Affordable Multi-touch Teaching Station for Engineering Classes

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Abstract

This paper presents the development of a cost-effective multi-touch teaching station that supports existing educational applications and a custom-made Multi-touch Teaching Module used by instructors to teach undergraduate engineering laboratory classes at Multimedia University. The technology-enhanced teaching station was developed based on an optical tracking technique known as Frustrated Total Internal Refraction (FTIR), to achieve multi-touch capabilities on the table surface. The Adobe Flash-based Multi-touch Teaching Module supports popular multi-touch gestures including panning, rotating, and zooming in and out, on multimedia educational content such as streaming video lectures, animations and schematic diagrams. The Multi-touch Teaching Module enhances the way lecturers manipulate teaching materials such as enlarging a complex electronic circuitry with just fingers' gestures when operating the teaching station. When operating the multi-touch teaching station with existing educational applications, lecturers are able to use it as a normal touch screen to directly interact with the application instead of using a mouse or keyboard, making the interface more intuitive. Some lecturers have evaluated the teaching station and provided positive feedback over the standard computer, because it is much easier to operate. In short, the paper summarizes the experience in developing a universal multi-touch teaching station and Multi-touch Teaching Module, as well as the system evaluation by instructors in an undergraduate engineering laboratory class, which is valuable for those who intend to enhance teaching platforms with such technology in a university.

Keywords: Multi-touch, Gesture Control, Teaching Station, Natural User Interface, Effective Teaching.

1. INTRODUCTION

New technologies such as interactive whiteboard, digital visualizer, tablet PC and Smart Podium have been adopted by universities in developed countries as a way to support modern educational activities by providing educators with an intuitive user interface to teach more effectively. These equipments allow educators to handwrite impromptu notes easily with a stylus, keeping the metaphor of a paper notebook. Commercial off-the-shelf interactive whiteboards and visualizers allow instructors to add digital notes on the fly. The tablet PC and Smart Podium provide similar functionality with the additional feature that when operated with collaborative learning software such as Classroom Presenter [1, 2, 3], provides an innovative learning environment that supports lecturer-students interaction and promotes effective teaching that gives students a more valuable experience. Despite the positive results in students' learning experience found in the studies of the integrations of educational collaborative software with recent electronic educational equipments, acquiring such technologies in developing countries is limited due to the huge amount of up-front investment required. Furthermore, existing affordable solutions such as the tablet PC or Smart Podium pose a challenge for educators to manipulate teaching materials intelligently with fingers' gesture on a large interface (22 to 32 inches). The design and implementation of an affordable multi-touch teaching station that offers a large (32 inches) intuitive user interface and Multi-touch Teaching Module that allow instructor to interact with teaching materials conveniently using fingers' gesture in a budget-constrained environment will be discussed.

2. REVIEW OF EXISTING TECHNOLOGIES

A multi-touch tablet PC is a mobile computer that consists of a digitizer screen that allows stylus or finger input, enabling a very natural way of writing and drawing. A number of universities adopted the tablet PC as part of their teaching tool for instructors to easily write notes or sketch schematic diagrams during lecture session to improve teaching or learning process [4, 5]. Examples of two-touch-point tablet PCs with a 12-inch screen include the Fujitsu LifeBook T4410, Lenovo ThinkPad x201 and Dell Latitude XT2, with a selling price in the range from USD 1,500 to USD 2,500, depends on the customizations (prices from Google product search as of 1 March 2011).

Smart Podium from Smart Technologies is a mobile display that allows the instructor to control computer applications or to add digital ink over applications such as Microsoft PowerPoint using a stylus or finger [6]. Once the Smart Podium is connected to a computer and projector, the instructor can comfortably interact with teaching materials at the front of the classroom while students can simultaneously view the same content on the large projected screen. The Texas A&M University adopted Smart Podium as a tool to ease instruction in engineering courses that required frequent impromptu additions of annotations or diagrams, calculations and writing of equations during lectures, as reported by Smart Technologies in 2006. The Smart Podium has a screen size ranging from 15 to 22 inches with a selling price from USD 1,500 to 3,000 (details at http://www.wedgwood-group.com/interactive_panels.htm).

