PolyPie: A Novel Interaction Techniques For Large Touch Surfaces With Extended Wall Displays

Ihab Maged *, Michael Louis *, Mohamed Thabet * and Ayman Atia †
* Faculty of computer science
MIU university , Cairo, Egypt
Email: ihab090178, michael.louis, mohamed.thabet @miuegypt.edu.eg
† HCI Lab, Faculty of computer science and information systems, Helwan University
Email: ayman@fci.helwan.edu.eg

***Abstract*—The paper presents new interaction techniques for large touch tables and large-wall projected screens. The extended projected screen is integrated as an extension to the touch table where the user can grab the menu items on the projected screen from the touch table or by interacting directly with the projected screen using hand gestures. The system proposes multi-touch controls and hand gestures that aim to minimize the user effort and body movements while interacting with the large touch table and the extended projected large-wall display. We present "PolyPie" as a group of three touch interaction techniques for large display touch surfaces and two hand gestures techniques for interacting with the large-wall projected display. The proposed touch techniques are the Dynamic Pie Magnifier, Poly-Fingers Grab, Five Fingers Shadow Grab. We conducted a preliminary study for the proposed interaction techniques. The results showed that the proposed techniques helped the users to interact much easier with large display table and wall screen. The users were able to access distant files in acceptable time and more smoothly.**

***Keywords*-Large Display Interaction;Gesture Interaction;Multi-touch Tables;Interaction Techniques**

I. Introduction

Large Display Screens are becoming widely used after recent progression of technology. Ball and North [1] showed that by launching several windows on a single large screen will facilitate different advantages for the users. The main benefit for working on those large displays is gaining the usability of previewing relatively large sets of data. The main challenge is to find out the proper interaction techniques that fit with interacting with those displays. Tan et al. [2] stated that large display screens save much time and effort when they are compared to the normal display devices especially when they are used in group-ware activities. Although those large displays may be perfectly used by a single user but by the help of certain interaction techniques. Also, the interaction techniques designed for traditional computers, such as the trackball mouse are not always appropriate for use with other form factors, especially for large displays. The traditional trackball mouse needs to be dragged from the bottom of the display up to the end in order to a grab or select a single menu item. Khan et al. [3] stated that in certain circumstances, the user spent a significant amount of time trying to find out where the mouse pointer was on the screen. The problem the users face is that it is impossible for them to reach distant windows and keep track of many launched windows. Vogel et al. [4] showed that in some certain scenarios, users have to step back or move from their place in order to access a specific item on a large display. There are some tasks that are needed to be handled from a distance in some specific environments, such as sorting slides, photos and pages spread over a large display surface or even a public place that contains a large mounted display that is needed to be accessed. Radloff et al. [5] showed that large displays in meeting rooms will assure a high level of presentations and interactions between the users.

In this paper, we proposed some new interaction techniques for working on a large touch table which is also extended to another projected large-wall display. The main concern is to embed the interaction techniques into the seamless interactions figured out by the user in order to gain the maximum usability and the minimum effort. Our motivation in this work is to prevent the user from being frustrated while working on these large extended displays, so the extended projected display and the touchable surface must be logically integrated and accessed as a single regular display with the proposed techniques. We conducted a preliminary experiment concerning the time of the proposed interaction techniques. We discussed the advantages of each technique and its usage in different situations and applications with large surfaces.

II. Related Work

Parker et al. [6] showed that large display screens are now facing a problem in finding useful interaction techniques that will help its users to reach any far object. There are some techniques presented by researchers by using several input method like laser pointers. Myer et al. [7] showed that using laser pointers are problematic in terms of accuracy and speed. Moreover, Laser pointer are used more effectively on wall projected screens not a big display table.

Malik et al. [8] showed that there are several interaction techniques implemented for accessing far distant desktop items on a touchable surface to maximize the comfort of the user. They implemented their interaction techniques on a touch pad. A technique similar to the Vacuum [9] was implemented in which all the menu items between the angles of two fingers are dragged to each finger. Also, on touching the touchable

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surface with the five fingers, the nearest five menu items are dragged to each finger on the touch surface. Drag and drop is also implemented as if the user is catching a menu item and then leave the menu item to be dropped with his five fingers.

