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A MULTI-TOUCH COLLABORATIVE SOLUTION FOR MEASUREMENT DATA VISUALISATION

Septimiu Crisan, Valentin Dan Zaharia, Leonard Voicu Brender, Titus Eduard Crisan.

Department of Electrical Measurement, Faculty of Electrical Engineering, Technical University of Cluj-Napoca, Str.C.Daicoviciu nr.15, 400020 Cluj-Napoca, Romania,
E-mail:crisans@mas.utcluj.ro

Abstract − Multi-touch devices and their applications are one of the newest trends in human interaction research. While this approach has been envisioned more than 20 years ago, advances in computational power and display resolution have allowed the implementation of impressive hardware devices with virtually unlimited tracking capabilities. A large number of eye-catching applications have been implemented around the world but there is a clear need for practical engineering applications in order to allow this technology to become appealing even for industrial and academic purposes. This paper tries to address this issue by proposing a complete hardware and software solution for multi-touch multi-user data visualisation. A new interface for analysing measurement data as well as manipulating virtual instruments has been created in the belief that it will help students and researchers alike.

Keywords Multi-touch, data visualisation, infrared measurements

1. INTRODUCTION

In 2005 Jeff Han [1] has presented a low cost multi-touch device based on FTIR (frustrated total internal reflection). Since then, many researchers and companies have created optical multi-touch devices, the most notable being Microsoft (Surface, ThinSight)[2,3] and the work performed by the NUI Group [4].

Optical multi-touch systems are not the only ones being built, a lot of capacitive devices have also been developed (Apple Iphone [5]). The major drawback of such systems is the difficulty to sense many points since capacitive systems are usually duo-touch. Also such devices are difficult to scale.

The most common approach is to use a near infrared sensitive camera to track the fingers of the users and in some cases even objects placed on the screen (fiducials). This technique can be easily scaled and, with the help of modern computational systems, many fingers can be tracked and processed in the same time.

This paper aims to provide a complete optical solution including both hardware and software aspects in order to act as a platform for user interaction, data collection and visualisation.

2. HARDWARE TECHNIQUES AND IMPLEMENTATIONS

The goal of infrared multi-touch devices is to offer a fast scanning solution, allowing multiple users to interact with a display. Many techniques have been used recently:

- FTIR (Frustrated Total Internal Reflection) [1]
- DI (Diffused Illumination) [2]
- LLP (Laser Light Plane) [4]
- LED-LP (LED Light Plane) [4]
- DSI (Diffused Surface Illumination) [4]

2.1. Hardware setup

The research conducted by the authors has focused on refining the FTIR technique and use it in conjunction with the DI method.

Fig. 1 shows the optical technique used to achieve a FTIR setup.

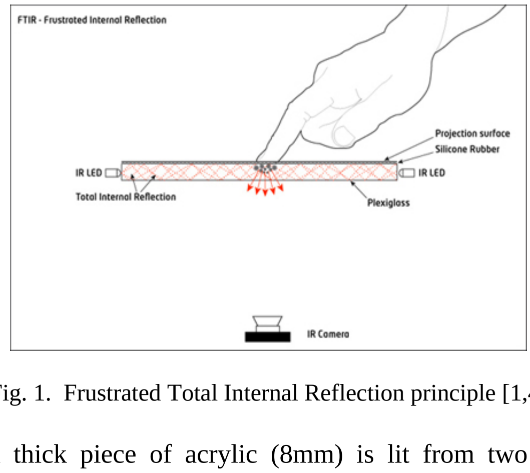

Fig. 1. Frustrated Total Internal Reflection principle [1,4]

A thick piece of acrylic (8mm) is lit from two sides using infrared radiation produced by LEDs. The hardware setup created for this research uses 130 SMD 850nm IR LEDs linked in a flexible ribbon that shines infrared radiation into the acrylic from the longer sides. The result is a 4:3 format display screen 80cm by 60 cm. Light is trapped into the acrylic by means of total internal reflection if the angle of incidence is lower than 42 degrees.