The tabletop is a computer on which input layer is overlaid on top of the large horizontal display. Lately this technology has been implemented in the education industry in developed countries [7, 8]. Existing commercially tabletops usually support multi-touch capability in recognizing at least two contact points at the same time. Existing multi-touch tabletops can be divided into two main types, one uses the electronic field sensing technology while the other uses camera-based technology [9, 10]. Multi-touch tabletops allow multiple interactions by the user via finger touches on the table surface, making it easier to access digital content, giving rise to the term natural user interface. Examples of off-the-shelf tabletops include Microsoft Surface (screen size of 32 inches) and Mitsubishi DiamondTouch (screen size of 32 and 42 inches), with the cost around USD 10,000 to 20,000, including the on-site installation [11]. Smart Table from Smart Technologies is a tabletop with a screen size of 27 inches that was designed specifically for educational purposes and comes with a price tag of USD 6,650 (see http://www.smarttables.co.uk/products/). Rapid adaptation of the multi-touch tabletop in universities has not been realized because of the high price tags.

3. SYSTEM DESIGN AND IMPLEMENTATION

The primary objective of designing the multi-touch teaching station in this work is to technologically enhance instructors' teaching experience by providing a more natural user interface for easier and effective teaching at an affordable price. This includes providing a large horizontal digital writing area (32 inches) for instructors to hand draw or write digital notes intuitively with their fingers or an Infrared (IR) pen. Furthermore, instructors would be able to control teaching slides more effectively through fingers' gesture to zoom in and out, pan and rotate when conducting a lecture.

The design of the camera-based multi-touch teaching station developed in this work is shown in Figure 1. It consists of an IR camera, an acrylic surface with IR LEDs installed along the edges, a standard projector, two mirrors, a diffuse compliant surface and a computer CPU. The design principle is based on the FTIR technique [10] where when finger touches the table surface, IR sources will be reflected and tracked by the IR camera. The projector is used to provide a large visual feedback on the table surface. Mirrors are used to create a long virtual path between the projector and the projection surface such that the teaching station can be built at a reduced height with a large display. IR LEDs are installed along the edges of the acrylic surface to provide an IR illuminated surface. An IR band pass camera is mounted at the bottom of the teaching station to act as an optical sensor to differentiate between finger touches (reflected IR source) and projected teaching materials (visible light) on the table surface. The diffuse compliant surface on top of the acrylic is made out of tracing paper coated with silicon material that serves as projection surface as well as a proxy to easily frustrate the total internal reflection whenever it is touched.

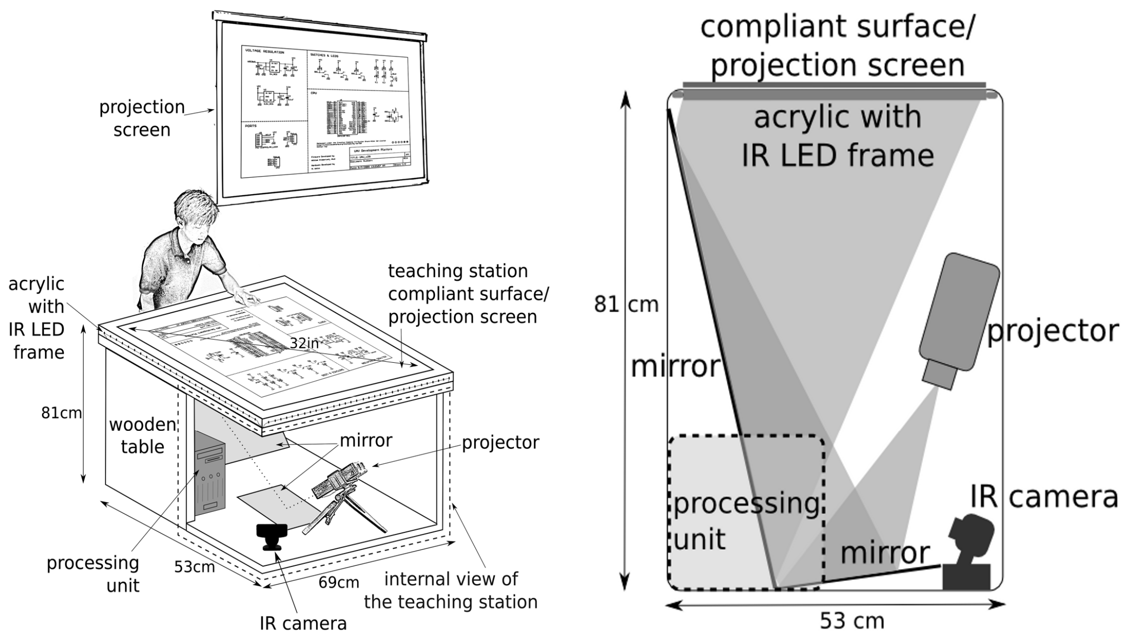

FIGURE 1: The design of the Camera-based Multi-touch Teaching Station.

