An infotainment table for interactive learning based on Infra-red touch overlays using TUIO protocol

Sanjana Khater
Department of Information Technology,
Pune Institute of Computer Technology,
Savitribai Phule Pune University, Pune, India.
khater.sanjana10@gmail.com

Sneha Kulkarni
Department of Information Technology,
Pune Institute of Computer Technology,
Savitribai Phule Pune University, Pune, India.
snehakkulkarni@gmail.com

Abstract**—**Development of multimedia technologies coupled with need of making the learning process engaging has led to the emergence of many interactive applications in recent times. By utilizing the ease of using touch based applications, it has become possible to make teaching-learning system more interesting for students, by incorporating these technologies in the process of imparting education. In this paper, we propose to develop an interactive game that runs on an Infra-red touch based multi touch surface that would enable elementary students to learn basic geometry. The software would utilize Tangible User Interface Object (TUIO) protocol for communication.

Keywords*-multi-touch, Tangible user interface, interactive, IR touch.*

*****

I. Introduction

The approaches to providing education have undergone many changes in recent times. Far from the traditional approach where a student is expected to sit at a desk and learn passively, lessons have become much more interactive and engaging. Interactive learning is a hands-on, real-world approach to education. The purpose is to actively engage the students in wrestling with the material. As schools advance and add technology to the classroom, lessons also become more captivating and interesting for students. For example, there are hundreds of interactive programs for students in areas like math and science. With the advent of multimedia technologies it has become feasible to incorporate interactive methods into the process of learning. The emergence of affordable hardware and development of new environments, has led to the popularity of these technologies [4][5].

One such approach is to use table top tangible user interfaces along with development of applications that provide the user with an interactive source for infotainment. The table top tangible interfaces make the link between physical and virtual objects, enabling users to grasp and interact with their components in a physical manner, besides including multi touch interactions. In certain situations tangible interaction seems to offer advantages for learning [4]. Empirical results show that the touch-based and Tangible User Interface-based systems offered much better ease-of-use performance than that of the mouse-based system [1]. Regarding learning efficacy, experimental results show that the TUI-based system achieved higher skill improvement, as compared with the WIMP (Window Icon Menu Pointing Device) -based system and a non-computer training method [1].

We propose to design an interactive game for elementary students which would provide them with an engaging method to learn geometrical properties of various figures by placing objects which would be prototypes of geometrical figures, on a multi touch surface. The multi touch surface would serve the purpose of dispensing the output as well.

II. LITERATURE SURVEY

Before Windows native touch or concept of overlays arrived in the market, touch based systems were designed with cameras and object detection had been limited to computer vision based systems. Computer vision output is affected by occlusions and ambient lights. Additionally, accuracy is not up to the mark. In order to solve these issues, we can develop a software that runs on Tangible User Interface Object (TUIO) based touch surface using Infrared (IR) overlays. Since this software will allow object recognition without camera, it could be used at various places without any problems of ambient lighting conditions. From amongst the various types of touch screen technologies available, we have chosen to use Infrared based touch overlays. The drawbacks of the common types of touch screen technologies namely: capacitive touch, resistive touch and infrared camera based touch have been listed in table 1.

III. OVERALL DESCRIPTION

Research shows that, when students study using an interactive medium, the learning process is easier, and faster[1]. Therefore, we thought of this system which can help young students to learn about different shapes in an easy and faster way. A shape recognition game is developed for the kids, where the students have to place a particular shaped object in the boundary designed for that particular shape. After the student places the shape in the boundary, the properties of the shape along with some other objects of the same shape are

TABLE 1. COMPARISON BETWEEN TOUCH TYPES [3]

Touch Type	Limitations
1.Capacitive (used in mobile phones)	• Not scalable • Requires human touch only • Expensive for larger screens.
2. Resistive (used in ATM kiosks)	• Supports only single touch • Does not scale easily • Not durable
3. Infrared camera based	• Affected due to ambient light • Expensive

displayed on the screen. For example, if the child places a circle on the boundary of a circle, then the properties of a circle (area and circumference formula etc.) will be displayed. Also, circular objects like CD will be shown. This is a timed game, where the player has to place the correct object within a specified time. Also, this system is useful for the adults, as it allows them to watch various videos. A few videos will be there in the database, and each video will be mapped with a particular shape. And when the user places the shape on the screen, the mapped video starts playing, the user can also increase or decrease the volume by rotating the object on the screen. The system is programmed using TUIO protocol to detect the markers attached to the object, and mathematical processing is applied to recognize the shapes, translation and rotation of the marked objects.