Bezerianos et al. [9] conducted the Vacuum technique, which works by drawing two projected lines till the end of the screen from a single source point, a polygon will be drawn and all the items covered in the polygon area will be dragged to the source point. The Vacuum technique was compared with the Drag-and-Pop technique and the experimental results showed that the vacuum technique is relatively faster and more accurate. The Vacuum technique has some limitations on the touch table especially on changing the angle between the two fingers. The user needs to remove his hand and hold it one more time on the touch table to change the angle.

Radloff et al. [5] discussed grouping of several large displays and how the user interacts with them. The user interacts with the projected displays using a Wii remote where he/she is able to manage and drag the menus and graphs instantly from one screen to another. The paper stated that the interactions with the projected screen by using a depth camera could be more appropriate than the Wii remote.

Kim et al. [10] showed that there are some interaction techniques used on the multi-touch screens where these techniques have to be predefined according to the number, position, and movement of the fingertips of the user. When the user touches the screen an image is captured and preprocessed to remove the noise and determine the movement of the fingers. The gesture commands were to manipulate the user interface. Bi et al. [11] conducted the MagicDesk that works on integrating touch capabilities with desktop work, which brings maximum accuracy and speed for the user as the keyboard and mouse technique is one of the fastest techniques but with integrating some touch interactions for desktop work introduces a new way for working on a desktop environment. The main contribution in the paper is using an interactive tabletop by interacting with touch techniques on the table and updating the monitor in real time.

Potter et al. [12] used Leap motion for Australian sign language. Leap Motion is a small usb device which can be placed on any physical surface , facing upward . It uses two monochromatic IR cameras and three infra-red LEDs , the device can detect motion to a distance of 1 meter (3 feet). The LEDs generate a 3D pattern of dots of IR light , the IR cameras then generates almost 300 frames per second of the reflected data. The leap motion controller software synthesize 3D position data by comparing the 2D frames which is generated by the IR Cameras. Marquardt et al. [13] showed that the main idea of unifying touch and gestures on and above a digital surface is to create a continuous interaction space where the user moves any tangible objects in the space and can also use touch and gestures techniques. The continuous interaction space can be illustrated as follows; a 3D area above the touch surface is conducted where the user interacts with his gestures without even touching the touch surface. For example, Mirrored Gestures for Redundancy is one of the techniques used where the person interacts with the touch surface using hand gestures instead of interacting directly on the surface. Kin touch is a way of integrating touch capabilities with Kinect [14] for facilitating the life of visually impaired people by using tactile or interactive maps. The software works on two applications, one for tracking fingers with Kinect image and the other for detecting the position of the fingers on the touch surface.

Shoemaker et al. [15] showed a new way for human computer interactions dealing with 5m X 3m large display wall depending on reality based interaction and whole body interfaces. The major contributions of their work was presenting a new body-centric approach specific to large display walls. The first step in their work was to sense the body by a vision tracker, then modelling the body position and at last analysing the interaction done by the user. Fikkert et al. [16] proposed new hand gestures for interacting with large-wall projected screens. They conducted their experiment on a large projected display where the task is to allocate a specific town on a large map. They introduced a set of gestures, such as the point, select, deselect and three other gestures for activating, deactivating and resizing.

Adrian et al. [17] implemented the SuperFlick, which is a technique for long-distance object placement on digital tables. SuperFlick is based on a remote Drag-and-Drop technique on a thrown object. The user does not need to wait until the flow is finished and the system knows the final position of the object as soon as it is thrown. Drag-and-Pop and Drag-and-Pick are techniques for accessing remote screen on touch and pen operated systems. Patrick et al. [18] showed that the users conducted some errors when the menu items are close to each other or when they are removed from their home screen. Doeweling et al. [19] implemented a new way for representing the Drag-and-Drop technique for large display touchable surfaces, which aims to optimize the short-backs of the regular drag and drop technique. A fully interactive proxy- targets operations are introduced and compared with the regular Drag-and-Drop technique.

