An Adaptable Rear-Projection Screen Using Digital Pens And Hand Gestures

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Abstract

INTOI is a rear-projection setup which combines accurate pen tracking with hand gesture recognition. The hardware consists of an Anoto pattern printed on a special rear-projection foil and an infrared tracking system. INTOI is a low-cost system that is scalable and provides highly accurate input (to less than 1mm). Finally, our setup supports a novel multi-user interaction that combines simultaneous interaction of both hand and pen gesture input.

1 Introduction

Whiteboards, flip charts, walls, and tables are still the primary tools used for explaining, developing, and communicating ideas during the early phases of design [4]. While traditional flipcharts and whiteboards are used in many settings, users still face a range of restrictions: for example, to draw with different colors one needs different colored pens, it is cumbersome to flip between pages and add additional sheets, and there is a limited size of the available drawing area. In addition, although people often use PowerPoint presentations in combination with paper flipcharts, there is still no simple way to combine both in a powerful presentation tool.

Over the last decade, large, interactive vertical displays have become increasingly popular. 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. An overview of the most important features is depicted in table 1.

Reasonable latency	Hardware robustness
Inexpensive to manufacture	Drawing area of infinite size
Multi-point interaction	Direct interaction
Few additional devices (e.g. just one controller)	Physical objects should not interfere (e.g. body)

Table 1. Design Requirements for an interactive, large, vertical display

In this paper, we present a low-cost interactive vertical display that fulfills these requirements. Our display combines digital pen technology from Anoto[1] and infrared optical tracking in a new way. We describe an appropriate presentation application, INTOI, that demonstrates the benefits of the system. In contrast to most related work, we use digital pens as styli for an intuitive and easy-to-use interaction with large surfaces. The research described in this paper presents a new way for tracking on large surfaces and presents design guidelines for large interactive vertical displays.

2 Related Work

In the late 1988, Xerox PARC developed the LiveBoard [1], the first blackboard-sized touch-sensitive screen capable of displaying an image. SMART Technologies Inc.[2] 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

[1]http://www.anoto.com
[2]http://www.smarttech.com

to track the user input [7]. 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[3]. Again, embedded cameras can track up to two points at the same time. The MIMIO[4] and eBeam[5] 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 [6]. 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 [10], 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 four IR cameras for tracking users' input. Starner et al. [9] used an infrared 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 [3] 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.

Unfortunately, in most of this related work, users can either interact with fingers or hand gestures or with an input device. A combination of both is only possible with the DViT and the NextWindow system. These interfaces, however, do not allow a multi-user/finger interaction. 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 [5]. 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]http://www.nextwindow.com
[4]http://www.mimio.com/
[5]http://www.e-beam.com/

3 Our Approach

The Shared Design Space [2] was our first demonstration, where we combined digital pens with surface tracking for a large tabletop setup. Figure 1 shows our current prototype and illustrates the hardware setup of an interactive table and a digital whiteboard in combination with a rear-projection screen.

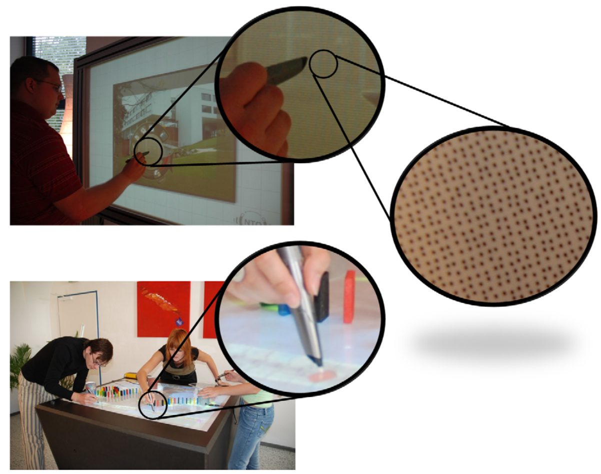

Figure 1. The rear-projection screen has tiny dots printed on a special foil.

