Large interactive surfaces based on digital pens

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Abstract

Interactive surfaces are becoming increasingly popular. A table/wall setting provides a large interactive visual surface for groups to interact together. After describing the user requirements, we demonstrate different possible solutions for both the display and the tracking implementation. We propose an easy-to-implement solution for tracking large surfaces based on digital pen from Anoto.

Keywords: Digital Whiteboard, Interactive Table, Digital Pen, Advanced User Interface

1 Introduction

Interactive walls and tables are becoming increasingly popular and large augmented surfaces are already part of our physical environment. These newly emerging form factors require novel human-computer interaction techniques. Although movies such as Minority Report and the Island popularized the idea of novel, off-the-desktop gesture-based human-computer interaction and direct manipulation-based interfaces, in reality, making the interactions with a digital user interface disappears into and becomes a part of the human-to-human interaction and conversation on these large interactive surfaces is still a challenge. Conventional metaphors and underlying interface infrastructure for single-user desktop systems have been traditionally geared towards single mouse and keyboard-based WIMP interface design, while people usually meet around a table, facing each other. A table/wall setting provides a large interactive visual surface for groups to interact together. It encourages collaboration, coordination, as well as simultaneous and parallel problem solving among multiple people.

In this paper, we describe particular challenges and solutions for the design of tabletop and interactive wall environments. To better understand the design requirements for interactive displays in a business setting, we carried out an explorative field study at voestalpine, an Austrian steel company. We found the following design recommendations for an interactive, large vertical/horizontal display:

- Multi-point interaction & identifaction,
- Robust tracking under non-optimal condition,
- Hardware robustness,
- Physical objects should not interfere,
- No additional devices (at least one) should be required for use,
- User can interact directly with the system,
- Reasonable latency, and
- Inexpensive to manufacture.

Albert noticed in [Alb82] that finger-operated touch screens are best in speed and worst in accuracy. We also noticed in our study that a direct touch on the surface seems to be an intuitive interaction metaphor. Especially at the beginning,

users are not interested in using additional devices. On the other side, the user's finger often obsure parts of the screen. Moreover, the screen gets dirty from finger prints. Therefore, while working longer with the system users want to have more accurate and a more formal input technology.

2 Related Work

Our work draws on work in two areas: collaborative interactive horizontal/vertical systems and digital pen technology.

Wellner's DigitalDesk was one of the first interactive tables that combined both real and virtual paper into a single workspace environment [Wel93]. Wellner used computer vision technology to track user input. Current digital tabletops vary widely in their size and shapes [DL01, SGH98]. Since many tabletops have a physically shared space, it becomes difficult for people to reach digital items that are across the table. In the late 1988, Xerox PARC developed the LiveBoard [EBG+92], the first blackboard-sized touch-sensitive screen capable of displaying an image. SMART Technologies Inc.[1] introduced its first interactive whiteboard in 1991. The tracking is based on the DViT (Digital Vision Touch) technology and uses small cameras mounted in each of the four corners of the panel to track the user input [Mor05]. The system is mainly designed to be used with pens, but it can also track finger touches. However, not more than two inputs can be detected simultaneously. A similar technology is the touch frame provided by NextWindow[2]. Again, embedded cameras can track up to two points at the same time. The MIMIO[3] and eBeam[4] ultrasonic tracking devices, where participants use special styli, are a good and cheap alternative tracking surface. However, they are limited in their range, and line-of-sight restrictions reduce the tracking performance.

Matsushita and Rekimoto built the HoloWall, a vertical surface allowing tactile interaction [MR97]. The authors achieve good tracking results using a special diffuse rear-projected screen, infrared (IR) LEDs and a camera with an IR pass filter. The system tracks any object which is near enough to the surface detected by the camera. Wilson's TouchLight [Wil04], is a similar imaging touch screen technology, which uses simple image processing techniques to combine the output of two video cameras placed behind a semi-transparent Holoscreen in front of the user. Wilson's research results also strongly influenced the success of Microsoft's Surface which uses five IR cameras for tracking users' input. Starner et al. [SLM+03] used an IR tracking environment for the Perceptive Workbench tabletop system. The application features the recognition of gestures on the surface that enhance selection, manipulation, and navigation tasks. The tracking is based on shadows created by infrared illuminants that are mounted above the table. Finally, Han demonstrated in [Han05] an impressive scalable multi-touch interaction surface that takes advantage of frustrated total internal reflection (FTIR). This technology introduces a new way to create scalable multi-touch displays at a manageable price.

