My AppCorner: Personal Interaction Areas on Public Multi-touch Displays in a Smart Campus Environment

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Public spaces are being filled with interactive displays as information points. Companies take advantage of the technology to build a bridge between them and users. Interactive displays provide an efficient way to interact with the user but also have a lot of constraints. In the recent years the use of screens that support multiple users have been on the rise. Multi-user interaction systems present several challenges because most of the existing systems do not have the necessary flexibility to offer an adequate experience.

In this thesis, we introduce a new way of interacting with public multi-touch displays named My AppCorner, with the goal of finding the efficiency and practicality of the system also with the goal of giving the user the sense of ownership. The system gives the users the option to create their own space inside the screen, move it around and decide what application suits them best. The system takes advantage of two main interaction techniques: "*Drag and drop*" and "*hold*". User-centered design is used to design and implement the interface in order to meet the needs of a smart university public space. A system testing was conducted with the main target users being university students, staff and visitors. The main applications used were related to a university setting including; campus map, bus timetable and university newsfeed. Results showed that participants liked the idea of creating everything dynamically, having their own window and interaction with other users. Overall, the system is an appropriate solution for multi-user interaction on a smart campus setting.

Keywords: Public displays, Multi-touch displays, User-centered design

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1. Introduction

Interactive displays have spread around public and private places in the recent years. Traditional location maps have been replaced by interactive systems that offer several options on the same surface. Most of these displays have been used as information points in schools, train stations, companies and institutional offices. They provide a way to be approach the user without the need of a human involved in the interaction.

In a technological society, interactive displays have become a great option for companies to use them as a tool, and there are several reasons why displays are the most appropriate devices to use: hardware have become cheaper over the years, mobiles have spread around the globe, tactile interactions are the most common way to interact with devices these days. These reasons have made interactive displays the reasonable next step in providing users with information.

Even though interactive displays are popular nowadays, there is still a stigma of them being slow and in general not been able to provide a good User Experience (UX). UX has been defined as the overall experience while using a product or service in terms of aesthetics, ease of use and efficiency [Norman & Nielsen, 1998]

There are several multi-touch displays available for the public in the market, some of these displays have predefined sections to support multiple interaction. Oftentimes, these predefined sections have preloaded and predefined applications and can be used by one user at a time. For instance, in a sport facility in Oulu [Kukka et al., 2011], a touch enabled display installed has two defined sections; one section containing the digital signage content and the other section containing several interactive applications. This in the end tends to limit the number of users and the freedom for each one of them. This led to us to come up with My AppCorner a multi-user interactive interface. My AppCorner tries to tackle the stigmas by providing a different way to interact with multi-touch displays.

My AppCorner is a multi-user interactive interface that goes beyond the traditional multi-user display interaction and provide a personalize experience on public displays. The interface is designed for multi-user public displays, where users can create their own private screen on the public display through touch commands. My AppCorner offers the user the possibility to create his own window (by holding and dragging) wherever he decides to and gives him the freedom to decide the appropriate size of the window. After the window has been created, the user can choose from an interactive menu the most suitable application. The applications then can be dragged and dropped into the private window created. This allows the use of the same applications at the same time by different users. The private window and menu can be dragged to a preferred section of the screen by the user. The interface is also suitable for table top displays with the option of rotating the private window to face the side of the user. On a tabletop orientation, two users can sit on opposite sides of the screen and use the same private window as a means of collaborative interaction.

The present thesis is the result of a collaborative work between two students: Joy Saina and David Marin. Joy Saina was in charge of background research of Public displays, touch screens and smart campus, evaluation and results of My AppCorner redesign. David Marin was in charge of background research of multi-touch display, Design section and overall proofreading and structure of the thesis.

1.1 Research Question

The study is based on the application of My AppCorner in a smart campus environment. Therefore, the main research question is: how can an interactive public display support multiple users but still offer a sense of ownership and at the same time play a part in smart campus environment?