Figure 2 shows the multi-touch teaching station data path, beginning from touches on the teaching station surface to generating visual feedback on the teaching station display via an assortment of software components. Whenever fingers touch the table surface, total internal reflection will occur causing the IR light source to be refracted. The IR camera captures the IR sources and streams the video feed to the IR tracking module known as Community Core Vision (CCV) (available at http://ccv.nuigroup.com). CCV is a cross platform open source computer vision tracking application that takes in a video stream source as input and generates coordinate and blob size as output for each detected IR source in the video stream. Most of the processes involved in generating those blob tracking data such as video capturing, background removal, high-pass sharpening, high-pass noise filtering, brightness amplification and contour tracking are handled by OpenCV (available at http://opencv.willowgarage.com), an open source vision library from Intel that provides various C-language-based image processing algorithms. The accuracy of the IR sources (finger touches) corresponding to the computer coordinates are assured by the dynamic mesh calibration that is normally performed once during setup. Data from CCV is output and broadcasted as TUIO messages utilizing the OSC libraries included in CCV to any TUIO-enabled application directly or to XML-enabled applications via Flash Open Sound Control

(FLOSC) [12]. FLOSC is a Java application that performs as a proxy to convert UDP port 3333 TUIO messages to TCP port 3000 XML messages.

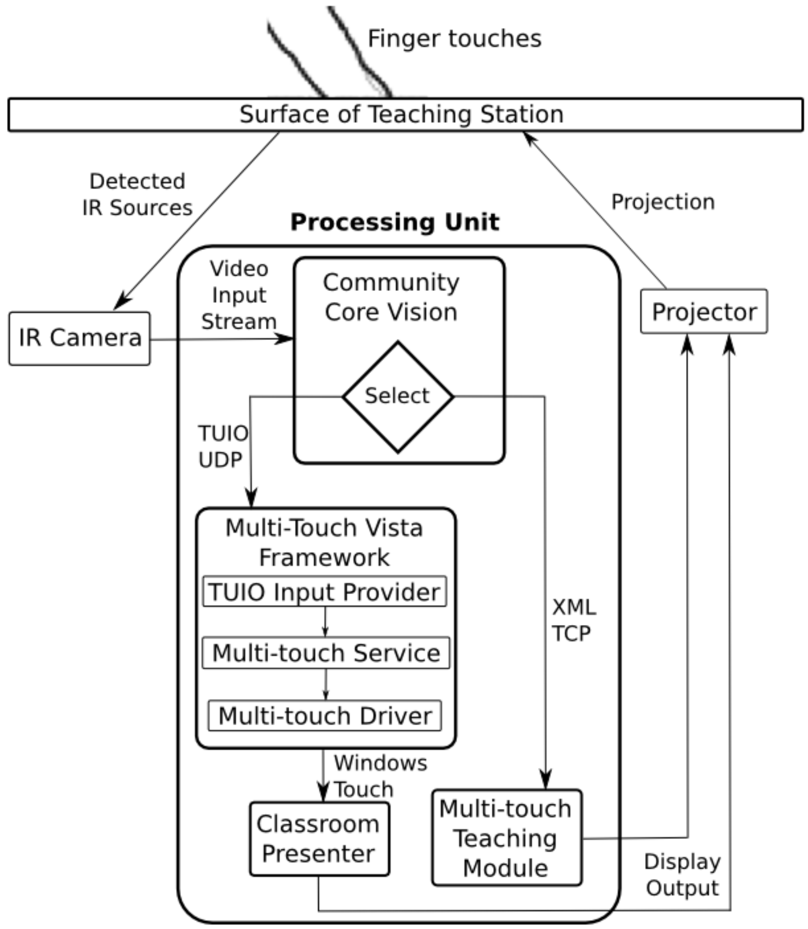

FIGURE 2: Multi-touch Teaching Station data path.

