Shvil: Collaborative Augmented Reality Land Navigation

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Abstract
We present our prototype of *Shvil*, an Augmented Reality (AR) system for collaborative land navigation. *Shvil* facilitates path planning and execution by creating a collaborative medium between an overseer (indoor user) and an explorer (outdoor user) using AR and 3D printing techniques. *Shvil* provides a remote overseer with a physical representation of the topography of the mission via a 3D printout of the terrain, and merges the physical presence of the explorer and the actions of the overseer via dynamic AR visualization. The system supports collaboration by both overlaying visual information related to the explorer on top of the overseer's scaled-down physical representation, and overlaying visual information for the explorer in-situ as it emerges from the overseer. We report our current prototype effort and preliminary results, and our vision for the future of *Shvil*.

Author Keywords
Augmented Reality and Tangible UI; Computer Supported Cooperative Work (CSCW); Visualization; Route Finding; Mixed Reality

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities
H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work

Introduction

Collaboratively planning and executing route finding, land navigation, and exploration tasks can be time-consuming and exhausting both physically and mentally, even when the topological terrain is known. Collaborative land navigation tasks are common in many domains including archaeology, geology, reservoir engineering, petroleum engineering, military operations, and mountaineering.

Shvil (Hebrew for path or trail) attempts to address tasks where a remote overseer (indoor user) and an in-situ explorer (outdoor user) are performing land navigations collaboratively. *Shvil* also attempts to provide better situational awareness [1] and task awareness to overseer and explorer by allowing both of them to experience the task representation physically through a tangible medium, as well as visually via AR techniques.

Figure 1: overview of *Shvil*, the collaborative system

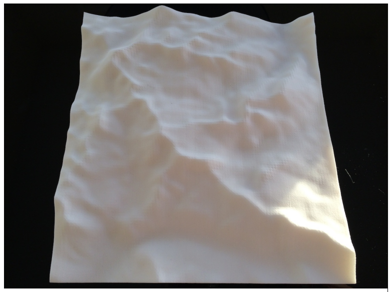

Figure 2: 3D printout of the terrain model

Shvil is designed to enrich the experience of both explorer and overseer and improve the efficiency of their collaboration by grounding it in the physical and spatial aspects of the task. Our prototype (figure 1) provides an offsite overseer with a 3D physical printout of the terrain and with interactive AR visualizations showing the task status superimposed on the 3D topographical representation. At the same time, the in-the-field explorer is provided with interactive AR visualizations superimposed on the terrain in-situ.

Beyond the immediate scope of computer supported cooperative work (CSCW) that *Shvil*, with its mixed reality augmentation, affords, we see value in using the 3D printout of the terrain as a physical representation of topographical data. The physical printout can become a rich interactive medium, capable of providing tangible modality and feedback in addition to the abstract, scaled-down representation of the environment, which the traditional map provides.

Here we present our current prototype of *Shvil*, critique our design and outline our future plans for this project.

Designing *Shvil*

> *"We now use the country itself as its own map, and I assure you it does nearly as well"*

Lewis Carroll's *Sylvie and Bruno*, 1893

Shvil aspires to convey the spatiality of the area being navigated into an interactive medium. For the overseer, this spatiality is embedded in the physical 3D printout, and for the explorer, the spatiality is expressed via the actual physical terrain that becomes an active, one-to-one-scale map (figure 1).

The component of *Shvil* used by the overseer handles the data visualization technique in an offsite (indoor) facility, while the explorer component deals with the data visualization in the field. In addition, each component also takes care of the presentation of the shared data, which allows *Shvil* to facilitate the collaboration between the explorer and the overseer. Both the overseer and explorer components of *Shvil* use AR to enhance the interactive environment and to access the 3D spatial navigational data in real-time. The explorer interacts with the physical terrain using AR directly in the field; however, the overseer benefits from accessing the 3D printout of the terrain, not only as a realistic illusion enhanced by the superimposed AR visualization, but also the tangible provides additional perceptional advantage and understanding of the terrain as experienced by the explorer.

Shvil is based on a 3D printout model of the terrain data (figure 2). With the current advances and accessibility of 3D printing technology, such printouts are easy to generate and becoming less costly. We expect that, similar to how conventional 2D maps are commonly printed and distributed, 3D printouts of terrains could be easily produced and distributed in the near future.

Shvil's overseer interface combines the 3D printout with AR tracking (see the bottom left image of figure 1). The route information is rendered via mobile devices running the AR library with the virtual representations overlaid and correctly aligned on the physical 3D printout. When changing content in the virtual image, the overseer sees these changes instantly applied upon the physical 3D printout. The experience is enhanced when the overseer moves around the physical model, since the AR device automatically detects the location and orientation of the

Terminology

The Overseer Part: an exocentric visualization system of the route data, a.k.a. the mission control center.

The Explorer Part: an egocentric visualization system of the same piece of route data, a.k.a. the field site.

Overseer: user of the overseer (indoor) component of the system.

Explorer: user of the explorer (outdoor) component of the system.

Route: The travelling path of the explorer, including past route, planned route, and suggested route if the explorer separated from the planned route.

Point of Interest: Other items to display, including labels, timestamps, etc.

3D Printout: The physical entity of the terrain model produced by 3D printing.

model in real-time and adjusts the virtual image along with it. Various routes and related points of interest from the explorer are rendered in the AR environment in real time. Since the virtual image presented to the overseer is aligned with the physical model, it feels like those routes and points of interest are marked on the physical presentation of the terrain directly (see left half of figure 1).

