FLUX – A Tilting Multi-Touch and Pen Based Surface

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Abstract
FLUX is an interactive touch-sensitive tilting surface that can be used either as a sketching board, as an interactive discussion table, and as a digital presentation whiteboard. The surface, based on a rear-projection screen, supports both multi-touch interaction as well as multiple pen interaction with individual identification of each pen. Our setup combines two tracking technologies. For the hand-tracking, we take advantage of the Frustrated Total Internal Reflection (FTIR) technology. For the pen-tracking, we are using the tracking technology developed by Anoto.

Keywords
Tabletop, Digital Whiteboard, Sketching, Design Room, Design Environment, Frustrated Total Internal Reflection, Pen-based Interface, Multi-Touch.

ACM Classification Keywords
H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems— [H.5.3]: Collaborative computing—Computer-supported cooperative work

Introduction
In the future, displays will increasingly be embedded into everyday furniture, such as the tables in a meeting

room or in a café, and the seating areas on a train. Furthermore, displays as well as physical objects will communicate more and more with each other. By observing such evolution of physical environments, which shows the pervasive distribution of interactive displays in different form factors, we can gain insight into the emergence of future interactive spaces.

The success of devices with novel interaction techniques (e.g. Apple's iPhone[1]) and the increasing availability of multi-touch surfaces (e.g. Microsoft Surface[2], SMART Table[3] etc.) show that users have a growing interest in using these devices in their daily lives. Multiple metaphors and interaction paradigms using pen, touch, and visual recognition are coming together with the other elements to create a new user experience. With the progress in interactive walls, interactive tables, and multi-touch devices, companies and academic institutions are evaluating the potential use of these technologies for wider use. These emerging form factors require novel human–computer interaction techniques. An increasing number of related research projects are dealing with natural large surfaces. This development popularized the idea of futuristic, off-the-desktop gesture-based human–computer interaction and direct manipulation-based interfaces. However, making these interfaces is still a challenge.

FLUX (Fully Liberating User Experience) is an interactive surface, which enables multiple modes of interaction in a variety of configurations, allowing increased flexibility, usability and productivity. FLUX's application interface is automatically optimized for the intended use depending on its orientation.

Summarizing, FLUX has the following novel features:

- Immediate transition between multiple hardware/user configurations,
- Optimized user interface based on the configuration and hence intended use,
- Breakthrough multi modal input possibilities with independent, simultaneous hand and pen tracking based on Frustrated Total Internal Reflection [5], and Anoto tracking [2], and
- Separate, individual and simultaneous interaction of multiple users facilitated with pen (user) recognition.

In this paper, we describe our experiences with FLUX and discuss the underlying tracking hardware.

Related Work

Matsushita and Rekimoto built the HoloWall, a vertical surface allowing tactile interaction [8]. Wilson's TouchLight [9] 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. Wilson's research results also strongly influenced the development of Microsoft's Surface. In 2005, Han demonstrated in [5] an impressive scalable multi-touch interaction surface that takes advantage of Frustrated Total Internal Reflection (FTIR), a technique used in biometric applications such as fingerprint scanning. The DiamondTouch table developed at the Mitsubishi Electric Research Lab [3] is able to identify which user is touching the surface but it does not support rear-

1. http://www.apple.com/iphone/technology/
2. http://www.surface.com
3. http://www.smarttech.com/smarttable

figure 1: Different setups of FLUX, as a drafting table *(left),* as a discussion table (*middle*) and as whiteboard *(right)*. Context-aware applications are adapting to the current orientation.

projection. Finally, ThinSight [7] is an optical sensing system, which can be embedded behind a regular LCD panel. The retro-reflective sensor board (infrared (IR) emitters and detectors) enables to capture multi-touches as well as physical objects in front of the screen.