III. System Overview

Our system is composed of a large touch surface and a large projected display integrated together, as shown in Figure 1. The user interacts with the projected screens using a Depth camera that is above the projected screen and in front of the user. The projected display is continuously extended and integrated to the touch surface. There are two scenarios for the user to grab the far away menu items. The first scenario, is working with the touch techniques to grab the far away menu items on the touch surface. However, this touch technique can work as an extension towards the projected display in order to grab all the menu items over the projected display and the touch surface. The second scenario is that the user grabs multiple items from the projected screen to the touch surface instantly using some hand gestures. A continuous interaction space is achieved between the projected display and the touch surface.

A. Hardware Configurations

The touch surface is created by Frustrated Total Internal Reflection (FTIR) technique used by the multi-touch community for building touch tables. A Stream of Infra-red LEDS is surrounded within an acrylic sheet where the Infra-red light enters the acrylic with a higher refractive index, at an angle of incidence greater than a specific angle. The FTIR method

Figure 1. Extended wall and large touch surface system overview

uses this principle of Total Internal Reflection in order to flood the Infra-red light inside the piece of acrylic. When the user touches the surface, the light rays are frustrated, since they can now pass through the contact material and the reflection is no longer total at that point. This frustrated light is scattered downwards towards an Infra-red camera in terms of blob positions where the camera software can track and analyze them.

A projector works as a displaying tool for the touch surface. Basically, the projector is inside the table and it is directed and positioned to a mirror. The mirror reflects the display with a higher index to the acrylic surface that is covered with a compliant layer. Our touch table dimensions are 150 X 120 X 100 *cm* where a single camera works on covering all the acrylic sheet. We used a single graphics card with multiple outputs for connecting the projector displaying the Projected-Wall screen into the same PC connecting the touch surface projector.

B. Software Configurations

Figure 2 shows the system's overview. It is composed of :; Input Layer, Intermediate Hardware Layer, Hardware Layer, Software Server Layer, Software Client Layer, Application Service Layer, Application Layer and Presentation Layer.

The Hand Gestures block is the Kinect Depth Camera input layer while the Touch Input block is the touch surface table input. The Intermediate Hardware Layer block contains the FTIR Touch table components that works for reflecting the IR light into the Camera. The Hardware Layer block includes the PlayStation 3 (PS3) Eye-Cam block that captures the reflected IR light and the Depth Camera block, which is the Kinect that capture the body skeleton of the user. We used the Community Core vision (CCV) as a Software Server Layer, which is the camera software that works on filtering the captured image and calibrating the touch input with the projected Screen. The TUIO protocol used for exchanging messages between the software client layer and the software server layer. The Microsoft Kinect Software Development Kit works for analyzing the users hand gestures. Gesture was used to select multiple items from projected display and other one for selecting all items on the projected screen.

The Application Service Layer is the Gestures Recognition Part, it implements the TUIO Client interface and the Microsoft