All 4 sides are encased into a U-shaped aluminium profile that prevents radiation from leaking outside. If an object with a different refractive index is placed on the surface, some of the radiation will scatter towards the bottom of the display. An infrared sensitive camera reads the location of the points where the scattering phenomenon occurs and translates them into x,y coordinates calibrated with the projector image space.

In the DI technique, light is emitted from below the touch surface. When an object touches the surface it reflects light and the result is a bright spot, sensed by a camera. Depending on the setup, this method can also detect objects placed on or just above the surface.

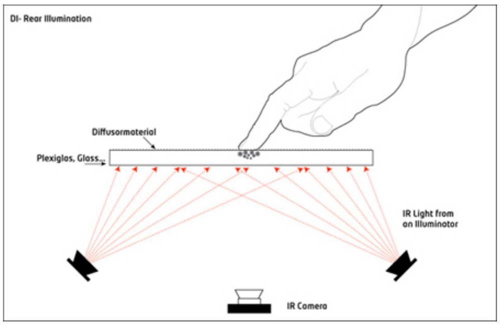

Fig. 2. Diffused Illumination principle [4]

A dual system (FTIR and DI) was chosen to prevent some of the errors that could arise from using only one technique. The FTIR method performs very well even in lit rooms but it is impossible to detect objects placed on the surface. The DI system is harder to tweak and to function properly in daytime but it allows objects to be placed and also a smoother interaction with the display.

The image source is a Benq MP622c DLP projector placed under the screen. In order to achieve a long enough optical path, capable of projecting a 100cm diagonal, 2 mirrors are used to bounce the image back to the screen as shown in Fig. 3.

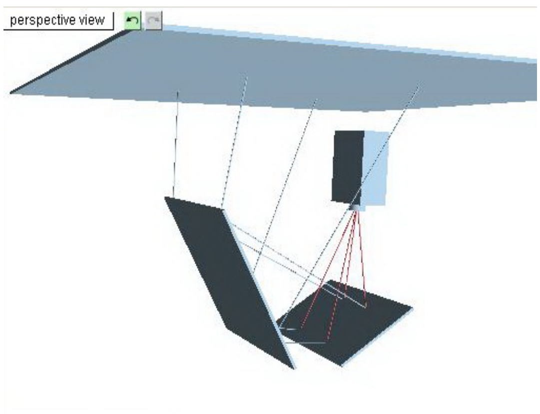

Fig. 3. Projector and mirror placement inside the table.

Infrared radiation is used for the light source instead of visible light in order not to interfere with the projection of the display. However, this particular type of projector, while having a good contrast and luminosity, emits 5…10% in the near infrared spectrum. To prevent false points to be triggered by the camera, a hot mirror has been placed over the projection lenses.

The camera used for detection is a PS3 Eye webcam, capable of recording live video with a resolution of 320x240 pixels at 125 frames per second. The IR-cut filter has been removed from the camera and replaced with a narrow band pass filter from Omega Optical 850DF10 with a central wavelength of 850nm.

When using the FTIR technique, a good optical coupling between the fingers and the acrylic is required. Drag operations on the screen will lose tracking sensitivity because of the air gaps formed between the fingertips and the touch surface. A layer of silicone was created using an improved version of the technique used in [8]. Transparent RTV silicone is thinned using toluene and rolled on a projection surface. A carbon fibre grid is applied on the cured silicone and is heat-pressed to create a tight mesh with peaks and valleys. The grid is then removed and the result is a compliant silicone layer able to couple and decouple from the acrylic surface when pressed. On top of the silicone layer, projection and low-friction materials are added to increase the usability of the system. The final order of the materials is as follows (top-down):

- Low-friction matte film
- Semi-rigid self-adhesive plastic sheet
- Projection material
- Silicone compliant layer
- Acrylic
- Rigid screen base

An environmental light sensor is used to automatically switch between FTIR and DI light sources. The option is also software controlled. In a DI setup a compliant layer is not needed since light is reflected directly from the fingertips but it doesn’t interfere with the point tracking operations. In this situation both systems can be used at once but with minimum benefits.

Figure 4 shows the internal components of the device and their placement.