IV. SYSTEM ARCHITECTURE

A. *System Components*

The system consists of a screen with an Infrared(IR) overlay on the top. Fig. 1 shows the system architecture. It is a multi-touch overlay which can work with Linux, windows, Mac OSX, and Android. The input given to the system is either a marked object, or a human touch. The IR overlay consists of a matrix of IR rays on two sides and receptors, on two sides. Whenever the screen is touched, the IR ray gets obstructed, and therefore, the position of this touch is detected. The position of the touch is then detected by the TUIO tracker. The working of the TUIO tracker will be explained in the next section. The output of the TUIO tracker i.e. touch positions, are sent to the computation unit, where all the mathematical processing is done. The processor is a laptop connected to the screen. When the input is given to the processor, the computation unit does processing like recognition of shapes, detecting translation, rotation and then performing the required actions. The output from the processor is then given to the TUIO Client which then sends the output on the screen with the overlay.

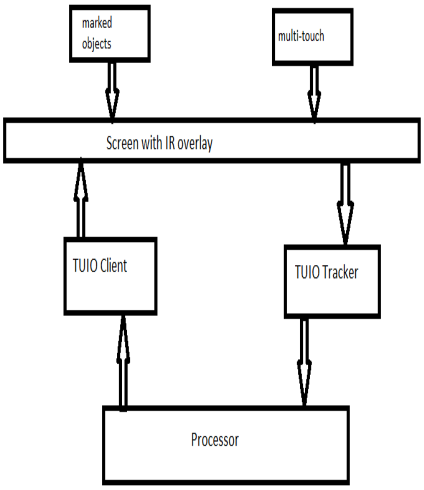

Fig. 1 System architecture

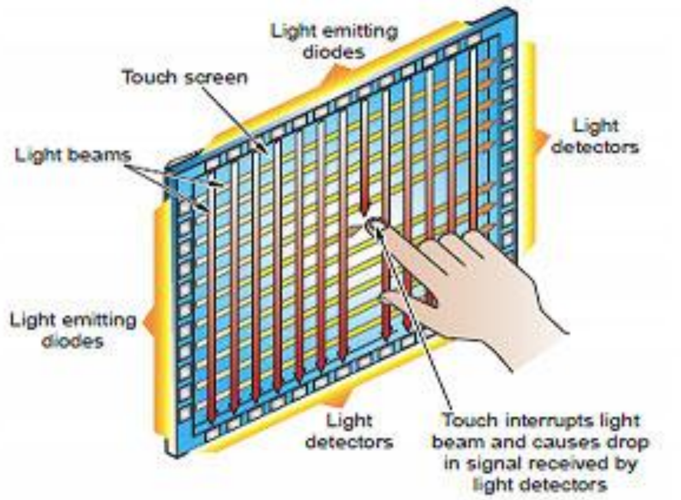

Fig 2. Working of an infra-red touch surface

B. *Requirements and specifications:*

The specifications and requirements were created to fulfil the objectives. A table would be created. The requirements were that it would be at least 40 inches diagonally to allow for multiple users and be sturdy enough to support the weight of several users that may be leaning against it. The table will act as both the input device as well as the display. It was decided that Diffused Surface Illumination would be used. This required the inclusion of infrared LEDs.

As shown in fig 2, an infrared touchscreen uses an array of X-Y infrared LED and photodetector pairs around the edges of the screen to detect a disruption in the pattern of LED beams. A major benefit of such a system is that it can detect essentially any input including a finger, gloved finger, stylus or pen. It is generally used in outdoor applications and Point-Of-Sale systems which can't rely on a conductor (such as a bare finger) to activate the touchscreen. Unlike capacitive touchscreens, infrared touchscreens do not require any patterning on the glass which increases durability and optical clarity of the overall system. Advantages: No overlay, Superior image, can detect any object which blocks

C. T*ouch and fiducial recognition software system*

The Touch and Fiducial Recognition Software System takes the input from the IR camera and processes it to output position, orientation, speed, and identification information about finger touches (or blobs), as well as markers (or fiducials), on the surface.

