Multi-touch display using the combination of FTIR and HD LCD display

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Abstract

We present a multi touch display based on optical tracking on a LCD display. We describe motivations for building multi touch display from the perspective of Human Computer Interaction. We start by describing the hardware configuration used to build such a system, then showing an image preprocessing part. Next we propose various usages of multi touch systems coupled with HD display. Finally we conclude our work by comparing the image preprocessing quality using various setups.

Keywords: Multi-touch, Tangible interface, Surface computing, Tabletop interaction

1. Introduction

Natural interaction has been always the goal of Human computer interaction researchers to enable simplicity and intuitiveness of interaction with interactive systems. Touch displays, touch sensing input devices with display capabilities of output device, made promises to enable this type of interaction by incorporating the direct manipulation paradigm, which is essentially very natural. On the other hand, several difficulties of direct manipulation paradigm have been reported [CRC07], especially: too small click targets, difficulties with soft-keyboards and drag-and-drop intricacy. There are various approaches to create multi-touch sensing surface: resistance, capacitance, optical - infrared based, and optical - camera based. Lately infrared based solutions have been vastly explored. After Jeff Hans publication [Han05], there have been several different adaptation using infrared illumination in order to track users hands, finger tips and finally touch points. The best known infrared solutions are frustrated total internal reflection and diffuse illumination, which allow easy segmentation of touch points in the near infrared light spectrum. There are two known diffuse illumination methods, rear and front. The former is when illuminator is on the same side of the touch surface as an infrared sensitive camera, the later is when the illuminator is on the other side than the camera.

2. Related work

People use hands as a primary means of interaction in everyday life. Weve been using them as our tools for interacting with computer since the invention of the computer itself. Multi-touching as an interaction technique has been known since the first keyboards have spread out. Sequences, such as SHIFT in combination with other keys, are probably the first known multi-touch interaction technique. Bill Buxtons report [Bux09] on multi-touch systems is an exceptional document showing the history of multi-touch systems and presenting several important axioms and various differences of multi-touch systems. Finally, we present the timeline of an evolution of multi-touch systems. Since the 80's pretty much exploring have been done in the field of multi touch input devices, which ended up in the reinvention of principles allowing constructing low cost multi-touch systems. In 2005 [Han05] Jeff Han used Frustrated total internal reflection of infrared light in plexiglass surface to build a multi-touch system. In current years the research is leading into inventing various different, more ambitious interaction styles. Usage of two multi touch sensitive surfaces with one displaying surface have been described in [WLF$^+$06], similar concept but in smaller scale, i.e. mobile device, has been presented in [WFB$^+$07]. Enhancing the input precision of hand based multi-touch systems with the stylus based interaction has been shown in [LPB$^+$09]. [LPB$^+$09] also came up with an idea of orientation aware multi-touch system, allowing their context-aware application to adapt according to the current orientation . Using a pressure as a third dimension of touch based input has been shown in [RGH$^+$09]. Jorda et al. has shown the capability of infrared based multi-touch display for tracking objects placed on the touch table using special markers known as fiducials to enable music composition using physical artefacts in [JGAK]. In [HIB$^+$07] by Microsoft Research, Hodges et al. has shown the multi-touch surface based on infrared transcievers inbuilt into an ordinary LCD display known for example from notebooks. Infrared transceiver is a electronic component combining the functions of both infrared transmitter and infrared receiver. The biggest benefit of such approach is its small form factor while preserving the ability to track fingers as well as objects using fiducial markers. In [BWB08], a multi-touch system which use a spherical input and output surface. Detecting the shape of touch in [WBHH08], instead of just the position where the hand or finger has touched the surface showed some promises for controlling the gesture based interaction. Tangible user interfaces as presented in [UI00] describe the interaction with physical objects which is mapped to the virtual objects manipulation. This interaction style can be easily extended for using in combination with touch surfaces as presented in [WWJ+09]. Very common disadvantage of low cost multi touch surfaces like in [Han05] is in their limited display resolution as well as its display quality. This is due to the usage of projectors as a display devices. Nima Motamedis showed the potential of ordinary LCD panels to be used as a display devices for low cost multi touch surfaces in [Mot08], with combination of Jeff Hans method [Han05]. Drawbacks of this system are in its increased demands on hardware implementation, as the LCD panel has to be disassambled and modified in order to let pass through the infrared lighting used for touch detection.

3. Motivation

There are various use case scenarios as a motivation behind building multi touch systems, especially those coupled with high quality display capabilities as an HD LCD display provides.