Figure 2 depicts the different layers of our setup. The tracking is realized by using a large Anoto pattern printed on a special rear-projection foil (d) and digital pens (a). Anoto-based 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.

The pattern was printed by using black ink. In our setup we used the HP Desginjet Z2100 plotter in combination with the HP Colorlucent Backlit UV foil to generate the pattern. The Backlit foil is mainly designed for back 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 (cf. figure 2 (b),(c)). The panel in the back has a width of 6mm and guarantees a stable and robust surface while the panel in the front

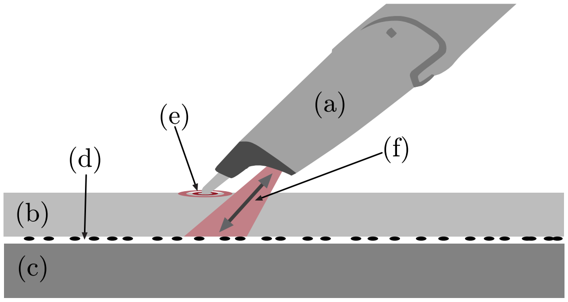

Figure 2. Users can interact with the projected image using digital pens from Anoto.

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.

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. 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 8 devices can be connected to a single Bluetooth dongle. We have tested our setup with eight participants interacting simultaneously without having serious performance penalties.

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 touching the surface are recognized as sharp outlined shapes (cf. embedded image of figure3).

Figure 3 illustrates our general hardware setup that enables a stable tracking in an IR light scenario. The light illuminating the scene from the back casts a high contrast shadow of the user's body on the screen. Without additional light from the front, the resulting contrast image seen by the camera would include the full body shape. Notice that the IR lights at the front of the panel do not interfere with the tracking results of the digital pens.

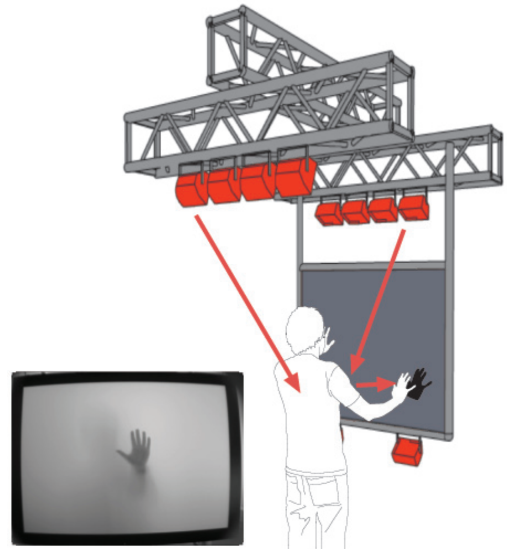

Figure 3. Infrared lights at the back of the user and on top of the screen guarantee an optimal lighting condition for the hand tracking. The camera with the IR-pass filter is mounted on the back of the screen.

3.1 Multi-User Interaction

Our method has many advantages over related solutions. One of the most important features is the multi-user interaction and identification. Using a single Bluetooth dongle, we can support a maximum of 8 users, who can interact simultaneously with the system. Since the pen data is sent over UDP to the rendering software, there is no problem in using additional Bluetooth dongles attached to other machines to increase the number of users. Thus, the application is very scalable. All of the Anoto pens have unique IDs in order to keep track of each users' drawings. Moreover, pen settings such as color, stroke width and the currently selected tool are stored for each pen separately.

3.2 Simultaneous interaction of hand and pen

Another important feature of our display is the support for simultaneous hand and pen input. The infinite sized drawing area of the demo application can be panned by sliding one hand over the projection surface. Using two hands together enables the user to zoom in and out of the current page by moving the hands either apart or together (cf. figure 4).