An alternative to using computer vision or other technology for hand tracking is capturing input through digital pens. Many researchers are working with digital pens from Anoto [LGH05]. Although the Anoto tracking technology has been available for more than five years, in the last year it became possible to use a real-time Bluetooth connection to retrieve live pen data. In contrast to most related work, we use the Anoto digital pen as a stylus that allows the tracking on large augmented surfaces. The setup itself is scalable, easy-to-manufacture, and accurate - even on very large surfaces.

3 Our approach

Figure 1 depicts the different layers of our tracking surface. The tracking is realized by using a large Anoto pattern printed on a special foil (d) combined with digital pens (a). Anoto-based digital pens are ballpoint-pens with an embedded infrared (IR) camera (f) that tracks the pen movements simultaneously. The pen has to be used on a specially printed 600dpi paper with a pattern of small dots with a nominal spacing of 0.3mm (see figure 2).

The maximum size of the pattern that can be successfully printed is A0. However, stitch-

[1] http://www.smarttech.com
[2] http://www.nextwindow.com
[3] http://www.mimio.com/
[4] http://www.e-beam.com/

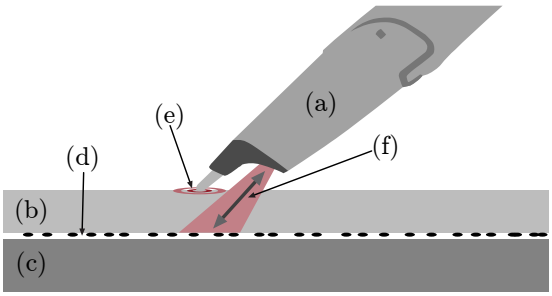

Figure 1: Users can interact with the projected image using digital pens from Anoto.

ing multiple A0-sized patterns together can result in larger tracking surfaces without any tracking penalties (the theoretical size of the surface is 60 Mio km^2). Once the user touches the board with the pen, the camera tracks the underlying Anoto pattern. It can then derive its absolute coordinates on the pattern and send them to a computer over Bluetooth at a rate of 50Hz.

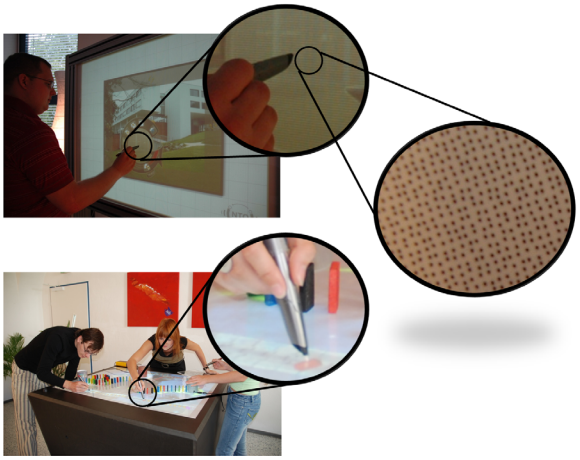

Figure 2: The rear-projection screen has tiny dots printed on a special foil.

Both the surrounding light and the lights coming from the projectors (placed in the back of the panel) do not interfere with the pen tracking, because the camera tracks the pattern with its IR camera. Currently, Anoto pens with Bluetooth are available from Nokia (SU-1B), Logitech (io-2), and Maxell (PenIT). All of these pens are pressure sensitive which allows for additional functionalities (i.e., better control in a sketching/drawing application). In our setup, we used the pen from Maxell. From the pen, we receive the pen ID, the ID of the pattern sheet, and the position of the pen tip on the pattern. Theoretically, there is no limit to how many people interact simultaneously. However, only seven Bluetooth devices can be connected to a single dongle. We have tested our setup with five participants interacting simultaneously without having serious performance penalties. The pattern should be printed with the black ink cartridge (which is not IR transparent and therefore visible for the IR camera), since the colors Cyan, Magenta, and Yellow (even composed) are invisible for the IR camera.