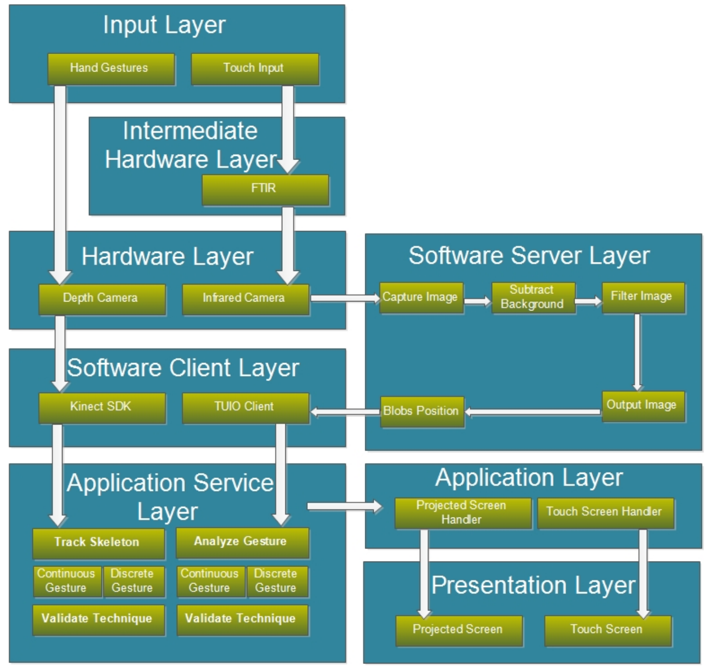

Figure 2. Block Diagram: System Overview

Kinect interface in order to start analyzing the gestures and compare the input gestures with predefined gestures. The Application layer works on animating and grabbing the selected items for the user's position based on the validated technique received by the Gesture Listener in the Application layer and displays the feedback to the presentation layer for the user.

IV. Interaction Techniques

Interaction with large display screens requires some special interaction techniques in order to grab the far away menu items on the screen as it is impossible to select these items from the user's position. The user needs to move and stretch his arm towards the touch surface in order to select a specific item. The user cannot select the first top left item from his place. We implemented three touch interaction techniques for large display touch surfaces. The touch techniques are, the "Dynamic Pie Magnifier", the "Poly-Fingers Grab" and the "Five Fingers Shadow Grab". We used the Ray Tracing algorithm for all the techniques that works on checking the items inside a polygon.

A. Dynamic Pie Magnifier

The Dynamic Pie Magnifier is basically based on interacting with the touch surface for grabbing multiple items from any position on the screen by using two fingers. The user holds down the thumb finger on the touch surface, then points with his second finger on the screen and start moving the second finger to the right position in order to maximize the size of the polygon. The shape of the drawn polygon is a cone polygon in order to insert the highest number of items possible.

The polygon area is maximized as long as the user drags his finger to the right and any allocated item inside the polygon will be moved and inserted into the Pie Menu. The Pie Menu appears on inserting the first item into the polygon. The

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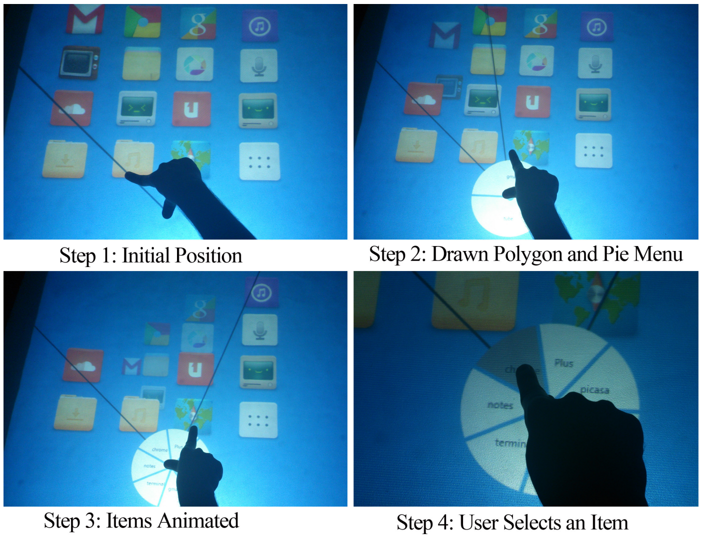