The CCV of the multi-touch teaching station when operating with the Multi-touch Teaching Module (MTTM), will pass TUIO UDP data via FLOSC to become XML messages that are transferred to TCP port 3000 that the MTTM polls. XML messages received by the MTTM include touch IDs, 2D coordinates and different events including touch up, touch down, touch out, touch move etc. that are used for gesture controls. The MTTM in this work was developed with Adobe Flash using ActionScript 3.0 to take advantage of its superior quality in manipulating and showing multimedia content in teaching materials [13]. The instructor can upload teaching materials such as PowerPoint slides, schematic diagrams, videos etc. to the MTTM. When using the MTTM, instructor can manipulates teaching materials easily with fingers' gesture such as panning, rotating, zooming in and out etc., especially when dealing with complex schematics diagrams. The Slide Canvas class is called within the MTTM to act as the entry point to display a slide or diagram in JPEG format. The RotatableScalable class is used to support fundamental gestures on teaching slides, as shown in Figure 3. Teaching materials can be dragged freely with a single touch. Rotating and size changing of teaching materials are possible only if there are two touch points. The rotation involves a computation based on the tangent of the angle made by the two points with a reference line while the size changing involves a more complex computation to first determine the center point, and then compare the two distances between the two coordinates before and after the manipulation. The code listing illustrated in Figure 4, showed how the MTTM extends the RotatableScalable class and actively listens to port 3000 for data sent from the FLOSC.

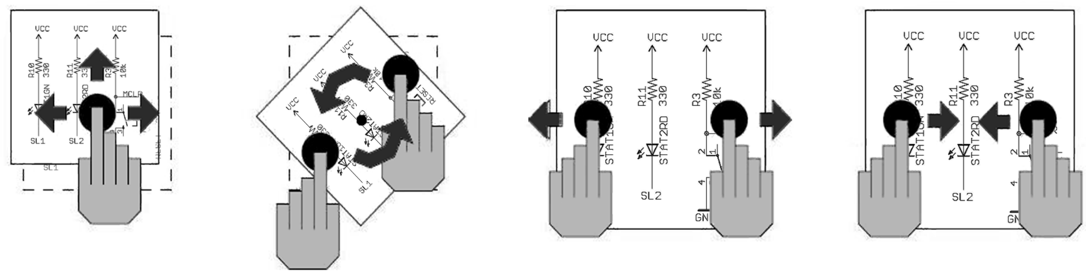

FIGURE 3: Fundamental gestures in manipulating teaching slides.

```
package{
        import app.core.action.RotatableScalable;

        //Extends RotatbleScalable class to support gesture controls on schematic diagram
        class schematic extends RotatableScalable{
        public function schematic():void {

                //Actively reading port 3000 for touch information from FLOSC (127.0.0.1)
                TUIO.init(this,'127.0.0.1',3000,'',true);
                ..
                ..
```

FIGURE 4: The code listing of using RotatableScalable Class.

When the multi-touch teaching station is running existing engineering applications such as Matlab, PSpice, AutoCAD etc., the CCV channels the TUIO data to the Multi-Touch Vista Framework, a user input managing layer obtainable in CodePlex open source hosting site at http://www.codeplex.com/MultiTouchVista. This layer bridges the connection between the teaching station surface touch inputs and the engineering applications by processing and decoding the TUIO UDP messages from CCV into some 255-touch-point stylus input events understand by the Windows 7 operating system. This enables instructors to use their finger as the input device to interact with existing applications running on the multi-touch teaching station.

Table 1 shows that the total hardware cost to deploy the 32-inch multi-touch teaching station was roughly USD 1034 using a conversion rate of USD 1.00 = MYR 3.05 (as at 1 March 2011). The cost will be higher if a projector with better specification is used.

4. RESULTS

Figure 5(a) shows the implementation of multi-touch teaching station prototype in Multimedia University. The 32-inch-diagonal-display teaching station supports both single-touch on existing educational applications and multi-touch on the MTTM with gesture controls. Once the teaching station is connected to a computer and projector, the instructor could easily interacts with the teaching materials using fingers (without mouse and keyboard) in front of the classroom while students pay attention to the same content on a large projected screen. The MTTM provides instructors the flexibility to manage the course of the lessons by choosing and zooming in a particular slide in the teaching materials in a non-linear manner. The multi-touch teaching station when operating with educational collaborative software such as the Classroom Presenter, instructors can easily add digital notes over PowerPoint slides using their finger or an IR pen.

Components	**Price (in RM)**
IR Camera	400
Projector	2000
Power supply	45
Mirrors	60
32" Acrylic	200
Table	250
Compliant surface	50
Infrared circuitry	150
Total	**3155**

TABLE 1: Hardware cost to develop the Multi-touch Teaching Station.