4 Applications

In the following sections, we describe different demo applications which are based on our tracking hardware combined with the digital pens.

4.1 Interactive Table

The Shared Design Space [HLL$^+$06], a collaborative interactive table, was our first demonstration, where we combined digital pens with surface tracking for a large tabletop setup. The system is mainly designed for brainstorming based on the design requirements mentioned in the previous sections. The current hardware setup consists of three DLP-projectors (with a high-resolution of 1280×768 pixels) mounted above the interactive table with a projection size of 170cm×90cm (see figure 3).

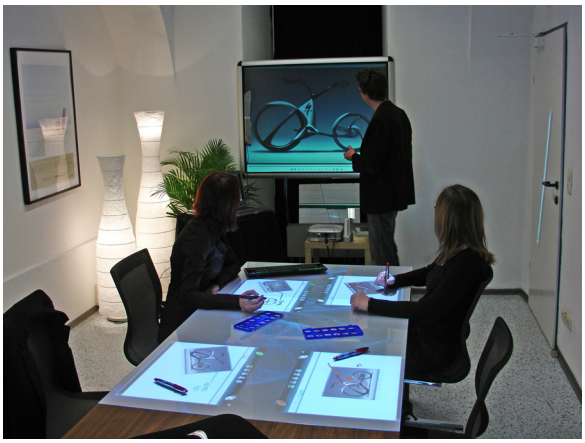

Figure 3: The Shared Design Space demonstrates our hardware setup in action.

In our setup, we use the Anoto technology in different ways. As depicted in figure 4, we use the digital pen to produce digital ink on the horizonal surface. Moreover, participants can interact with

tangible (graspable) objects (e.g. with a real color box). In each of the color tiles of the box, we used again the Anoto tracking technology. Thus, the pen does not track directly the color, but the underlying pattern. For all these different patterns, we implemented a calibration tool, which allows a fast and robust calibration and registration of the pattern. After choosing a color, participants can draw with the digital ink or combine it with virtual content (e.g. images, videos, or 3d geometries).

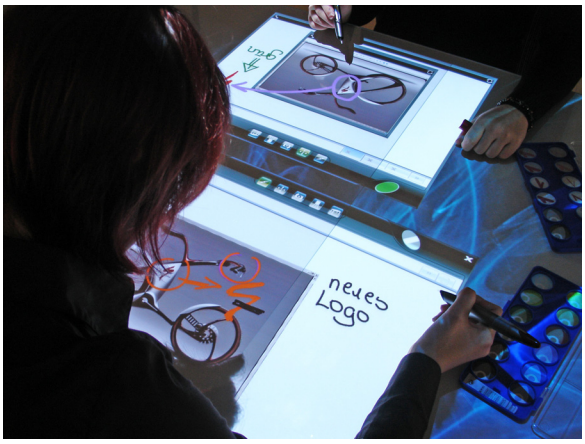

Figure 4: Users can either interact with the surface, choose different ink properties in the palette, and sketch their ideas directly on the table.

Palettes allow efficient and fast interaction with the system on large tracking surfaces and do not require any hardware.

4.2 How to create a rear-projection surface?

During our tests with the tabletop surface, we observed that users did not have huge problems with self occlusions and shadows. We noticed that also in our daily life, we have similar conditions (e.g. while working on the table with a light mounted on the ceiling). However, we often got asked for a rear-projection solution. It is important to mention at this point that a rear-projection solution also implies a projector mounted under the table's surface, where users usually want to put their feet. In our setup, we propose a rear-projection table designed for people standing arround the table. Again, we used the Anoto pattern printed on an HP Colorlucent Backlit UV foil (see figure 5).

