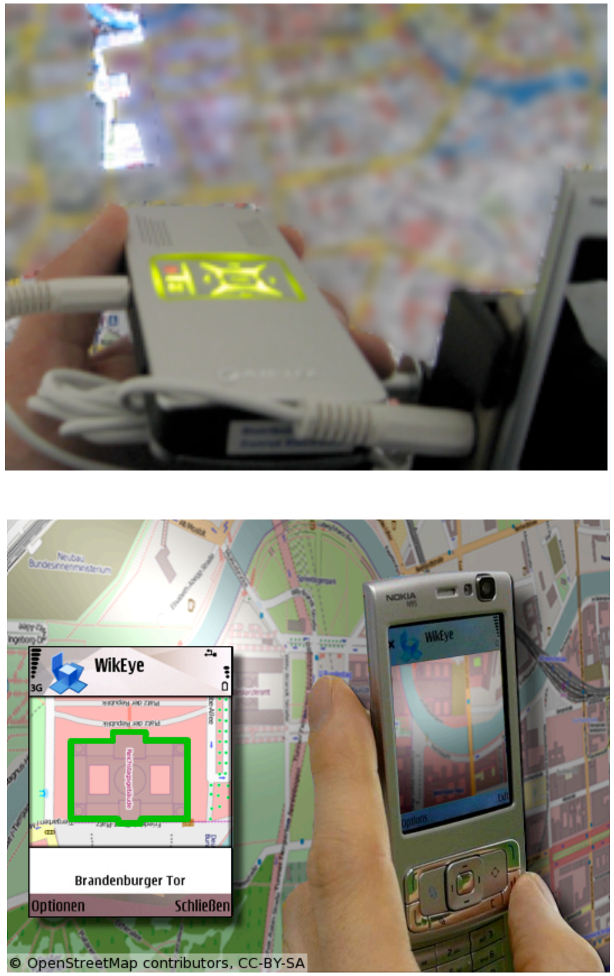

Figure 2: Mobile Projection (top) vs. Magic Lens Interface (bottom). Mobile Projection interfaces help to avoid switching visual attention between the device and the background. Moreover, the projection is much larger than the display (about 4 times in our setup). (top) User the overlaying a map of Berlin with the historic pathway of the Berlin Wall. (bottom) User is retrieving information of a single POI (mobile device screen is displayed on the lower left part).

scenario. In contrast to the few mobile devices with built in projectors, our projector and camera are mounted in such as way that the camera field of view is overlapping the projected area. Figure 1 shows our prototype in use.

Interaction Concepts

The main advances of a mobile projection system also show up in our Map Torchlight system: The projection area is larger and the mobile projection can overcome the switching cost of a magic lens interfaces. The basic interaction pattern is similar to magic lens interfaces. Sweeping the camera projector unit over the map, the projector will, for instance, highlight different points of interest (POI) on the map. Because the projection is significantly larger than the device display (around 4 times in our setup) more dynamic information can be directly presented on the map (as can be seen in figure 1 and 2). It also provides a higher resolution compared to a standard mobile device display, if the projector is controlled independently from the device display. As shown in figure 2, larger objects can be highlighted compared to a traditional magic lens interfaces. The projector can also be used to collaboratively interact with a map by using the map as a used as a shared screen [4]. For instance, one user can tell another a route through the city by moving a projected crosshair over the map. The waypoints could then be stored in a KML file and transferred via Bluetooth to the second user's mobile device. Again, in all of these examples, there are no switching costs for the users. A downside of projection is that the real-world view cannot completely be blocked out, as is possible with (video see-through) magic lens interfaces.

First evaluation

Method & Test Setup

We conducted an initial user study by comparing the Map Torchlight with a magic lens interface in a map augmentation task. The study was conducted with 12 participants: 5 female, 7 male, with a mean age of 23.3 years (ages 21-33). The study had a within-participants design and the test setup was very similar to [7]. With both interfaces, the same tracking technology with the same parameters was used [8]. In each trial, the participant had to find all five parking lots on the map and physically point to the cheapest. A user had to perform 20 trials for each condition. The main performance measures taken are trial time and error rate.

Results & Findings

The overall average trial time is 12.6 sec (95% confidence interval: 11.6-13.6 sec) and the overall average error rate is 11.5% (95% confidence interval: 7-16%). With a mean of 11.1 sec, the Map Torchlight is 15% faster than the magic lens interface (13.5 sec). An analysis of variance (ANOVA) on trial times shows a significant effect ($F = 20.22$, $p < 0.05$). The differences in error rate (map torch: 11%; magic lens 13%), are within the limits of the 95% confidence interval and thus not significant at the 5% level.

Implementation

The Map Torchlight is fully implemented for Nokia mobile camera phones (S60 3rd edition). We use the tracking toolkit by Rohs et al. [8] to track the mobile device with the attached projector in real time relative to the map (6 DoF). The actual prototype is a Nokia N95 mobile phone with an AIPTEK V10 Mobile Projector (640x480 pixel) attached to the phone using a standard AV cable. The whole setup weighs about 360 grams. Due to technical limitations the mobile phone screen can only be mirrored and not be extended on the projector. Due to this issue, the projector always shows the mobile screen content, even if detailed information is presented on the mobile device screen. The focus and projection size needs to be calibrated manually, because the focus of the projector can only be adjusted manually. The tracking algorithm processes about 12 frames per second. We have produced a video that shows the first prototype in action:
http://www.youtube.com/watch?v=raRC9x5bM7c

Conclusion & Future Work

We have presented the lightweight combination of a mobile camera projector unit to augment the paper maps directly with additional information. Due to its small size and weight, it fits into a pocket and can be used "in the field". We have highlighted different interaction techniques such as information highlighting and annotation for paper maps. By applying a mobile projection approach, we have shown that high resolution and large-scale physical maps can be augmented with dynamic and personalized content without requiring great changes in the infrastructure. We have also shown that there is a lot of potential for small group interaction with this technology, as also explored in [4].

In a preliminary user test, we showed that these interfaces can overcome the switching costs of magic lens interfaces. The current prototype is only a first implementation of the concept. In the next design iteration, we intend to have a smaller and lighter camera projector unit. The current projector has several limitations in terms of the light intensity, and it needs to focus on a particular distance. The low light intensity means that the projection is barely visible outdoors and that the features printed on the map will deteriorate the quality of the projected image. For mobile projection with variable distance between projector and projection surface, laser projectors seem to be better suited, because they always show a sharp image. Additionally, the tracking technology needs to be improved to work without additional marking points on the map. We want to evaluate more elaborate interactions beyond just annotating and highlighting points of interest on the map. These interactions would involve projection of spatially extended features, such as in the interactive routing example outlined above, and collaborative interactions involving multiple projectors. We aim to investigate user interaction with such a shared projected mobile screen in other contexts than the presented map scenario.

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