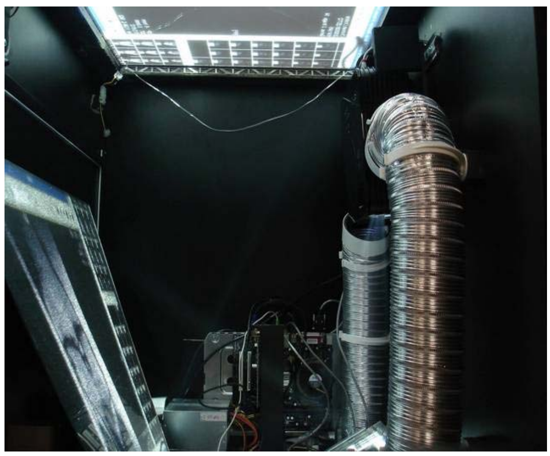

Fig. 4. Internal components of the multi-touch device and the cooling system.

The device is powered by an ATX power supply and the necessary processing is performed by a custom-made personal computer with a dual core processor. Due to the nature of multi-touch applications – computationally intensive – a high end video card was used to insure fluid movement of the graphical interface.

2.2. Observations and challenges

The whole system is enclosed in a black, laminated wood box to diminish the effects of other nearby infrared sources (tungsten lamps or the sun). Being a large setup, vibrations can occur from tapping the touch surface thus slightly modifying the position of the projected image. The mechanical system used to hold the mirrors and the projector in place has been fitted with high density shock absorbent pads to decrease this effect.

Also, the large FOV of the camera creates distortions of the acquired images. Using a software calibration grid with an increased number of control points has reduced this problem.

No infrared touch system is capable of working in direct sunlight, but by positioning the system in a better angle greatly improves the quality of the touch points. The top material used over the acrylic reduces the sun's interference by up to 65%. Transparent IR-blocking materials with more than 80% efficiency are widely available but the Diffuse Illumination part of the multi-touch system is affected if the camera can not sense the touch points. At 65% infrared protection, using advanced software filtering the scattered radiation can still be tracked by the device through the matte film.

The system is modular by design and can be easily disassembled. The mobility is assured by using four break wheels.

The enclosed system contains the projector and the computer used to perform calculations and to display the image. Both devices emit a lot of heat and, in the case of a lamp projector proper cooling is needed. A heat exhaustion system has been implemented using 4 fans and aluminium airflow pipes to direct heat away from the projector lamp and from the computer. Two fans are pulling colder air from the environment while the other two are pushing the hot air out. All fans are on the bottom of the box and the pipes direct the airflow to the problem areas. Since the hot air would accumulate under the table, each exhaust or intake is directed into a different position, thus not allowing for air recycling.

A set of thermal photos have been taken to test the efficiency of the cooling system. With all the fans running at 80% speed (1400…1600 rotations/min) the temperature is kept under 45 °C for the most heat-sensitive components as shown in figure 5. When the cooling system is stopped, temperatures exceed 67 °C in less than 10 minutes. To prevent accidental power failures, the rotation speeds are measured constantly for each fan. The motherboard internal temperature sensors are used to provide active feedback for the fans' voltage regulators and the current multi-touch system temperature can be displayed on the screen at any time.

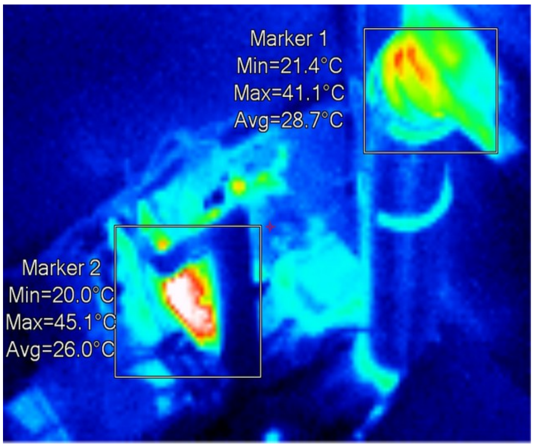

Fig. 5. Thermal photo of the projector and video card inside the device with the cooling system activated

The LED ribbons are also heating up but the aluminium frame acts as a radiator and the heat damage is kept to a minimum.

