ABSTRACT
NetEyes is a system that allows remote and co-located partners to collaborate by annotating maps printed on digital paper. It combines natural language capabilities, in particular the interpretation of sketched symbols, with the display of three-dimensional representations of recognized objects, allowing users to jointly visualize a planned or evolving situation in detail. Visualization can take place either on a conventional monitor or through optical see-through, head-mounted displays. Seamless collaboration is promoted via the use of tangible paper maps, which makes it possible for multiple parties sitting around a table to place annotations as they would using regular paper and pen. To account for movements and rotation of the maps that are common during collaborative annotation sessions, a vision-based tracking component is used. This component recovers the location of the paper map in the real-world, and scales and rotates the digitally displayed objects so that they keep aligned with the map.

KEYWORDS: Tangible Interfaces; Collaborative Interfaces; 3D interfaces; Digital Paper; Natural Language Interaction; Augmented reality; Vision-based tracking.

INDEX TERMS: H5.3 [Group and Organization Interfaces]: Collaborative Computing; Synchronous Interaction; H.5.2 [User Interfaces]: Input devices and strategies.

1 INTRODUCTION
In a wide variety of domains, sketching over tangible paper artifacts, such as maps, floor plans and other schematics remains the most convenient collaboration practice. Paper is light-weight, robust (works even if punctured or thorn), does not require a power source (is always “on”), is high-definition and come in a variety of sizes. That makes it ideal both in situations in which a group of co-located people wants to collaborate, as well as in situation in which mobility is important.

In this work we explore a combination of techniques that aims at supporting this type of practice in a seamless way, matching the convenience of paper with the advantages derived from the use of computers, such as for instance rich 3D visualizations and support for collaboration across remote sites. A 3D scene is constructed iteratively as user sketched symbols are interpreted via natural language processing techniques. Both the digital ink and the 3D representations are propagated and displayed across remote sites to promote collaboration.

A variety of different techniques have been explored in the past to bridge paper and digital technologies, starting with Wellner’s DigitalDesk [6]. Augmentation of planning exercises based on digital paper were explored by our Rasa and NISMap systems [4]. Similarly to Rasa, NetEyes interprets sketched symbols written on paper.

Paper-augmentation techniques are usually based on the projection of images of digital objects over some surface that may contain paper documents. The technique we explore is similarly based on the composition of digital elements that are projected over paper documents, namely a map that is annotated by the users. NetEyes is distinguished by the use of digital paper as the means to collect information, and the display of three-dimensional elements whose location over the map is kept stationary via a vision-based tracking technique. The latter makes it possible for see-through optical displays to be used, even while the map is rotated or moved around. Haller et al.’s [2,3] “Shared Design Space”, also used Anoto digital paper, tracked via the ARToolkit. Besides supporting sketch recognition capabilities, NetEyes goes beyond this system in its support for remote collaboration.

In the following sections we provide an overview of Net-Eyes – a system that integrates sketching recognition over digital paper maps with a vision-based tracker system to provide support for co-located and remote collaboration.

2 COLLABORATION VIA NETEYES
NetEyes allows multiple co-located participants to share a map and perform simultaneous annotations. Similarly, remote participants may annotate copies of the map, or use a Tablet PC to perform their annotations (Figure 1).

Figure 1. Users collaborate by writing on digital paper maps. Users can be remote, or use multiple pens on the shared map, if co-located.

Users communicate by sketching on the maps. These sketches are interpreted by the system, which then displays 3D representations of the recognized objects. The current prototype
recognizes standard military symbols, rendering them as “flags”, or other 3D objects such as: an airport’s air-space as green cylinders, a threat envelope of anti-aircraft batteries as a red dome, and air corridors as yellow cylinders (Figure 3).

System display can take place on head-mounted see-through optical displays or on conventional monitors/projectors. The combination of paper-based input capabilities with a head-mounted display makes the system ideal for mobile field situation. As the user moves around, the system keeps track of the position of the map (as later described), scaling and displacing the displayed elements so that they coincide with their intended position on the map. The 3D nature of the display makes it furthermore possible to examine a configuration from multiple points of view – the display is adapted to show elements from the perspective of the observer, independently of where she is located. This makes it possible as well to examine a situation from multiple perspectives by physically rotating the paper map.

3 DIGITAL PAPER INPUT

The underlying technology we exploit is based on Anoto’s Digital Pen and Paper [1]. Anoto-enabled digital paper is plain paper that has been printed with a special pattern, like a watermark. A user can write on this paper using a pen with Anoto Functionality (Figure 2), which consists of an ink cartridge, a camera in the pen’s tip, and a Bluetooth wireless transceiver sending data to a paired device. When the user writes on the paper, the camera photographs movements across the grid pattern, and can determine where on the paper the pen has traveled. In addition to the Anoto grid, which looks like a light gray shading, the paper itself can have anything printed upon it using inks that do not contain carbon.

The use of tangible paper maps, including larger format ones, makes it possible for multiple people to collaborate in a seamless way, as they would when using regular pen and paper. A single map may be shared by multiple co-located users, which may use the map in different ways, as they would when using regular pen and paper. A single map may be shared by multiple co-located users, which may use the map in different ways, as they would when using regular pen and paper.

4 VIDEO-BASED TRACKING

To be able to display the 3D representations on their corresponding positions on the map even when the user moves or rotates the map, NetEyes integrates a vision-based tracking system, the ARToolkit [5]. NetEyes can use either fiducial markers or natural feature points (Fig 3) for vision-based tracking. An example of the latter could be patterns in the topography, such as contour lines, or color variations. Natural feature tracking makes it possible for users to “zoom in” by moving closer to the page. Tracking is maintained even if the area that is focused by the camera does not include any of the fiducial markers printed on the margins of the map.

The tracking system studies the features of a map and determines four unique points that can be readily discriminated [5]. It does this hierarchically, so that at any given instant four unique points can be discriminated. Once these points are found they are used to determine distance and orientation of the head-mounted display (in the real world) from the map in real time. Using this camera information, virtual information (including live 3D data) can be overlaid on the real map. In the current NetEyes system fiducial markers are used to initialize tracking. When there is no fiducial marker in the field of view of the camera, NetEyes uses natural feature points to keep tracking the map, as illustrated by Figure 3’s zoomed-in view.

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REFERENCES