Figure 3. Touch surface: Dynamic Pie Magnifier Technique

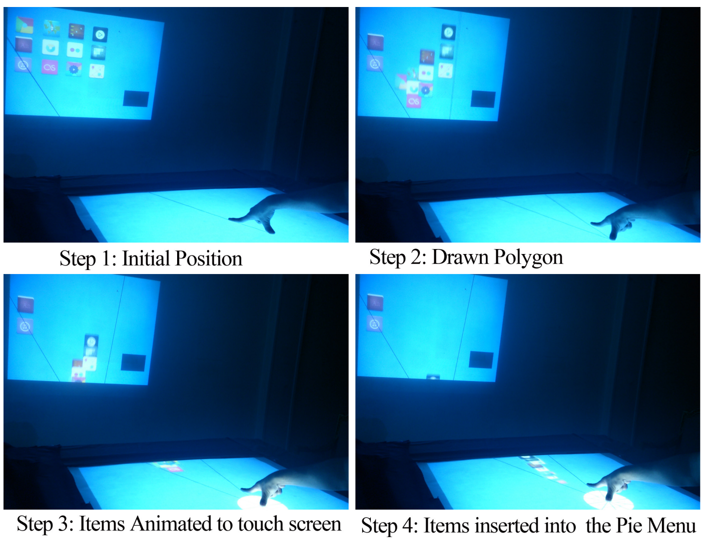

Figure 4. Extended Screen: Dynamic Pie Magnifier Technique

maximum amount of items that can be previewed on a Pie Menu are eight items. The user can swipe the pie menu in order to view more items. Figure 3 shows a single scenario for grabbing the far menu items to the user using the Dynamic Pie Magnifier Technique. The Dynamic Pie Magnifier technique can also work for grabbing the menu items on the Wall-Projected Screen to the touch surface as shown in Figure 4. The items are dragged from the projected display to the touch surface continuously and inserted into the Pie Menu.

B. Poly-Fingers Grab

The Poly-Fingers Grab works on holding down the two fingers of two different hands on the touch surface. A straight line is drawn till the end of the touch surface from each finger in order to display a polygon for the user. The user can change the size of the polygon by dragging his two fingers to the left or right for maximizing and minimizing the polygon. The items inside the polygon are animated and dragged to the user's left finger position. Other menu items are grabbed to the user as long as the polygon is maximized.