An alternative to using direct touch tracking is capturing input through digital pens. The Shared Design Space, a collaborative interactive table, was the first demonstration that featured accurate, fast and highly scalable digital pen tracking for a large tabletop set-up [4]. In this project, Anoto technology was combined with a top projected surface. In a follow-up project to the Shared Design Space, the Anoto tracking technology was used in a rear projection setup for the first time [2]. Both an interactive table and a digital whiteboard were implemented based on rear-projection screens with digital pen input.

FLUX

To better understand the design requirements for interactive displays in a business setting, we carried out an exploratory field study at voestalpine, an Austrian steel company, and Nortel, which wanted to use a large interactive surface for brainstorming sessions.

To summarize, we identified the following key design criteria for the implementation of a large vertical/horizontal interactive display:

- Ability to support multi-point interaction and identification,
- Robust tracking under non-optimal conditions,
- Robust hardware implementation,
- No interference from physical objects,
- Direct user interaction with the system,
- Low input latency, and
- Inexpensive to manufacture.

We also noticed in our study that *direct touch* input on the surface seems to be a very important interaction technique, because it allows a fast manipulation of data. On the other side, in our observations, users immediately tried to touch the interactive surface with bare hands. The pen allows a unique identification of the user and provides high accuracy (660 dpi pattern resolution, 1mm max. tracking error). As discussed in [1], a combination of both hand and pen generally seems to be the ideal interaction technique for large surfaces (cf. **figure 2**). It allows a direct, intuitive and fast interaction with fingers and a highly accurate manipulation of data with the pen interface.

Integrating this combination into a flexible hardware setup was the main motivation for building the FLUX. The final rear-projection setup, featuring both FTIR [5] and Anoto pen tracking [2], allows multi-user, multi-modal interaction in various configurations. An embedded accelerometer allows tracking the actual rotation of our device (cf. [6]). Applications implemented for FLUX are context-aware, i.e. they adapt to the current orientation (table, sketching board or whiteboard).

So, for example, images on the table are rotated according to the orientation of the surface. **figure 1** depicts the different configurations. The left image shows a drafting table-setup for designer, the middle image shows a table-setup for discussions and the right one a whiteboard-setup for presenting the results to the audience.

figure 2: Multiple users can interact with both pens and fingers simultaneously.

The transformation between the different orientations is easily achieved with a single hand.In summary, FLUX provides unmatched flexibility and capabilities in setup, use and user input; it sets the path for a new generation of multifunctional interactive surfaces.

Implementation Details

One of the main requirements was to develop a more flexible surface that could be used as a presentation surface, as a discussion table, as well as a sketching board.

The integrated tracking solutions should be usable and robust in all configurations. Moreover, the switch between the different hardware settings should be performed easily and quickly.

The FLUX hardware setup features a rear-projection screen with a Toshiba EX20 short-throw projector. Due to the projectors high lens offset it is easy to use this projector in combination with only one mirror. The mirror and projector can be simply mounted at a 90° angle. The overall table box has a height (depth) of only 550mm with an operative screen size of 35.4″×26.75″ (900mm × 675mm).

Pen- and hand-tracking principles

The key element of combining the pen-tracking based on Anoto and FTIR based hand-tracking is using a material which fulfills requirements of both tracking techniques. We identified three main requirements: Firstly this material should be printable and should work with the Anoto digital pens. Secondly the material should be suitable for rear-projection, and finally it should trigger the FTIR effect.

In our setup, we use Maxell DP-201 digital pens which are sending stroke data via Bluetooth to a PC. For optimal tracking results, the IR-camera built into the digital pen must capture high contrast images. It uses an embedded image processing chip, to calculate its absolute position on the pattern using the captured frames. Once illuminated by the IR-LED, which is also embedded in the pen, the Anoto dot pattern appears dark (carbon-based ink is absorbing the IR light). The optimal base-material (reflecting the IR light) appears bright resulting in a high contrast image. If the material is too transparent or too glossy, the contrast between background material and dot pattern is not high enough to ensure good pen tracking.