D. *Communication*

The TUIO specification is used to transfer the information detected to external pieces of software. “TUIO is an open framework that defines a common protocol and API for tangible multi touch surfaces.”[6] The standard defines how touch events and objects placed on the surface are encoded so they can be sent as control data to the client application. The client application would then be responsible for decoding this information and using it. TUIO is based on Open Sound Control, a network communications protocol originally designed for communications between computers and midi instruments. TUIO tracks three types of objects. The first, fiducials, can be uniquely identified and their position and orientation can be determined on the surface. The second type of object is finger touches. These do not get specific orientation data. The third type of object is any untagged object on the surface whose shape is tracked by an ellipse with a bounding box so that orientation and area information may be calculated. As stated earlier, TUIO is encoded using OSC so that the information may be transmitted more efficiently. TUIO can be used with any UDP implementation and sends packets on the default port, 3333. As of TUIO 1.1, TUIO can also be transmitted through TCP and FLC (Flash Local Connection) in order to support communication with Adobe Flash applications. UDP implementation is the default to keep the latency of communications down.

TUIO contains two different types of messages: SET and ALIVE. SET messages transmit information about an object’s position and orientation. ALIVE messages state which objects currently reside on the surface. In order to distinguish one segment in time on the surface from another, a time stamp is also delivered with each set of SET and ALIVE messages. This is called the FSEQ message. In the event multiple sources are being used with one client, a SOURCE message can also be sent to identify one TUIO source from another. In order to mitigate packet loss in this communication scheme, redundancy optimizations have been built. This ensures the system is still reliable. Since TUIO doesn’t send a message when objects are added or removed, the client side application is responsible for tracking this. A typical TUIO bundle will consist of the optional source message, an initial ALIVE message, a number of SET messages indicative of all objects on the surface, and lastly an FSEQ message that contains the ID number of the frame we’re on. Every object on the surface has a unique identifying number called a Session ID that it keeps until it is removed from the surface. This allows for the ability to track many fiducials with the same symbol ID. Any new blob or cursor that appears on-screen also gets its own unique ID. Different attributes are tracked for different objects placed on the surface. These include X and Y coordinates as well as vectors for velocity. Fiducial objects contain additional information such as their object id, angle, and rotation values. The attributes are normalized for each axis and are represented by floating point numbers. The TUIO tracker implementation takes the sensor data and divides by the sensor dimension. Position values are expressed as follows:

x = sensor_x / sensor_width
y = sensor_y / sensor_height

Velocity is measured by calculating the movement over a distance in one axis in one second of time. Normalization also occurs in in these values. Rotation velocity is measured by calculating how many rotations have occurred in a timespan of one second. A rotation velocity of (1.0) would mean that one rotation happened in one second. Rotation values are also normalized and the change in angle is calculated by subtracting the current angle of the object from the angle held previously by the object divided by the time difference between the two samples. The rotation acceleration, r, is calculated by taking this change in angle and dividing it by the change in time between the two frames.

E. *Implementation*

Activity diagrams, using the UML 2.0 notation, for the detection of triangular objects and the subsequent steps after trailing the object are shown in the following figures. Figure 3 depicts the flow of control

between the user, the object tracking system and the computation unit, for the overall high level scenario. Figure 4 depicts the activity diagram for a valid triangular object detection scenario. It tests the existence of a valid triangle by checking if the property of triangular inequality holds between the three detected ‘sides’. This validation would be performed by the computation unit which is nothing but a program written by us to apply the mathematical logic. Figure 5 depicts the activity diagram for detecting the change in motion of the object if it is trailed. The translation computation is done using the distance formula. In order to detect the change in orientation of the object, change in slopes of the sides has been used. As the object is trailed along the overlay, the information displayed by the object, for example the geometrical properties of a particular figure, will also get trailed along with the object. We have developed our code in C# and the front end has been designed using Unity 3D.

