Low cost optical Multi-touch Tables: Projected versus LCD Optical

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ABSTRACT

Based on our experience, in this paper we present the main aspects of two different approaches to implement low cost multi-touch tables: projection based and LCD based. The former uses a video projector to build a feedback image on the surface of a multi-touch table and the latter uses an LCD display for the same purpose. We discuss the main advantages and disadvantages we have faced during our design and building experiences.

Keywords: Multi-touch tables, surface, tactile interaction, optical systems, projector, LCD, interface

1. INTRODUCTION

We can use two basic types of touch input devices, touchpad and touch screen. Although sometimes the difference between them is diffuse, we can establish a clear criterion to distinguish between them: touch screens are superimposed on a display device, while touchpads are not.

The touch screen adds to the functionality of the panel the opportunity to interact directly with the display, so that the user has a global view of the effects of his gestures. The first touch screen was developed in the mid-sixties [1], but it was in 1972 when they began to be generally known as the computer PLATO IV appeared and included a touch screen terminal. However, they were all single-touch screens. Then in the early 1980's, the Flexible Machine Interface [2] allowed multi-touch by using a camera. Since then, the technology has undergone significant advances to develop multi-touch surfaces: optical-based, capacitance-based, resistance-based or surface wave touch systems [3][4]. We focus on optical-based systems whose main advantage is its low cost compared to other systems, which require industrial quality fabrication facilities.

The use of multi-touch surfaces has been multiple and varied, especially in information panels (tourism, museums, dissemination...) and they have become part of our everyday life in form of cell phones, tablets, game consoles or digital cameras. The later introduction of the smartphones has given a strong boost to the touch screen as an alternative mechanism of human-computer interaction.

The detection of multiple contacts has greatly expanded the possibilities of touch panels with the use of gestures to interact with the computer.

Touch screens allow simultaneous detection of multiple touch points that enables the development of completely different interaction methodologies. The user has a more natural and intuitive communication with the computer. The common gestures used to select, drag, rotate and scale objects have evolved to visual versions in which the user uses multiple fingers or both hands to perform the same actions, providing mechanisms that have become common standards for digital natives. It has established a new paradigm where the intuition and naturalness in gestures replace the traditional systems of interacting with the computer.

On the one hand, continuous advances in hardware and the unstoppable expansion of these devices have led to a significant reduction in production and marketing costs. However, these costs still remain prohibitive for considerable sized screens. On the other hand, multi-touch large displays have become more and more necessary due to the rising of cooperative work, where two or more people interact in the same environment. These devices are referred to as surfaces, multi-touch tables or tabletops. Multi-touch tables reached their greatest popularity with the commercialization of the Microsoft Surface (Smart table). However, its low portability and modularity and high price led to slow and limited sales.

The thirty inches Microsoft surface is a wireless device with a multi-touch screen as its only interaction device. Its infrared cameras detect a maximum of 52 simultaneous interaction points. A second version of the table (Surface 2) was built using a forty inches Samsung touch screen although its high price still limits its commercialization.

In the last years there has been a major proliferation of low cost systems based on different technologies that have been used in many different fields: education, rehabilitation, leisure or music. These systems have been developed mainly using optical technologies, following the trails of the first table from Microsoft: the user or objects interaction with the table is done via optical sensors and image feedback is achieved using either video projectors or LCD panels.

In this article, and from the experience gained during the construction of various optical tactile surfaces, we compare projectors and LCD screen-based multi-touch tables from a functional point of view in an educational environment. In [5], the author discusses the characteristics of LCD based systems. His main contribution is the demonstration of the feasibility of incorporating HD displays into interactive systems that have either finger or tangible input building a prototype. In this paper we compare these systems with projection based.

2. BUILDING TECHNOLOGIES

A multi-touch table is a surface, usually of a large size, which allows tactile interaction. One or more users can interact in a cooperative manner using one or more fingers and even manipulating objects on its surface (fiducials).

When designing and building a multi-touch table we must consider two important factors: technology for the detection of the interaction and technology for displaying images. To detect the interaction we may either use the well known resistive and capacitive technologies or the most specific scattering, infrared, optical and acoustic waves technologies. Except when using optical sensors, the most commonly used displays are LCD. This is due to the intrinsic nature of the sensors, which usually are physically manufactured on top of display devices.

Resistive panels consist on a glass covered by two conductive layers slightly separated. When the panel is activated, an electric current flows through the layers. If a user touches the screen then a contact occurs at this point. Specific circuitry detects the change in the electric field and calculates the coordinates to be sent to the device's operating system to be converted into a specific action.

The easiness of construction makes these panels the most affordable. The have been for a long time the most used. Their main advantage is that they can detect any kind of contact (they are based on pressure) so they allow the use stylus for high accuracy interaction.