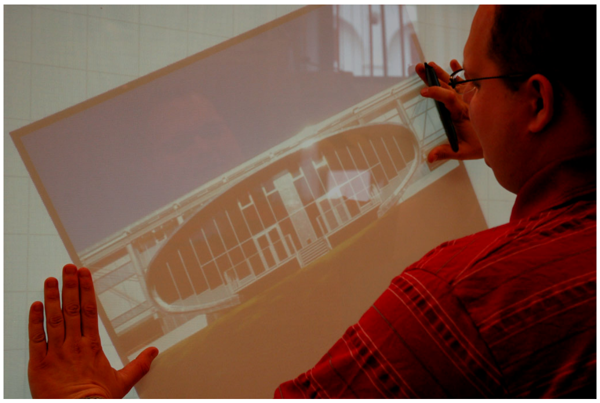

Figure 4. While zooming the content with a two-hand gesture, users can perform accurate interaction with the pen device.

In combination with the highly accurate digital pen we were able to achieve very intuitive interaction. The IR light from the spots in the front is reflected by the user directly onto the semi-transparent surface. Whenever a user touches the panel, the hand produces a shadow that can be captured by the camera behind the projection surface. If a digital pen is used at the same time, the size of the stylus tip is too small to be recognised by the camera and therefore does not affect the visual tracking. This fact enables the simultaneous use of stylus and hand gestures without interference problems.

3.3 Accuracy and Performance

We achieved a pen tracking resolution of less than 1mm. For the hand tracking we use a PAL-resolution camera that is calibrated to the actual area of the INTOI surface. Even though the accuracy of the shadow boundaries tracked by the camera is too low to recognize individual finger tips, it is accurate enough to enable robust hand tracking for navigating through the page. While our application is idle, it renders around 350 frames per second on an Acer Travelmate 8200, Mobile DualCore Intel Pentium M, 2.0GHz, 2GB RAM, ATI Mobility Radeon X1600 with 512MB. During writing/drawing with the pen we still achieve 130fps. As all the stroke data is stored on the graphics hardware, rendering of processed strokes does reduce the performance significantly. The hand tracking is accomplished by a separate PC that streams the data via network to the INTOI client. Using common computer vision techniques, we achieve a framerate of 30fps on the tracking server, regardless of how many hands tracked.

3.4 Using the pattern anywhere

The maximum size of the pattern that can be successfully printed is A0. However, stitching multiple A0-sized patterns together can result in larger tracking surfaces without any tracking penalties. Palettes allow efficient and fast interaction with the system on large tracking surfaces. Figure 5, for example, depicts a scenario where application properties can be chosen by a simple shortcut palette. The tangible palette allows a fast and efficient interaction with the system and does not require any hardware. Again, we use an Anoto pattern, which is printed on a paper. The pen tracks the feature and triggers the according shortcut.

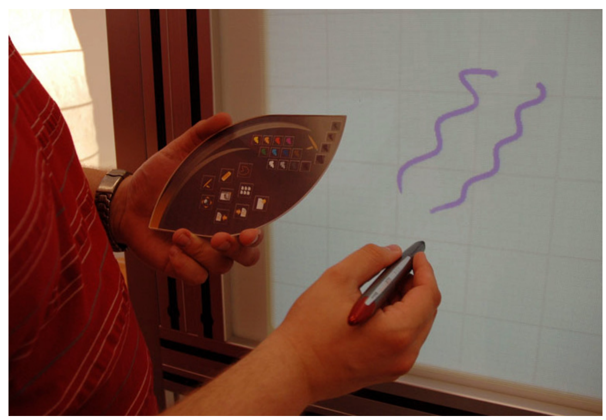

Figure 5. Palette-interaction with the system.

4 Interaction Techniques

Using a pen is a very common and natural way to write or draw on a sheet of paper. In a pilot study, we found that most subjects moved the page by hand, while writing with the pen (see figure 6). In order to follow this natural interaction model, the application uses pen devices for sketching while the infinite sized drawing area is panned and zoomed by hand gestures.