Smart campus refers to a university setting where campus life is made convenient, efficient ways of accomplishing daily activities are provided and social interaction is enhanced [Lui et.al, 2017]. In recent years, smart systems have been on the rise worldwide. The systems are able to replicate human behaviors for instance responding to audio commands, controlling energy consumption. This creates a linkage between people and social infrastructure. These smart systems can be found on phones, buildings, homes and nowadays in universities. Universities are now venturing into creating their own smart systems that meet university needs. In this thesis, our main key focus was from the aspect of aiding in learning and teaching and supporting collaborative work through use of My AppCorner.

The thesis was carried out on an action design basis with the target environment being Tampere3 University. University of Tampere, Tampere University of Technology and Tampere University of Applied Sciences have been merged to form a higher education institution which will be known as Tampere3 [2017]. Tampere3 is gearing towards developing a smart campus that aims at ensuring that digitalization is on the forefront

[SCIL, 2017]. This is where My AppCorner comes in, the interface will allow users to access information on a private window of public interactive screen. Through the public screen users will be able to have a quick access to university related information in a digitized form.

1.2 Thesis outline

This thesis consists of 8 chapters. Chapter 2 presents the history of public screens; multi-touch displays and touch screens. It also reports about the touch interaction techniques that are used in My AppCorner and background research on territoriality and menu accessibility. Chapter 3 introduces smart campus concept, by reporting background study in smart campus and how different universities have introduced and utilized smart campus. Chapter 4 presents an extensive look at the design process. Chapter 5 summarizes the testing of the interface, the hardware and software needed for the implementation on the system. The chapter also explains the methodology used in data collection, environment where the testing took place and the participants who took part in the system testing. Chapter 6 proceeds with the evaluation of the interface after the interface testing phase. Chapter 7 discusses the findings of the interface. Finally, chapter 8 contains the conclusion and a summary of the thesis and future work and improvements to be done on the interface.

2. Public Displays

This chapter is about the history of public and multitouch displays. We will also present prior work done on interactions techniques for public displays as well as menu accessibility and territoriality as some of the focus areas in our study.

Over the years, technology has improved and has brought about new ways of presenting information in public spaces [Azad et al., 2012]. These technologies have led to the deployment of large displays in public spaces that users can utilize to get information from. The earlier displays were static and mainly for showing information and advertisement but over the years, they have been developed and have been turned into interactive displays [Kostakos et al., 2013]. Cinemas, shopping malls, theatres, and public transport stations are some of the public spaces where these displays have been utilized. Users can use these displays to search for locations and shops in malls, buy a movie ticket, check public transport timetables and maps of the city and so forth. The displays come in form of shop windows, tabletops and even interactive walls.

The applications found in the larger displays mainly provide a platform for entertainment and information sharing for instance games, interactive advertisement and news [Ardito et.al, 2015]. The popularity of public displays deployment has been due to an increase in supply of large displays, lowering costs and ease of availability. As a result, the Human-Computer Interaction community is in a continuous process of developing new ways of interacting with public displays for example: touch, gestures, voice input and gaze. In recent years, multi-user displays have been the main focus [Peltonen et al., 2008]. Multi-touch screen is currently being used in universities [Hardy et.al, 2011], shops [Perry, 2010], tourist information offices [Marshall et al., 2011] and on public spaces like busy streets [Peltonen et.al, 2008]. There have been studies on screen orientation regarding public displays which will be reported later in this chapter.

2.1 History of Public display and Touchscreens

One of the early desktop displays was DigitalDesk in 1991 [Wellner 1991], which had the same concepts used by Krueger in VIDEOPLACE [Krueger 1985]. For instance, a video camera was placed on top of the display which could provide an output of the interaction of virtual objects manipulation by users. In VIDEOPLACE, the output was on a different screen but in DigitalDesk output was projected back onto the screen being used. A DigitalDesk Calculator prototype was used to test the working of the system, where the calculator appearance was similar to a physical calculator with predefined numbers. User's input numbers using finger touch or any pointing devices, by pointing at the number they want to input, which the developers referred to as "Tangible Manipulation". A rectangle appears in front of the finger, showing the number being pointed at. When the finger taps on the number, the camera reads the number then the calculator outputs the number.