First off all, touch based interaction is one of the primary means of interaction for visually impaired individuals. Particularly if coupled with haptic and sound feedback, multi touch displays can provide adequate alternative for common interaction with computer systems.

Secondly, multi touch system are capable of providing more natural interaction, mainly by using a direct manipulation paradigm, which can lead into creating more useful, usable and finally more used interfaces, which eventually can lead into increase in users performance and effectiveness. Such interfaces can possitively affect our everyday lifes, making our works joyful.

Finally, incorporating large scale multi touch systems into workplaces can establish proper fundamentals for better collaboration of team members, resulting in better interaction between colleagues, encouraging their creativeness.

4. Hardware configuration

We use infrared based optical solution as an implementation of our multi touch system. Main part of our system, shown in Figure 1 is a plexiglass which is illuminated by infrared LEDs generating light of 850nm. Specifically

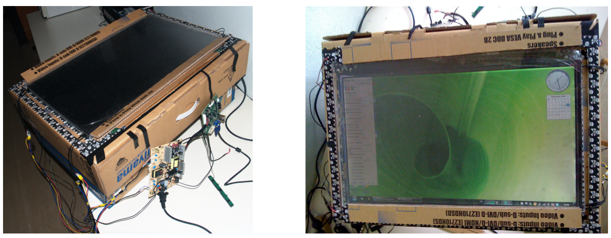

Figure 1: Current version of our prototype which consist of a LCD screen below a plexiglass which is edge illuminated with 80nm infrared LEDs

we use total internal reflection property of plexiglass and its frustration by finger touches as described in [Han05]. This allows us to easily proccess the input stream from camera to obtain a touch points and detect human gestures. Furthermore the plexiglass is coupled with a LCD panel from a ordinary 27 inch TN LCD display: iiyama ProLite E2710HDS, as described in [Mot08]. Since the LCD panel consist of several layers, usually a white reflective layer to direct background lighting towards user, plexiglass layer with white reflective dots, diffuse layer, fresnel lens, another diffuse layer and the main LCD panel, there is a need to modify this layers by removing a white reflective layer, in order to let an infrared light pass through the LCD display. What's more, since there is a possibility of mixing a visible light comming from a LCD screen, with an infrared light, comming from frustration of total internal reflection in plexiglass, usage of an infrared bandpass filter is useful, to let through just the infrared light with specific wavelength. We use a firewire camera from Pixelink for capturing images in infrared spectrum, with a wide angle lens mounted in to minimize the distance between camera and plexiglass, Figure 2.

Figure 2: Firewire camera from Pixelling with wide angle lens mounted

5. Image preprocessing

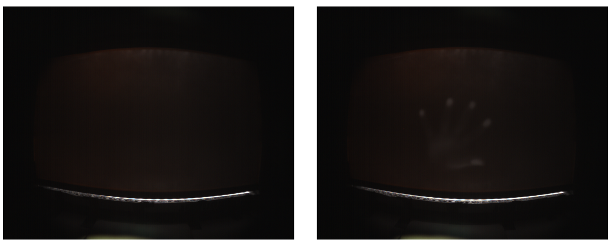

Figure 3: Two source images, on the left side image precaptured as a background for bakcground differencing, on the right image with hand touching the display's surface

In order to track the touch points or any other features, like fiducial or 3D gestures above the touch table we need to increase the quality of input images captured from camera. The main reason for image processing is to provide better input data for further processing, fingertips, fiducials and gesture recognition. The basic image preprocesing pipeline for multitouch systems consist of 4 simple operations.

Firstly, we do an image differencing, where we make a difference of precaptured background frame, shown on the left side of Figure 3, and a current frame captured from camera, shown on the right side of Figure 3. The result, as shown on top left image of Figure 4, is a grayscale image showing mainly the difference of mentioned frames, specifically a touch points.

Secondly, the usage of camera with wide angle lens, create a distorted image, basically with radial distortion but in general a tangential distortion is possible too. Radial distortion is due to the shape of the lens, as described in [BK08], it arises because the light rays which are farther from the center of the lens are bent more than those closer in. Fortunatelly, we can described this distorion by Taylor series, thus the corrected pixel position can be characterized by Equation 1.

$$
\begin{aligned}
x_{corrected} &= x(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) \\
y_{corrected} &= y(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)
\end{aligned}
\tag{1}
$$

As described in [BK08], tangential distortion is due to manufacturing defects resulting from the lens not being exactly parallel to the imaging plane. This defect is characterized by Equation 2.

$$
\begin{aligned}
x_{corrected} &= x + [2p_1 y + p_2(r^2 + 2x^2)] \\
y_{corrected} &= y + [p_1(r^2 + 2y^2) + 2p_2 x]
\end{aligned}
\tag{2}
$$

The resulting corrected image is shown on the top right image of Figure 4.