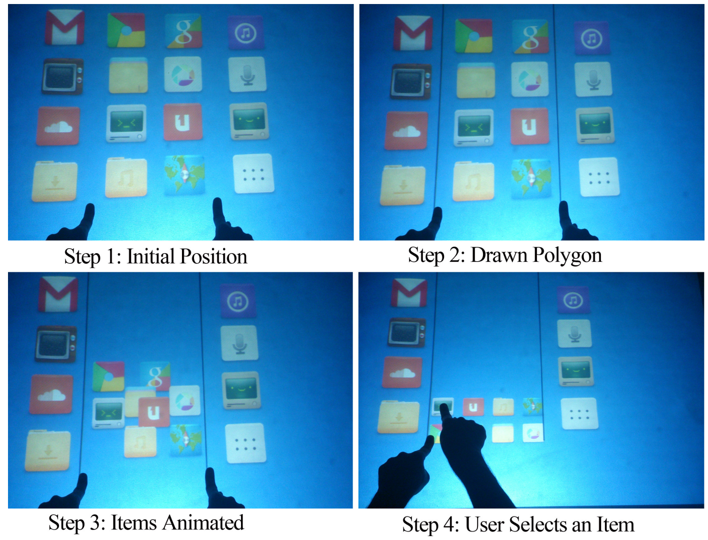

Figure 5. Touch surface: Poly-Fingers Grab Technique

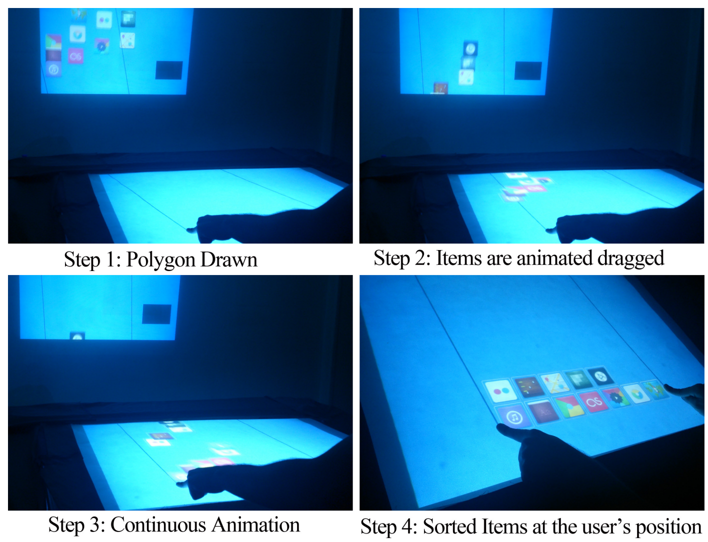

Figure 6. Extended Screen: Poly-Fingers Grab Technique

The user can change the angle of the drawn lines by increasing the top position of one finger with a higher index than the other finger. On the other hand, all the items that are not anymore inside the polygon are dragged to their original position as long as the user minimizes the distance between the two fingers. Figure 5 shows a single scenario for grabbing the far menu items to the user using the Poly-Fingers Grab Technique. The Poly-Fingers Grab technique can also work for grabbing the menu items on the Wall-Projected Screen to the touch surface as shown in figure 6. The items are dragged from the projected display to the touch surface continuously where the items are sorted at the user's finger position. The user can finally select the target item with on of his fingers on the screen.

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C. Five Fingers Shadow Grab

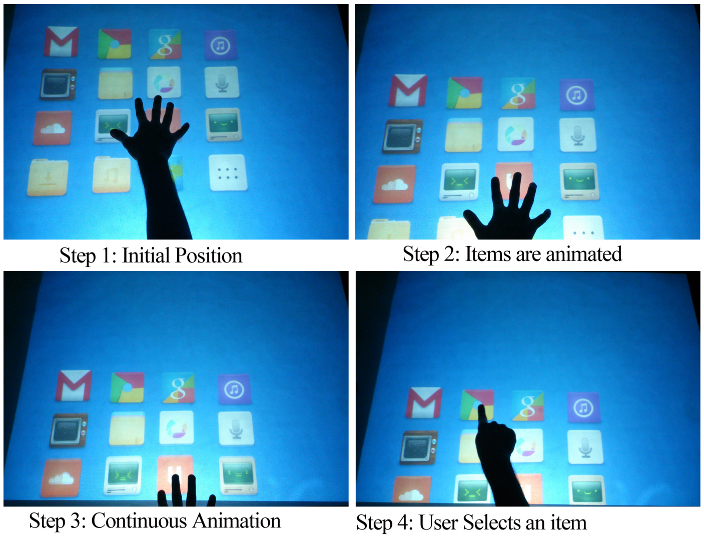

Figure 7. Touch surface: Five Fingers Shadow Grab Technique

The Five Fingers Shadow Grab technique simply works when the user puts his five fingers on the touch surface. The user starts grabbing his hand to the lower border of the table which is the user's position as shown in Figure 7. On the other hand, if the extended screen is activated, only the menu items on the projected screen will be dragged to the touch surface until they are close enough to the user. The technique works for grabbing all the items on the screen. The user finally selects one of the items from the grabbed items. The items are returned to their initial position if the user did not select any of the items for 2 seconds.

V. EXPERIMENTS

Two Female and 8 Male volunteers participated on trying the interaction techniques over the touch surface where their age range is from 20 to 25 years old. They are all familiar with the traditional mouse input device but they have never interacted with a large touch screen or extended displays. We conducted a training session for each user before performing the real experiments. The experiment scenarios were fixed across all users to grab the most far menu items on the screen to the user's and select a target item (icons or files). We showed the participants 16 items and ask them to select 2 item from the first row. The users repeat each scenario 3 times.

A. Experiment 1 - Large Touch Surface

The goal of this experiment is to measure the time for the interaction techniques on grabbing the far away items on the touch surface. Furthermore, we compared the interaction techniques with the mouse device. The interaction techniques on the touch screen results are shown in figure 8. After conducting the experiments, it was shown that the Dynamic Pie Magnifier is the fastest technique and achieve a near result to the mouse device. The Five Fingers shadow Grab conducted more time as it was frustrating for the user to drag his five fingers together at the same time for long distance over the surface. The Mouse is faster than the other interaction techniques as the user does not need to grab the items to his position. Although, the mouse cannot be used as an input device for the touch surface, but we compared our techniques with the mouse input device to ensure that our techniques does not waste time while interacting with the touch surface. Moreover, the participants were more familiar with the mouse device.