The major drawback is the loss of brightness that can be transferred to the display device due to the multiple layers required by the panel. Brightness can be reduced up to a quarter. Such displays are commonly seen in the almost extinct PDA, in many tablet-PCs and some mobile phones. Moreover, the detection of multiple contact points is expensive.

Capacitive panels are, without any doubt, the most commonly used touch screens currently. They are built from an insulating material; usually glass, covered by a conductor. Its transparency is higher than resistive panels (approximately 90%). When a finger touches the surface, there is an alteration of the electrostatic field due to our conductivity. This alteration can be measured as a change in capacitance and thus resulting in a contact position. The main problem of such panels is that only conductive objects can be detected. They work with neither a stylus nor a gloved hand.

Surface acoustic waves (SAW) use ultrasonic waves. When touching the screen, the changes in amplitude and speed are measured.
Infrared technology uses pairs of senders and receivers of infrared light mounted around a screen. Any disruption in the normal flow of light is considered a contact point. The main advantage of this technology is that we can use any device for interaction (finger, stylus or glove).
Although all these technologies can be used to design and built multi-touch tables, the growing need of considerable sized tables makes desirable the use of optical sensors because of cost and functionality.

3. OPTICAL MULTI-TOUCHES TABLES

Optical multi-touch tables use video cameras to detect interaction, this means that apart from being able to detect a contact on its surface, they can also distinguish and identify objects. The images obtained by the cameras are later processed using computer vision techniques. We also need proper lighting and feedback-display of images.
The use of cameras in multi-touch interaction started in the early 80's and has continuously evolved since then. As already stated before, the main advantage of optical technology is its low cost and high scalability compared to other systems that require industrial-quality facilities for their construction.
The screen of the multi-touch optical tables is usually built with a layer of transparent acrylic. Transparency is required for the camera to capture the user interaction,
As the multi-touch interaction is independent of display devices, feedback images can be displayed using projection or LCD panels. In neither case the images should interfere with the objects, hands or pointers devoted to user interaction. To avoid interferences these systems use infrared cameras. Infrared cameras capture only the infrared light, which lies outside the visual spectrum. They are not sensitive to the visible light. We only have to bear in mind that we must use infrared light to correctly illuminate the surface of the table to be able to detect the interacting objects.
The surface of the table can be illuminated in different ways:

- Evenly from behind or from the front. This technique is called front o back diffuse illumination (DI) respectively.
- Using meshes of LEDs on top of the surface (light plane).
- Using meshes of LEDs inside the plastic screen surface (FTIR).

4. PROJECTED OPTICAL MULTI-TOUCH TABLES

In this case, the display of images on the surface is achieved from a conventional digital video projector (Figure 1).
The transparent acrylic layer used as screen is a drawback for image projection, as the projected image passes through the screen. So, to solve this problem we have to add some kind of translucent projection screen. We can use a sheet of vellum, which is a kind of translucent tracing paper. An additional effect of this sheet, apart from serving as a projection screen, is the attenuation of the image seen by the cameras, the farthest objects are faded and only the nearest are seen. This makes the screen touching-objects much clearer than the background, so it makes easier the discrimination of what is a touch interaction and what belongs to background and decreases the importance of illumination variations.

Figure 1. Projector based table

When using projectors, we have to take into account the distance. The size of the projected image depends on the distance. So to get the desired size we will probably have to use mirrors to reflect the image and to get longer distance without increasing considerably the height of the table. To avoid double-reflected images, front surface mirror are required.

Projectors are also known for the heat they dissipate. We will have to correctly refrigerate the table using fans or locate a piece of heat absorbing glass in front of the projector.
Projected multi-touch optical technology has been by far the most used technology to build optical tabletops. However, there are situations like mobile or adjustable tabletops, where projectors are not indicated [6]. Projectors should not be used in multi-touch tables where the proximity of the user can be incompatible with the heat dissipation of projectors, like for example users in wheelchairs or users that need to work comfortably in a sitting position. Although in these situations non-optical tabletops can also be used, optical systems based on LCD screens are a cheap alternative.

5. LCD OPTICAL MULTI-TOUCH TABLES

In this technology, to display the images we do not use a projector anymore but a conventional LCD panel. In our research we have built a LCD multi-touch optical system from a commercial LCD screen. To use the LCD we have to disassemble the screen and remove some of the filters it includes to avoid any trouble with the visual path of the infrared camera. The white back diffuser has also to be removed because of its opacity, this somehow will reduce the panel contrast to a certain extend.
Figure 2 shows a disassembled LCD panel and its circuitry, and it is possible to see the back opaque diffuser. The wires on the side are for backlight lamps (CCFL). They can still be used in the tabletop although it may introduce some disturbing infrared light. Figure 3 shows the LCD panel mounted in the tabletop.