Thirdly, we use threshold operation on a distortion corrected image. The result is a binary image shown on botom left of Figure 4.

Finally, we crop the image, so it has the same aspect ratio as a output display, thus allowing an easy correspondence between the input and output surfaces.

6. Usage of multi touch display

We propose two possible scenarios for the usage of our multi touch system. Firstly, we propose the usage of finger touch as a main input, coupled with a handrefferenced haptic device for generating a tactile feedback when touch input is registered, and sound feedback. Then, we propose an extention of the multi touch screen with an output device known as Arm mounted display, as described in [BCF$^+$08], which will allow touch as well as gesture based interaction in three dimensions.

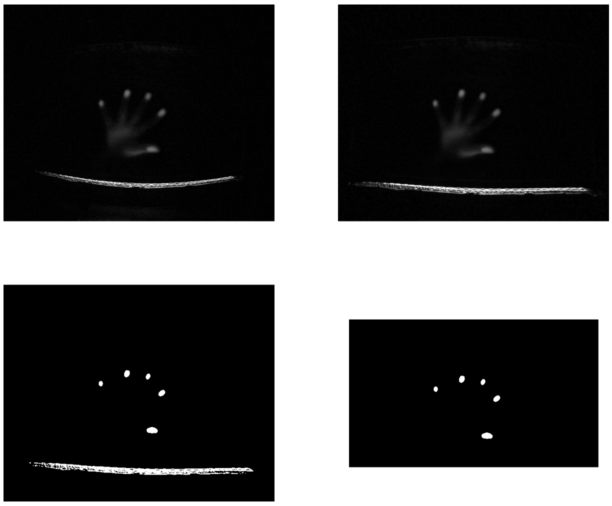

Figure 4: Image processing: Top left - image differencing, top right - image warping (we have adjusted images in order to increase the visibility of touch points), bottom left - thresholding, bottom right - cropping

6.1. Sound generating application with haptic feedback

Sound generating applications are well known from several demonstration of multi-touch systems. Virtual piano or even guitars are now available for small mobile devices like iPhone and others. The basic disadvantage of such applications is their small interaction space, limited by the size of touch display) and usually only a sound feedback. Sound feedback should be probably enough for piano application, but on the other hand playing on guitar is better with haptic feedback. Thus, coupling the touch display with some sort of touch display referenced haptic feedback device allowing tactile feedback to actually feel the guitars virtual springs, would be exceptional. Another usage would be for example for training surgeons, or even visually impaired people could use it for feeling the display. Of course some sort of special haptic device similar to tactile devices as described in [BCF$^+$08] would be needed.

6.2. Arm mounted touch table

Coupling the touch table with 3D orientation sensors known from arm-mounted displays as described in [BCF$^+$08], a system for modelling or animation purposes can be created. Display would be like a window to the 3D scene, which is a definition of arm mounted displays. This could be enhanced with touch based interaction as well as 3D gestures, thus allowing user to see and manipulate the scene from different angles with different interaction techniques. Enhancing the display with remote controlling using an infrared pointers would even enable more distant interaction with such device. Another improvement would be in including a Chung Lees head tracking for changing the scenes view transformation according to the position of users head as in [Lee08]. Even more precise system could be created by using eye tracking instead of head tracking to change the view transformation.

7. Validation

The image preprocessing phase, could be very difficult if the input image contains the whole light spectrum that can be captured by camera. In such a case the result of the image preprocessing could be very noisy. Thus we use infrared bandpass filter, which let through only some portion of light spectrum, in our case spectrum near the 850nm wavelength, which is the light generated by infrared LEDs illuminators. In Figure 5, the difference in the image captured without infrared bandpass filter on the left and the image captured with filter mounted on the table is quite noticeable.

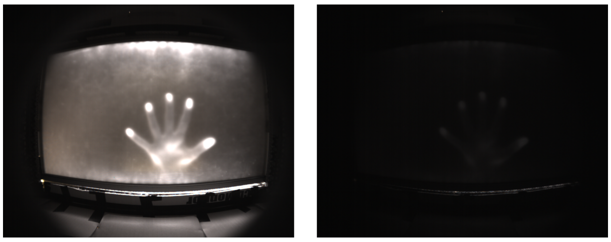

Figure 5: Captured image without infrared bandpass filter on the left, and with infrared bandpass filter on the right

8. Acknowledgment

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