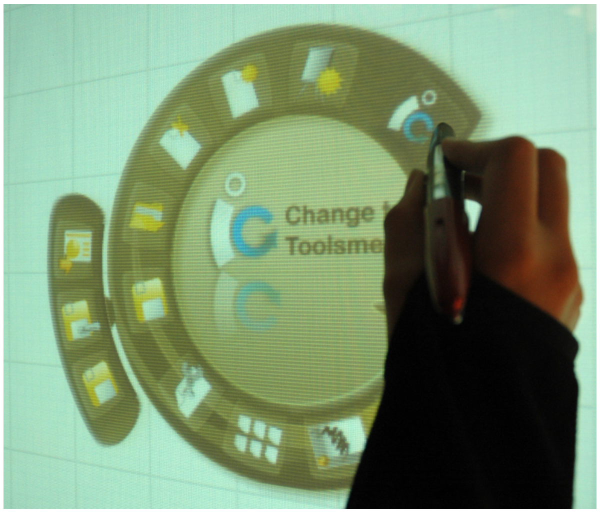

Figure 6. The system offers a pie menu for left- and right-handed people. The pie menu for right-handed users has placed all items on the left side of the menu.

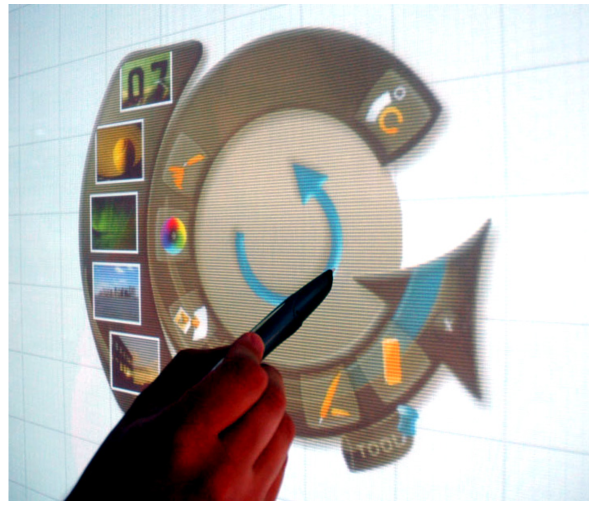

Figure 7. The Curve Dial technique allows an intuitive interaction on a large surface.

While related work also supports hand and pen interaction (since most hand tracking setups can automatically handle pen tracking), our system can provide a *distinction* between pen and hand input. The combination of both interaction techniques, using the hand-based gestures and the pen-interaction guarantees an optimal interaction with the interface . Precise and accurate interaction is provided by using the pen and large movements such as scaling or moving the panel were realized by intuitive hand gestures.

In contrast to classical WIMP-interfaces, we used a lot of pen- and gesture-based metaphors such as the Curve Dial technique [8]. Using a Curve Dial, users can easily browse through an image gallery, by rotating the pen in the middle of the pie menu. This method tracks the curvature of the path created by the pen and changes the values accordingly (cf. figure 7). The speed of how fast the user can browse through the content is controlled by the circle size made by the user: the larger the radius the slower the increase in the parameter and thus the slower the speed of the browsing of content. In the same way, users can change other parameters, cf. stroke width.

In addition to the Curve Dial, a pie menu appears by tapping the pen on the display surface. Consequently, users can change properties or functions. Each user gets his/her own menu and can interact individually with the system (e.g. change the colors or the stroke width). More complex functions (e.g. change to an overview of the slides) locks the system and avoids unwanted interactions. Loading content, such as images, presentation slides and stored INTOI-presentations can be done by simply browsing through the media library using the Curve Dial technique [8]. Finally, INTOI also supports simple pen-gestures (e.g. for removing objects, users just have to cross out the object). While we have not conducted formal user studies yet, over the past several weeks a number of groups of people have tried our prototype interface. In general they found that the simultaneous use of both hand and high accurate pen input are one of the most promising features of this system.

5 Conclusions and Future Work

In this paper we have 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 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 [3] 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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