Instructors can use the multi-touch teaching station together with the MTTM and Classroom Presenter to enhance a traditional slide-based lesson to support the following:

- Flexibility to control the presentation flow of teaching materials in a class
- Manipulating teaching materials with fingers' gesture controls
- Conveniently add impromptu annotations or figures on teaching slides
- Encourage active participation from students throughout the class

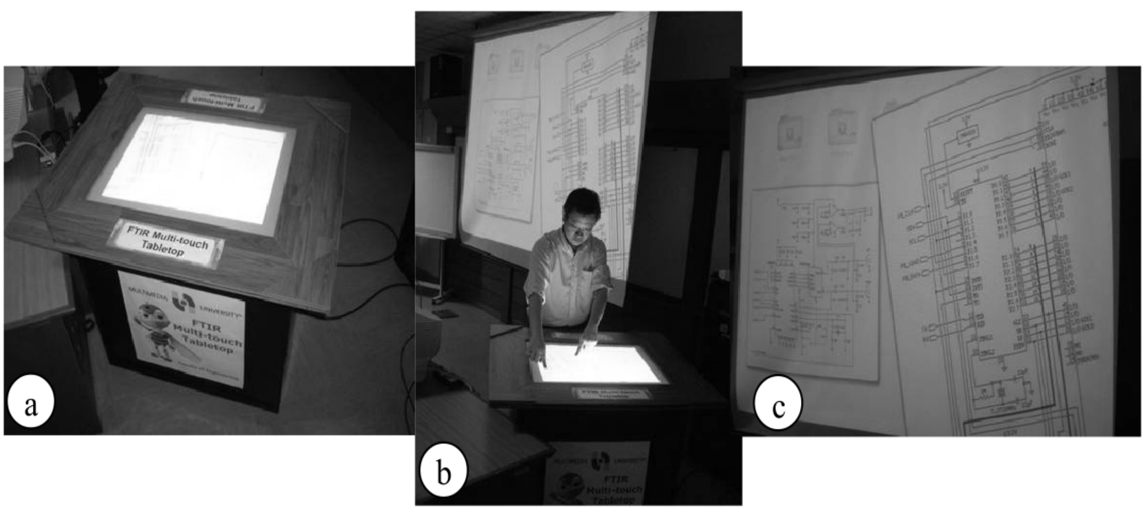

FIGURE 5: Implementation of the Multi-touch Teaching Station in Multimedia University

Figure 5(b) shows an instructor using the multi-touch teaching station and the MTTM in a real classroom environment to zoom in a desire slide using fingers' gesture to compare two different electronic circuits. Figure 5(c) shows the result of the action as projected on the large screen (identical view on the tabletop). An example of a more complex interaction using the system is given in Figure 6.

Figure 6(a) shows an instructor using the multi-touch teaching station with the Classroom Presenter to teach tree traversal in a programming class. The multi-touch teaching station driven by Classroom Presenter lets students submit answers directly to the instructor, thus enhancing their engagement. An example of question asked and the corresponding answer submitted by one of the student are shown in Figures 6(b) and 6(c) respectively. The instructor is able to review students' solutions and closely monitor the performance during a class. Figures 6(d) and 6(e) illustrate the instructor using the multi-touch teaching station with his finger to present a step-by-step walkthrough of the tree for the pre-order solution, allowing a better comprehension of the solution by the students.