Portfolio Wall is an example of vertically oriented display which was used for making changes on automotive sketches [Buxton et al. 2000]. The wall was 50-inch with a resolution of (1,280 × 768) and was touch enabled. It was mainly for public access and anyone in the design studio could use it. The new millennium brought about the possibility of actual implementation of large touch screens and interactive displays. This was mainly made possible by the need to use public screens to promote awareness and enable information exchange.

Semi-Public Display was used by a small group within a confined space [Huang and Mynatt 2003]. The screen was used for information exchange and awareness, where by several information could be displayed on the same screen at the same time by dividing the screen. The interface enabled users to use touch interaction. Lemur is one of the large multi-touch displays that is used by deejays for music control [JazzMutant 2014]. It has a 20-touch capacity which enabled two users to use the interface at the same time. DiamondTouch is a multi-user tabletop display that allows several users to use the screen without any interruption [DiamondTouch, 2001]. The chairs round the table top are connected to the display in order to show the point of touch by every user. This is made possible by the pressure exerted on the seat being transmitted back to the screen. When a user touches the screen, frequency from the users' body is collected by the chair which is then sent back to the screen, thus showing where each user is touching. Other Multi-touch displays that were also deployed into the market during the millennium include: [Microsoft 2014], an 82-inch display, [Paravision 2014] a 200-inch display, just to mention a few.

The first touch screens were already introduced in the early 1960s [Ardito et al., 2015], but due to technology advancements the actual implementation of large touch screens and interactive displays was made possible in the millennium. In 1965, a light pen was used to operate a cathode ray tube computer displays which increased the speed of computer interaction [Johnson 1965]. Through use of wires in the CRT, the researchers were able to test display sensitivity. From 1960-1975, PLATO (Program Logic Applied to Teaching Operations) project in University of Illinois successfully developed a large computer based education plasma display [McWilliams 1972]. The display size was 8.5 inches with tactile abilities.

In 1976, the touch input technique was first realized, for it to work user had to exert some pressure on the screen so that friction is created between the screen and the finger [Herot and Weinzapfel 1978]. The pressure and angle of the finger was used to determine and improve touch gesture. In 1985 came the introduction of using body movements as a form of data input [Krueger 1985]. This technique was used in the VIDEOPLACE project which was one of first artificial intelligence where children were the main users of the system. The system could detect when users' finger touches an object and it also supported multiple fingers interaction technique. Fingers could be used for selection of objects, moving the objects, typing and zooming objects. Most of these early touch enabled screens used cathode-ray tube and plasma technology and they were still small in size.

In the 21st century came the introduction of Ubiquitous computing, where computers come in different sizes and perform different tasks [Weiser 1991]. Furthermore, computing can be done anywhere and anytime in contrast to the traditional computers. This led to the introduction of large and small displays that can be manipulated from a vertical and horizontal orientation.