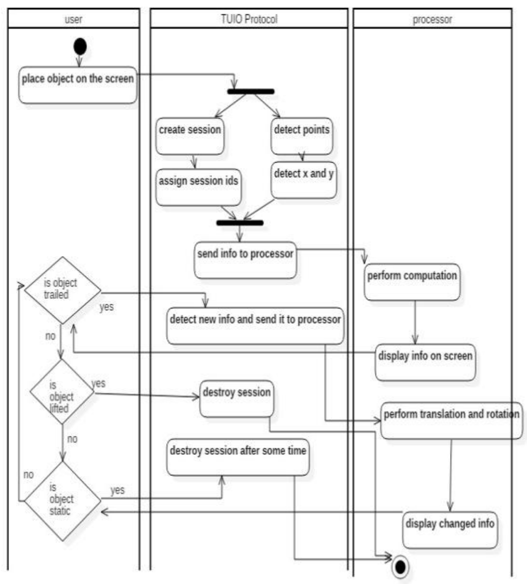

Figure 3 Activity diagram for overall high level scenario

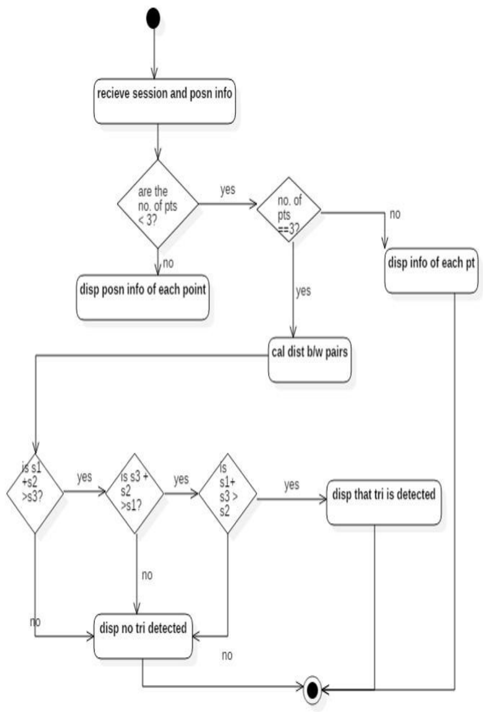

Figure 4 Activity diagram for a triangular object detection scenario

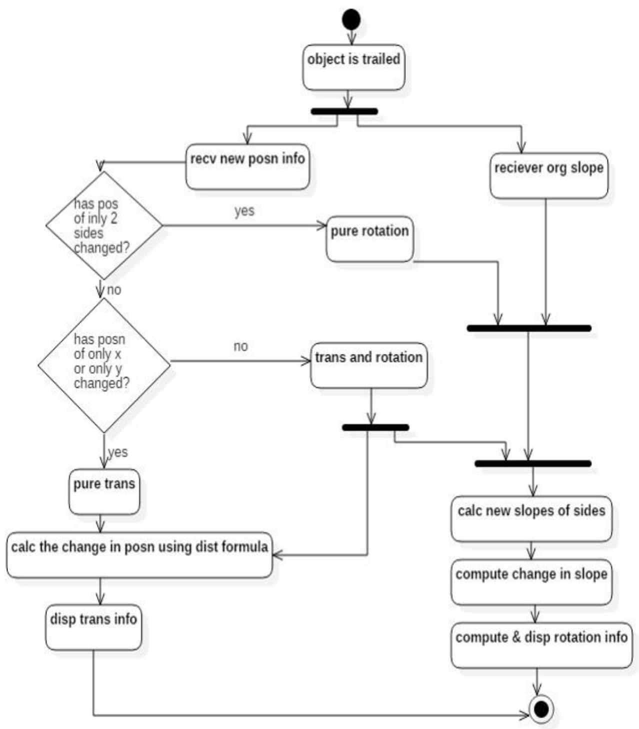

Figure 5 activity diagram for translation and rotation computation of a triangular object