The Backlit foil is mainly designed for back

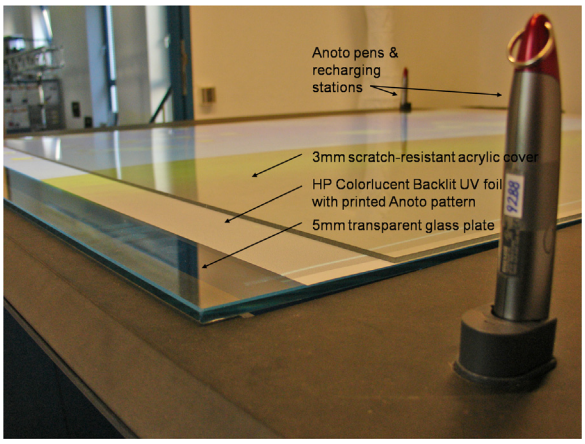

Figure 5: The different layers of our rear-projection table.

lighted signs so it generates a diffuse light. Thus, no spotlights from the projectors are visible at the front of the screen. Moreover, the rendering and the brightness of the projected image is still of high quality. In our setup, we used one A0 sized pattern sheet (118.0cm×84.1cm). The pattern is clamped in-between two acrylic panels. The panel in the back has a width of 6mm and guarantees a stable and robust surface while the panel in the front has a width of only 0.8mm to protect the pattern from scratches. We noticed that the acrylic cover in the front does not diffract the Anoto pattern at all. However, using thicker front panels (e.g. ≥4mm), produces bad tracking results.

While we tested also successfully our tracking with a transparent foil, we didn't achive good tracking results using this foil in front of a plasma or a LCD display. We think that these displays emit too much IR light, which interferes with our pen IR tracking.

4.3 Digital Whiteboard

Similar to the rear-projection table, we also implemented successfully a digital whiteboard using the exact same surface layers (see figure 6).

In addition to the pen tracking, our system also supports hand tracking. Behind the display surface, we mounted a common PAL camera (WATEC WAT-502B), and we track the user's hands on the screen by using brightness differences. The camera behind the screen captures a grey surface and objects coming near the surface will appear as blurred shadow. Thus, only objects directly

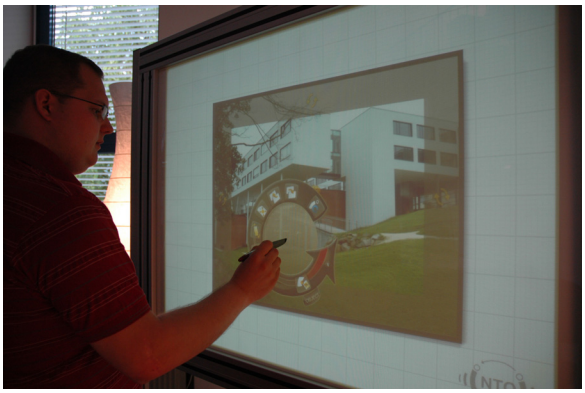

Figure 6: The digital whiteboard is also based on Anoto's digital pens.

touching the surface are recognized as sharp outlined shapes.

5 Conclusions and Future Work

Although there are already several projects focusing on ubiquitous environments, it is still challenging to design a large, digital surface which is seamlessly embedded in an existing environment. In this paper, we mainly focused on design requirements, we achieved from discussions with our customers. Based on that, we implemented an interactive vertical/horizontal display. The interaction is realized using digital pens with embedded cameras, which track a special pattern (with tiny dots) mounted on the table surface. The installation provides a cooperative and social experience by allowing multiple face-to-face participants to interact easily around a shared workspace, while also having access to their own private information space and a public presentation space combining both virtual and real sketches. The project is different from typical screen-based collaboration, because it uses advanced interface technologies to merge the personal and task space.

In this paper, we have also presented a rear-projection screen based on the Anoto technology in combination with digital pens and a simple IR-tracking setup. The scalable system allows multiple users to interact simultaneously. The hardware for tracking the digital pens is robust and allows a really precise interaction with high accuracy. Finally, the setup is easy-to-manufacture and cost effective. We are currently optimizing the hand-gesture tracking. Our current hand-tracking setup is depending on the lighting conditions of a room and requires a light room environment. Therefore, we are focusing on improving the hand feature tracking by using Han's FTIR approach [Han05] or a similar method. Finally, in the near future we will conduct detailed user studies to evaluate the usability of our interface and observe the impact the technology has on meeting dynamics.

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