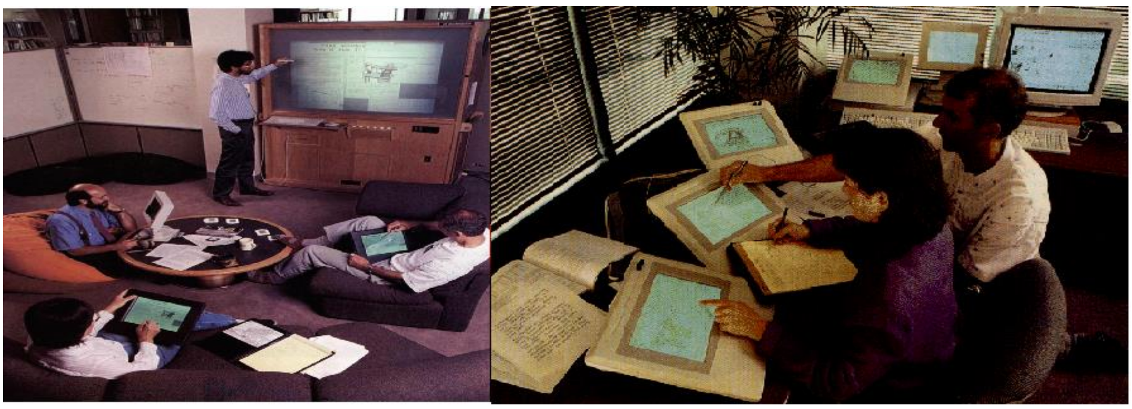

Figure 1. Live walls and scratch pads prototypes invented at the Xerox Palo Alto Research Center as alternatives for computers. They could be used on both horizontal and vertical orientation [Weiser 1991].

2.2 Touch Interaction

Touch interaction is the most direct and easy form of human centered interaction. It is also the most used mode of input currently integrated in most commercial devices such as information kiosks and ticketing machine. For touch interaction to happen, no external hardware is needed (e.g. a mouse). Although touch interaction has been found to be error prone in most cases, for instance a finger cannot select items smaller than the finger width and often times the finger or hand obscure some parts of the screen. For these reasons, it has not been possible to implement touch interaction in medical equipment and aircraft control where a single wrong touch can be very catastrophic. Prior research has been geared towards improving touch interaction to work like a mouse input with one-pixel selection points [Moscovich, 2009 & Potter et al., 1988]. In order to avoid some of the drawbacks from touch interaction, the screen issues constant feedback of finger pointing position. Enabling users to move the cursor to any part of the screen during the touch interaction would also provide the effect of a mouse input. One of the main problems experienced on touch screens as mentioned above is finger selection where the width of the finger is bigger than the object to be selected.

Zoom pointing is a technique that has also been used to improve touch interaction. It has been used for selection of 0.8mm small objects on the screen. Using a single finger, the user draws a rectangular outline around the area to be selected; the area is then zoomed to allow selection. In the same research, Cross Lever selection technique was also used for selection of small objects. Two lines are created on the point of touch from the first tap on the screen. Both lines can be adjusted to form a new intersection. The results showed that zoom-pointing was considered to be a fast mode of selection and with lower error rate. Offset cursor is another technique that was used in improving touch interaction. It was used for the selection of targets bigger than 3.2mm. During tapping tasks, the finger often times occludes the items being selected. This technique enabled finger selection without visual feedback [Albinsson & Zhai, 2003].

LinearDraggger is another approach that has been used to perfect touch selection. It was introduced for selection of object which are clustered together. The user uses the touch-drag-release technique for specific selection. The first step is to tap the screen then the section is zoomed out. The user is then able to scroll through the objects by dragging the finger through the objects. Nonetheless this approach could not be used to select multiple objects [Au, 2014]. These studies showed that touch interaction technique was introduced and will continue being used as it has proven to be easy and a natural way of object manipulation. Other techniques invented for target acquisition include: Tapping with a second finger to zoom out a smaller section [Olwal et. al, 2008], using two hands to zoom out a small target section [Benko et. al, 2006], “TouchCut” for a single selection and “TouchZoom” for multiple object selection [Yang et. al, 2011].

Pseudo-Direct Touch is a touch approach that was used to enable direct touch of the screen and avoid obstruction of sections of the screen. Users interact with a touch frame that is placed in front of the actual large screen. The touch point on the frame is then projected on the large screen where it is clearly visible. The touch frame was used to improve the accuracy of object selection. The frame is small hence items are within arm’s reach as compared to the large display. However, slight body movement caused a mismatch between finger touch and target object on the large display [Müller-Tomfelde et.al, 2011]. Further research on direct touch approach was done by Voelker et.al [2015] where horizontal and vertical screen were used at the same time. Manipulation were done on the horizontal screen and the actions are shown on the vertical screen. This study concluded that dragging technique is easy through direct touch and implementation of both horizontal and vertical orientation.

