Touch Sensing based on FTIR in the Presence of Ambient Light

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1 Introduction

Touch sensing based on the effect of frustrated total internal reflection (FTIR) can be used to build low-cost, multi-touch capable projection surfaces [Han 2005]. An acrylic panel is illuminated from the shorter sides. The refractive index of acrylic relative to air leads to total internal reflection within the panel, similar to optical fibers. If an object come close enough to the surface the total reflection is frustrated, light dissipates, and the object is illuminated. Thus, a finger touching the panel will be illuminated. The resulting illuminated blob can be captured and tracked with a camera.

Touch panels based on this principle have several advantages: they are cheap, the panel can be used as a screen in a rear projection, and multiple touches can be captured and tracked simultaneously. Apart form the space required for camera and rear projection, the main problem is that light from within the panel, which is not totally reflected, as well as ambient light can make make the detection of the FTIR effect difficult. To our knowledge, ambient light is usually accounted for by taking a reference image before interaction starts. This, however, can only compensate for light that directly reaches the camera and as a result, multi-touch displays based on FTIR are usually used in rather dark environments.

Figure 1 shows a camera image of a hand touching the panel, with and without the FTIR effect. Note that the hand is clearly visible, because it reflects ambient light towards the camera. This spurious illumination cannot be compensated with a reference image taken when the hand was not present (see the threshold image in Figure 1). The main idea of this work is to generate the two images shown in Figure 1 in short succession, i.e. generate a reference image for every image captured image. Then, comparing (e.g. subtracting) the two images allows detecting the FTIR points easily.

2 Setup

A reference image is generate by switching off the internal illumination of the panel. Consequently, the main point of our setup is switching the LEDs illuminating the inside of the panel on and off, in sync with the camera.

We have found that the best way is to use a per frame signal from the camera. We connect this trigger a flip flop, which connects to a driver for the LEDs. Not only can such a signal be tapped from almost every camera, while cameras with trigger input are more expensive, also triggering the camera usually comes at the expense of frame rate. In our setup, the camera runs at its maximum frame rate – the flip flop and LEDs are much faster and easily switch at the necessary frame rates. The additional circuit (see Figure 2) consists only of few elements and costs a few dollars.

It turns out that most camera APIs work asynchronously, i.e. not every frame captured by the camera is necessarily available for processing. Thus, reference images have to be identified reliably and easily. We install four LEDs in the corners of the panel, outside the area used for projection (the setup of LEDs is shown in Figure 2). These LEDs are illuminated when the panel illumination is switched off, i.e. they signal a reference frame. As these LED directly face the camera they result in bright spots, in a defined position on the camera image. Apart from being useful for detecting reference frames they can be used to compute the projective transforms between camera, projected image, and panel.

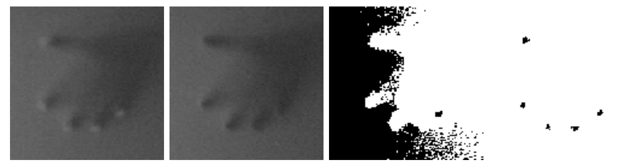

Figure 1: *Two images captured with the illumination inside the panel switched off and on, with ambient light illuminating the hand touching the surface. Simply thresholding fails to capture the touch points (middle right), while subtracting the images and thresholding removes the unwanted parts (right).*

3 Processing

Each frame is classified as either reference frame (LEDs in the corners are switched on) or touch sensing frame (LEDs illuminating the inside of the panel and leading to FTIR at objects touching the panel). The last reference frame is stored. For every touch sensing frame, this reference image is subtracted. Then, a simple threshold extracts the touch points, and counting the number of active pixels per touch point allows discarding noise.

4 Results & conclusions

As we show in the accompanying video, touch sensing works under daylight conditions. We are not aware of other multi-touch displays based on FTIR that work reliably under these conditions.

The additional cost for our setup is negligible; the main loss is frame rate, as touch points are captured only every other frame. We use a camera with 60Hz, leading to interaction at 30Hz, which works fine for many tasks except controlling time critical applications such as games. Also, if the touch points move at high speeds, the reference frame is inaccurate. Apart from losing touch points this can also lead to spurious ones.

References

HAN, J. Y. 2005. Low-cost multi-touch sensing through frustrated total internal reflection. In *Proceedings of the 18th annual ACM symposium on User interface software and technology*, ACM Press, 115 – 118.

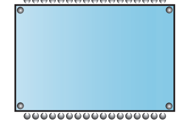

Figure 2: *Additional circuit for switching the LEDs and setup of the LEDs*