Various tests have been performed to decide the optimal speed for tracking the fingers and objects placed on the table. While the camera is capable of 125 fps, the higher the frame rate the lower the intensity of the touch points. A smooth interaction with the system is already achieved at 75 fps and it provides a good contrast of the raw video stream acquired by the camera.

3. SOFTWARE PLATFORM FOR DATA VISUALISATION

The points registered by the camera are filtered and calibrated to the projected image using an open source multi-touch framework [7].

The raw video stream is processed, removing the background and amplifying the point locations so that the camera can only register the touch points. The noise is dynamically subtracted.

The filtering process is shown in Fig. 6

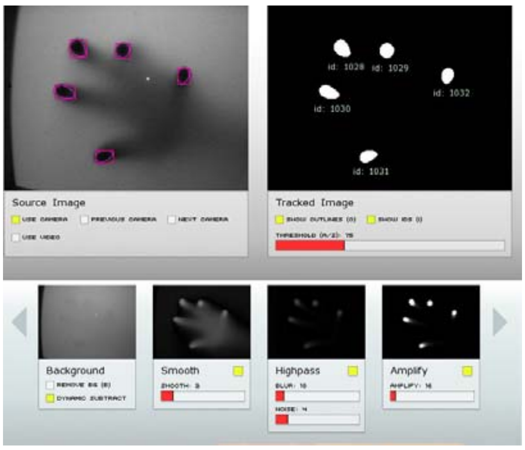

Fig. 6. Filtering the input stream using tBeta. [7]

The touch locations are then sent using the TUIO/OSC protocol. The great advantage of using this mechanism is that most programming languages have a way of interfacing with the incoming data from the TUIO parser.

Adobe Flash 9 has been used to develop a multi-touch software platform. It is a very simple and intuitive design medium capable of rendering spectacular 2D applications. While speed is not the best feature of Adobe Flash, test applications can be created very quickly and the results are visually attractive.

The National Instruments Labview environment has been used as an inspiration for the aspect and feel of the virtual instrumentation applications. Adding multi-touch, multi-user capabilities to process control greatly increases the efficiency of the measurement process. For the current size of the touch table, 4 individuals can work in the same time creating virtual instruments, analysing measurement data and visualising real-time graphs and charts.

Simple gesture recognition for virtual menus has been implemented and the learning curve for such an application is very short because of the more natural way of interacting with the table instead of using a keyboard, mouse or other peripherals.

To demonstrate the potential of a multi-touch table for collaborative use, a virtual circuit design tool has been implemented. Students or electrical engineers can create circuits on the fly, positioning various passive or active elements using their fingers. Fiducial objects can also be placed on the device simulating knobs or switches. The users can alter circuit pathways, dimensions, type of components etc.

Fig. 7 shows part of a demo application used to test the speed and the accuracy of the acquired finger touches.

Fig. 7. A virtual smoke application used to demonstrate the tracking accuracy.

The software part of multi-touch is still at its infancy. The applications developed in this paper are meant to be a start for real-time touch and gesture interaction systems. There are a lot of domains that can benefit from multi-touch environments and a complete hardware and software solution capable of supporting a large number of applications is desired.

4. CONCLUSIONS

The paper has shown a complete implementation of a multi-touch, multi-user system aimed at serving the engineering field. A fast and robust solution was implemented using a combination of two of the most used infrared optical techniques FTIR and DI. It is a low-cost device capable of analysing and processing more than 40 simultaneous points. The response is smooth, the latency being less than 10 ms. Several observations and challenges have been pointed out and solutions have been offered to the potential optical and mechanical problems

A software platform for collaborative use has also been implemented offering applications focused on the electrical engineering domain. The software includes process control and data visualisation instruments.

The hardware design of multi-touch systems is now entering a mature state of development but there is still a lack of mainstream solutions focused on targeting specific industrial or academic uses.

One of the greatest challenges of multi-touch devices is the ability to distinguish between different individuals touching the sensitive surface. Future work will focus on developing a biometric method to identify the users interacting with the device.

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