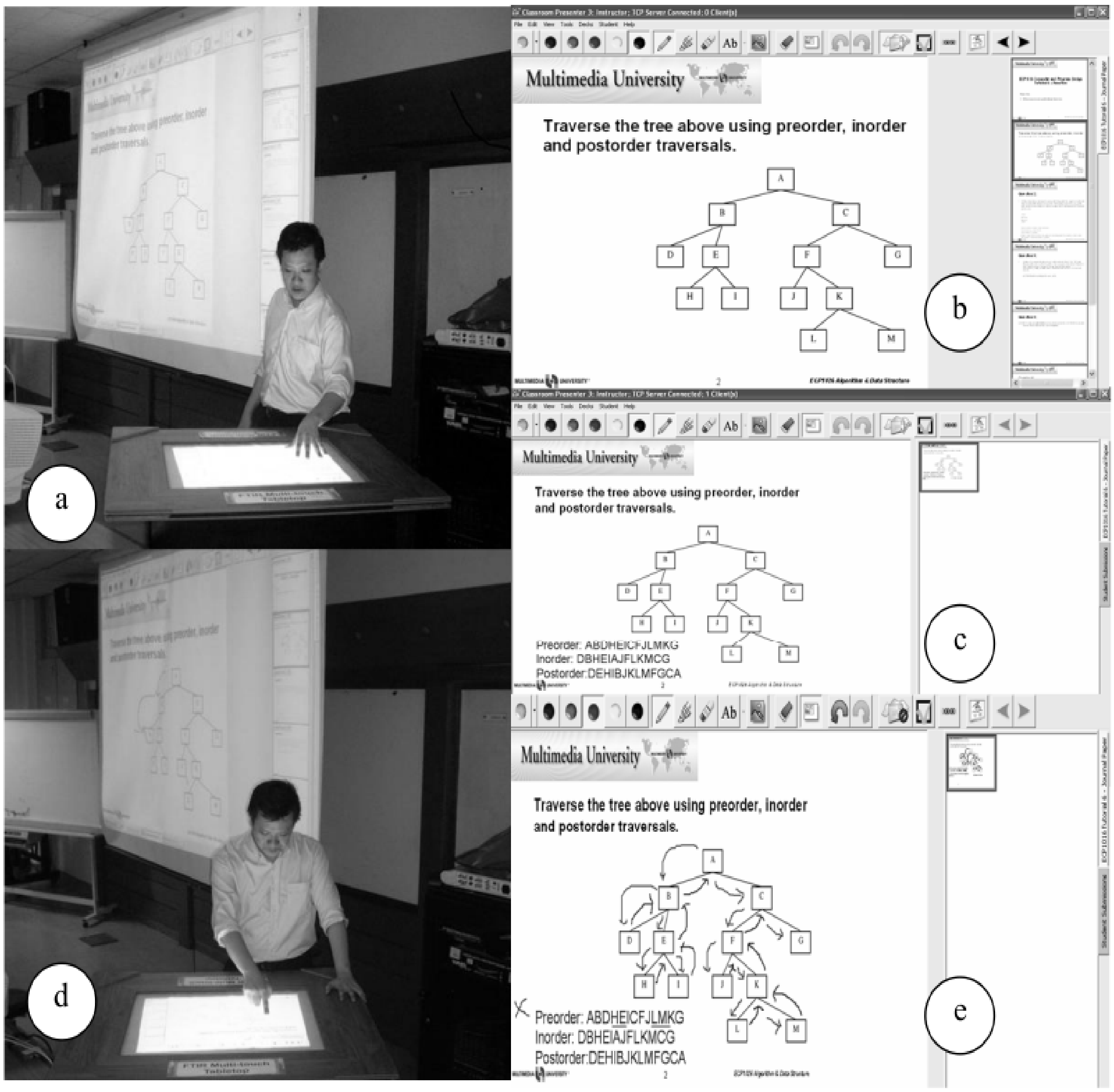

FIGURE 6: Multi-touch Teaching Station running Classroom Presenter.

Generally, the instructors who used the system were satisfied with the multi-touch teaching station in the classroom environment, as it offers a simple way to include additional digital content on teaching slides on a large interface using fingers or an IR pen, which is not possible on a standard PC. It was noticed that some instructors preferred to use an IR-pen instead of their finger to write on the tabletop surface for making annotations. This is because instructors are used to the conventional approach of writing notes using a pen. Some instructors commented that the response time in performing gesture controls using fingers on the teaching materials was a little bit slow although the delay was bearable. The delay was due to the additional touches tracking algorithm which converts finger touches to the corresponding coordinates in the display, and then identifies the resultant gestures. Nevertheless, the instructors were able to adapt to the slow response time and managed to use the teaching station at ease after a short while of practice.

5. CONCLUSIONS

The implementation of an affordable multi-touch teaching station, capable of operating with existing learning software and the custom-made Multi-touch Teaching Module (MTTM) allows instructors to annotate on teaching slides simply using fingers or IR pens while conducting a class. The MTTM allows instructors to manipulate teaching materials in a very natural way with fingers' gesture and to control the flow of teaching in a very flexible manner. Using this improved interaction, instructors are able to discuss and comment on students' submitted solutions with Classroom Presenter on the multi-touch teaching station while students are able to read and save the instructors' remarks on their PC simultaneously for future reference. In brief, a camera-based multi-touch teaching station can provide a cost effective way of improving teaching materials delivery to students with features such as multi-touch, gesture input, stylus input and large interactive display that can be found only in high-end electronic teaching tools. Complete evaluation of the teaching station with more instructors and a large group of students within an extended period was not done in this prototyping stage and will only be planned in coming semesters. However, the preliminary results and feedback from instructors are positive and this supports the development and promising use of the multi-touch teaching station in teaching.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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