The explorer component of the system is used as an aid for an in-the-field explorer to identify the routes and various points of interest on the terrain. It is essentially a geo-location based AR system that helps to identify aforementioned information in the scene, based on the explorer's location and direction. The system overlays this information onto the live camera feed in order to create the in-situ experience. The explorer interface demonstrates an egocentric system, while the overseer component presents an exocentric view of the terrain (see right half of figure 1).

Since the goal of this system is to facilitate the collaboration between the overseer and the explorer in real-time, both people in different locations are de facto examining the same set of data. However, rather than a birds-eye view as experienced by the overseer, the explorer observes the information in-situ. Also, information will be updated dynamically to either part of the system simultaneously.

Related Work

Augment reality (AR) has been frequently used in many areas, including civil engineering and design [2][3] and topographical terrain exploration [4]. Several past applications proposed using AR to support collaborations between experts and remote field users [5][6].

Moreover, AR has also been applied in coordinating terrain navigation between an indoor user and the outdoor user [7][8], with gestures and physical props [9]. However, as far as we know *Shvil* is the first to use a 3D printout of the terrain as the interactive medium representing the topographical data in a physical form in such collaborative task, and is unique in providing a combined experience of both visual (AR) and tangible (3D printout) contextual feedback within the collaborative task.

With respect to the tracking applications, there are many commercial applications such as "Apple Find My Friends" [1] and "Google Location History" [2] that superimpose locations on traditional 2D maps. However, rather than 2D maps, here we are more interested in visualizing 3D land navigation, thereby facilitating remote collaboration between the overseer and the explorer.

Implementation

Shvil is designed with loose coupling as a goal, so any component may be changed without impacting other parts of the system. There is an intermediate server to handle the information sharing, and standard REST APIs are used for data transmission in between. We implemented both the overseer and explorer parts on entirely different devices (iPad Air vs. Lenovo tablet) and coding environments (iOS vs. Microsoft Windows). The explorer component was implemented on Lenovo ThinkPad Tablet and Windows environment while the overseer component was developed on iPad Air and iOS.

[1] Accessed Jan 5, 2014: https://www.apple.com/apps/find-my-friends/
[2] Accessed Jan 5, 2014: https://maps.google.com/locationhistory/

In the overseer interface, the AR and the 3D printout of the terrain are used for creating the exocentric visual experience. Markers are placed around the 3D printout, and Qualcomm Vuforia[3] is used as the image recognition library for obtaining the location and orientation of these markers. Based on the spatial information, the mobile device adjusts the virtual image correspondingly when the viewer walks around the physical model. Navigational information, including the route of the field explorer and other points of interest, are visually mapped onto the physical model to give the impression that they are indicated and labeled on the model directly (see the bottom left image of figure 1).

In the explorer component, a Windows tablet is used as the portal device for the AR visualization. Location and orientation of the explorer are collected from the built-in GPS sensor, compass, and inclinometer. Based on this data, routes and points of interest are mapped to the physical position so that it looks like they are painted "on the ground" from the explorer's perspective (see the bottom right image of figure 1).

Critique and Limitations

Currently, *Shvil* is a proof-of-concept prototype. We are still developing and improving the accuracy of the GPS and compass readings, communication latency between the overseer and the remote explorer, and low route-mapping resolution.

Besides the aforementioned technical limitations, we are also aware of limitations related to our design approach. Our augmented reality mediators are based on consumer-level tablets. This results in the users, especially the explorer, needing to interact with relatively inconvenient and heavy handheld devices. This design approach could be improved dramatically by moving *Shvil* onto head-mounted or wearable devices, such as Google Glasses, that would likely provide a more natural experience. On the other hand, our topographical terrain 3D printout required considerable resources, and certainly there exist approaches that use other tangible mechanisms to represent the terrain [10][11]. However, with the progression of 3D printing technology driving down the cost, and with more precise 3D printers becoming abundant, this barrier could be reduced if not completely eliminated.

Future Work

We would like to extend the *Shvil* concept to multiple (non-collocated) explorers, and also to multiple (non-collocated) overseers, all relating to the same geographical location by either walking on top of it physically or by interacting with copies of its 3D printed representation. Another improvement to *Shvil* we are planning is to incorporate more sophisticated interaction techniques, such as using touch directly on the 3D model in the case of the overseer, and gestures in the case of the explorer.

We are exploring the possibility of applying *Shvil* to domains where the topography of the physical site could be augmented with metadata well beyond *Shvil*'s current basic terrain surface navigation. For example, we are planning to use *Shvil* for collaborative exploration of interactive visualizations of oil and gas reservoirs, where enabling collaboration between remote overseer experts and in-situ explorers can be very useful to track and explore complex domain specific features.

[3] Accessed Jan 5, 2014: http://www.qualcomm.com/solutions/augmented-reality/

Conclusion

In this paper we presented a collaborative land navigation system, named *Shvil*, which uses AR and 3D printing technologies to facilitate and visualize route planning and execution. This system allows two collaborators, an in-situ explorer and a remote overseer, to exchange route information during a field exploration using the terrain as the interactive medium. Although *Shvil* is a design concept with only a proof-of-concept prototype implementation, future directions and improvements were discussed.

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