V. RESULTS

The software received TUIO messages. Each object on the screen was represented with its own unique ID number. Each fiducial also had a unique ID number. This list of on-screen objects was received through a socket and read first by the software. The list of received objects was stored in the program temporarily. When an object first came into the system, it was checked against all the current elements in the shared structure to see if they already exist. If it does exist, the object was updated with whatever the newly received information is. If the object was not in the list, a new container for it was created and the object entered a function that will determine if it is a touch or a fiducial. If the function determines that the object was a fiducial, the fiducial ID's are determined, and the object and its corresponding information were packaged to be placed in the shared data structure. If the object was not a fiducial, then it must be a touch. Once all of the new touches have been saved into the data structure, the socket was checked once more for new data from and the process begins again. When an object was removed from the surface it was searched for in the list of objects maintained and was removed. A sample valid triangular object was detected and geometrical properties of a triangle were displayed on the overlay. The displayed information was trailed along with the object on the overlay.

VI. CONCLUSION

Thus, a system which is capable of detecting and recognizing distinct objects kept on an IR touch screen is designed. The changes are reflected on Unity 3D based content. Using IR overlays for the purpose of object identification for larger surfaces is cheaper than capacitive touch based systems and more accurate than resistive touch based system and IR camera based system. The system makes use of IR overlays attached over the display of Windows PC thus making it easy to handle and portable. The system is a cheaper and more accurate substitute for the traditional capacitive or IR camera based system. Even the markers used for tagging the objects are inexpensive in contrast to the markers used in IR camera based system.

Unique IDs are assigned to the detected trackers. Based on the marker the object is identified. The system follows the tracker and different types of motion related to it like clockwise rotation, anti-clockwise rotation and drag. The system is being utilized for the purpose of infotainment wherein an interactive game is developed to help the students identify and learn various shapes of objects and their geometrical properties.

VII. ACKNOWLEDGEMENT

We would like to thank our esteemed guide Prof. K. K. Nandedkar for her consistent support, inspiring supervision and valuable guidance throughout the course of the work mentioned in this paper. We would also like to express deep sense of gratitude towards Prof. S. A. Jakhete, Prof. S. S. Pande for their regular inputs and valuable suggestions.

VIII. REFERENCES

[1] Sitdhisanguan, K.; Chotikakamthorn, N.; Dechaboon, A.; Out, P."Evaluation the Efficacy of Computer - Based Training Using Tangible User Interface for Low-Function Children with Autism", Digital Games and Intelligent Toys Based Education, 2008 Second IEEE International Conference on, On page(s): 70 – 74

[2] Dourado, A.M.B.; Botega, L.C.; Araujo, R.B. "TTUI-SM: A New Specification Model for Tabletop Tangible User Interfaces", in Virtual and Augmented Reality (SVR), 2014 XVI IEEE Symposium , vol., no., pp.238-245, 12-15 May 2014

[3] Mudit Ratana Bhalla; Anand Vardhan Bhalla. "Comparative Study of Various Touchscreen Technologies", International Journal of Computer Applications (0975 – 8887) Volume 6– No.8, September 2010

[4] Michael S. Horn ; R. Jordan Crouser; Marina U. Bers. "Tangible interaction and learning: the case for a hybrid approach", Personal and Ubiquitous Computing, 2012, Springer-Verlag (1617-4909), Volume 16, Issue 4, pp 379-389, April 2012

[5] Abrahamson, D., & Trninic, D.. Toward an embodied-interaction design framework for mathematical concepts. In Proceedings of IDC '11 (pp. 1–10). New York, NY: ACM Press. (2011)

[6] Martin Kaltenbrunner, Till Bovermann, Ross Bencina, Enrico Costanza, "TUIO :A Protocol for Table- Top Tangible User Interfaces" .

[7] Mi Jeong Kim; Maher, M.L., "Collaborative Design in a Tabletop System employing Tangible User Interfaces," in Computer Supported Cooperative Work in Design, 2007. CSCWD 2007. 11th International Conference on , vol., no., pp.192-197, 26-28 April 2007

[8] Teoh, B.S.P.; Tse-Kian Neo, "Innovative teaching: Using multimedia to engage students in interactive learning in higher education," in Information Technology Based Higher Education and Training, 2006. ITHET '06. 7th International Conference on , vol., no., pp.329-337, 10-13 July 2006