As a consequence, we had to find a combination of materials that ensures translucency for projection while being opaque enough to the Anoto IR-tracking. **figure 3** depicts the final layer composition that provides good results for the pen tracking. The important layer for the Anoto tracking is the top layer material (cf. **figure 3** (c)), which has to fulfill two functions (projection screen and base-material for the Anoto pattern).

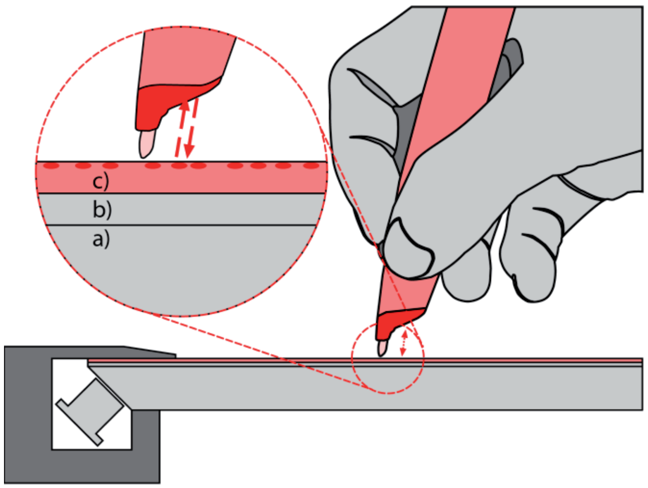

figure 3: In the final layer composition only the top layer (c) is relevant for the Anoto tracking. It acts as a projection screen and as a base material for the Anoto pattern. Layers (a) and (b) are used for the FTIR tracking. An optional scratch resistant film can be applied on top of (c) to increase durability of the surface.

The same combination of materials has to be suitable for the FTIR touch tracking. Initial tests showed that materials which provided good results for the pen tracking are not necessarily suitable for the FTIR tracking.

figure 4 highlights the relevant layers of our final composition. When pressure is applied on the surface, the coupling of the diffuse layer and the polycarbonate surface triggers the FTIR effect; this effect is intensified by the compliant surface layer.

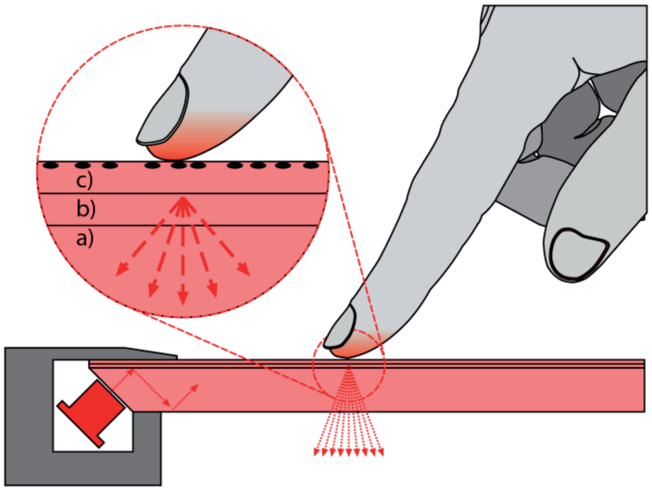

figure 4: The three layers needed to track the finger touches: The polycarbonate plate (a) is covered with a compliant surface layer (b) and a diffuse layer (c) on top.

Finally, we constructed FLUX with a surface containing two materials: a HP Colorlucent Backlit UV foil (**figure 4** (c)) with the Anoto pattern to enable pen tracking and as a projection surface and transparent latex[4] as a compliant layer (**figure 4** (b)) beneath it.

Future Work

So far we made first experiences with custom applications that make use of the context awareness of the system. We are also planning to put a strong emphasis on the multimodal input metaphors which will result in new interaction techniques and optimized user interface design.

4. http://www.fourdrubber.com/

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