B. Results 1

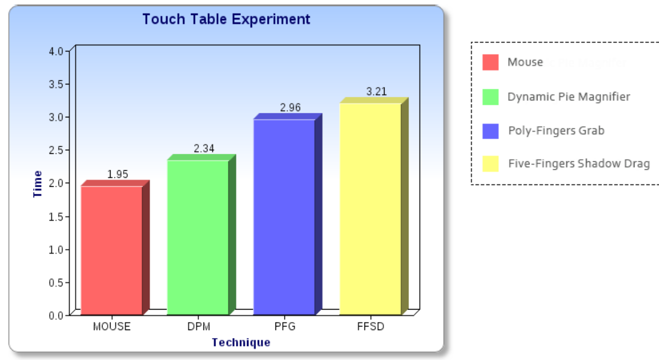

Figure 8. Large Touch Surface Interaction Techniques average time in seconds

The Dynamic Pie magnifier scored the best results after the mouse as all the selected items are inserted in a pie menu around the user's thumb. So, it was closer to the user and faster than the Poly-fingers grab, which works by grabbing the selected icons and listing them in rows and columns depending on the distance between the two fingers.

C. Experiment 2 - Extended wall display

The goal of this experiment is to test the interaction techniques on grabbing the projected display menu items to the touch surface. We compared all the techniques we developed in addition to mouse and hand gesture interaction. We tested two hand gesture techniques for the projected display. First, The "Multiple Selection" hand gesture that is based on the pause technique but the user has to raise his left hand in order to enter the selection mode. Second, the "Select All" Hand Gestures technique works for selecting all the items in the projected screen. The user has to raise his both hands in a crossing position, the user drags these items till the end of the screen coordinates and they are relatively dragged to the touch surface.

D. Results 2

The experiment shows that the user performance while interacting with the Poly-Fingers Grab is better than the Dynamic Pie Magnifier unlike the first experiment as shown in figure 9. The Poly-Fingers Grab was more accurate as the drawn straight polygon on the projected display was more imaginable to the user, while the cone polygon was not very familiar when it was extended to the projected display. The angle between the two drawing lines in the Dynamic Pie Magnifier relatively increases thus, lots of items are dragged to the touch surface which conducts higher time range on selecting the target item from the pie menu. On the other hand, the Poly-Fingers Grab drags the items directly to the touch surface and the user directly select the target.

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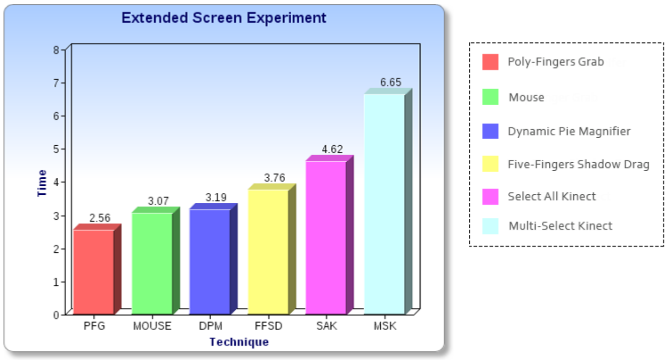

Figure 9. Extended Wall-Screen With Touch Surface Interaction Techniques Results average time in seconds

The Five Fingers Shadow Grab still conducts a higher time range for grabbing the items from the extended display and user movement over the surface was more longer. We have tested PolyPie with two different applications, first was live feedback presentation application for smart meeting rooms. We get some users feedback about feeling interested that they can access shared materials from the projected screen on their table interface smoothly. The second application was for sharing pictures between users sitting on the same large table. Users were found the pie menu interface easy to use and was fast way to access far items. Finally, the proposed interaction techniques will increase the productivity of large display touch tables.

VI. Conclusion and Future Work

We presented "PolyPie", an interaction techniques for large displays. Different touch interaction techniques are proposed in order to minimize the user effort while interacting with large display touch surfaces. The experiments showed that Dynamic Pie Magnifier achieved acceptable results while grabbing the items from the touch surface only. On the other hand, the Poly-Fingers Grab technique was better when the user grabs the items from the projected display to the touch surface. The Five Fingers Shadow Grab was frustrated while dragging the five fingers concurrently. Our future work is to create some techniques for grabbing the items from the touch table to the extended display.

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