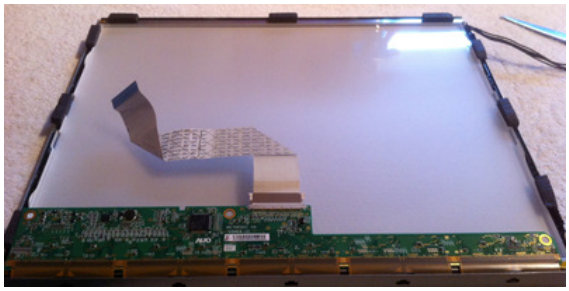

Figure 2. Disassembled LCD panel

Figure 3. LCD panel mounted in a tabletop

The user interaction is captured by an infrared camera in the same way projected systems do. FTIR and DI can also be used but there are some considerations to take into account. Projected systems use a projection screen that has the beneficial collateral effect of diffusing the background images and thus making the detection of interaction easier as there are much less visible objects to segment.
When using LCD, we cannot rely in this convenient advantage because using a projection sheet would greatly affect image brightness from the LCD. So, LCD systems are more sensitive to ambient illumination. In the projection systems we even worked without any additional illumination, ambient light provided most of the time enough infrared component to work in the system with little or no variation at all in the configuration parameters. The LCD system is much more sensible. First, because of the backlight infrared component and second, because of the much complex background image which can lead to false blob detection.
The first problem is faced using IR blocking film to considerable diminish unwanted IR light. In the second case we have to use additional illumination to ensure time-constant working conditions. We use IR-LED illumination on the top of the surface. The LEDs produce a constant illumination that only affects the nearest objects or fingers (LED lights are directional, so far objects have a fainter illumination). This makes interaction detection more stable.
During our research we have noticed that the projection-based system was more reliable although in fixed illumination conditions LCD-based was also usable.
Possibly, the most important advantage of LCD systems is the resolution of the display. High-

resolution projectors are still too expensive. Their cost increases significantly the total cost of the multi-touch table.
Another important difference is the available space for construction. If we need to project a wide image, the projector has to be located to a certain distance (proportional to cost). LCD requires less space as we only have to take into account the position of the camera to be able to completely capture the field of view.

6. CONCLUSIONS

In this paper we analyze the use of both projected and LCD based multi-touch optical tables. We have designed and built tabletops to help therapists and caregivers in their work providing systems that allow controlled autonomous stimulation [6].
Although projected systems are more widely used, there are situations in which they are not recommended. These situations include mobile or adjustable tabletops, which could require continuous time consuming calibrations. Heat dissipation can also be an issue when user's proximity is a requirement, like when they have to use wheelchairs and have to work close to the system.
LCD-based multi-touch systems have proved to be a convenient solution when projection is not an option. Resolution and image quality is better, they need less space and image visualization and frame fitting are easier to setup. However, we have also faced some problems related to lighting when using LCD:

- LCD backlit introduces an unwanted disturbing infrared component that we have to deal with
- The impossibility to use a diffuser in the surface of the tabletop -as it would importantly decrease the contrast and brightness of the image- makes background discrimination a more difficult task.
- Filtering parameters are more difficult to calibrate, more time consuming and more prone to detect false blobs.

If we want to ensure proper working of the table, we have to carefully set the illumination mechanism. Unfortunately, the choice for the best optical system is not yet an easy task from a global point of view. The environmental conditions, the final goal of the system and the needs of the user are the main factors to be considered.

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8. REFERENCES

[1] E.A. Johnson. “Touch Display - A novel input/output device for computers". Electronics Letters 1 (8): 219–220, (1965)

[2] Mehta N. A Flexible Machine Interface. In M.A.Sc. Thesis, Department of Electrical Engineering, University of Toronto supervised by Professor K.C. Smith (1982)

[3] Schöning J, Brandl P, Daiber F, Echtler F, Hilliges O, Hook J, Löchtefeld M, Motamedi N, Muller L, Olivier P, Roth T, von Zadow U. Multi-Touch Surfaces: A Technical Guide. In Technical Report TUM-I0833 (2008)

[4] Schöning J, Hook J, Bartindale T, Schmidt D, Olivier P, Echtler F, Motamedi N, Brandl P. Building interactive multi-touch surfaces. In Tabletops-Horizontal Interactive Displays , C. Müller-Tomfelde (eds.), Springer (2010)

[5] Motamendi N.. HD Touch: Multi-touch and Object Sensing on a High Definition LCD T. In CHI 2008 Proceedings, 3069-3074 (2008)

[6] R. Mas, C. Manresa-Yee, G. Moyà Entornos Interactivos de Estimulación Sensorial para Parálisis Cerebral. Actas Congreso Iberdiscap 2011, Eds. M. Mazo, F.J. Perales, vol.1, 85-9 (2011)
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