Latency effects have also been a focus area in touch input. It was concluded that increase in latency leads to decrease in user performance. Latency may originate from the screen itself, the software being used and the sensors that register the touch input [Ng et. al, 2012]. Ng further states that in modern touch screen the latency is between 50ms to 200ms. In the research they used a low-latency sensor and a projector which had a dedicated processing system. The operating system was replaced with a custom programmed system. This setup was able to reduce latency levels in dragging tasks to below the usual latency (50ms to 200ms). Jota et. al [2013] research concluded that latency was reduced to 20ms for tapping interactions hence why many touch devices e.g. Android and iOS have settled for tap as the main input technique. Nancel et. al, [2016] used prediction techniques compensate for latency. In the same research, they evaluated some of the “Next-point” prediction techniques e.g. Taylor series, Heuristics approach, Kalman filtering and curve fitting (prediction is based on recent touch points). Prediction of users’ next step was visualized to prevent users from noting system latency. Henze et. al [2016] used prediction of users next touch position to reduce end-to-end latency which is the delay between a touch action and a visual output of the action done. The results show that the prediction of users' next step reduced latency with low error rate and it increased speed and throughput of dragging tasks.

Multi-touch languages are on a developmental process to be able to support interaction gestures. Interaction techniques have made multi-touch displays and public displays cost effective since users do not have to use extra hardware when interacting with the interface.

2.2.1 "Drag and Drop" technique

"Drag and Drop" is the main interaction technique used to resize windows, scroll a long document, pan a map and sometimes move icons to different sections of an interface [Appert, 2015]. "Drag and drop" interaction is a technique commonly used on touch-operated devices and it can be easily learned. However, there are challenges that come with the use of "drag and drop" on large screens. Increase in display sizes for example makes users unable to access items which are beyond their physical limit [Doeweling & Glaubitt, 2010]. Increased distance on large touch displays makes "drag and drop" technique difficult to use. When the user accidentally loses contact with the item being dragged, the operation is cancelled or the item lands on a wrong screen area. In research comparing dragging technique on both vertical and horizontal orientations, dragging on a horizontal surface was considered faster than on a vertical surface. This was due to high error rates on vertical surface, participants were more able to reach targets on a horizontal display [Pedersen & Hornbaek, 2012]. In the same study, dragging was considered to have more fatigue on a vertical surface. Users also stated that it was difficult to maintain contact with the vertical surface while dragging.

Semantic weights have been found to have significant effect of "drag and drop" task. Physical objects have distinct weight in the real world for instance a car is considered heavy than a ball. When it comes to touch interaction, a user would move a car image faster than a ball image since the car is expected to be heavy [Aslan et. al, 2013].

2.2.2 "Hold" technique

Time is an important property to be considered in interaction techniques. For instance, in multi-touch input process, "hold and move" has been found to have a shorter dwelling time as compared to touch and drag interaction [Kulik et al., 2012]. Kulik states that "touch and drag" interaction has a dwelling time of 130ms. Due to this, he opted for "hold and move" technique using two fingers. The first finger holds the background and the second finger selects and moves the item making an average dwell time of 55ms thus long taps are avoided. This technique was preferred by many users of the system since it was very fast when dragging objects on the screen. “Press and hold” was a mode switching technique that was tried on a pen-based user interface [Li et al., 2005]. Users pressed the pen to the touch screen which was the “hold detection” phase and it was one second long. Once the one second passed, a red ring feedback appeared around the pen touch point, thus notifying the user that they have entered the “hold through” phase where a pop-up menu appears, and users could do further selections or quit the selection. The hold through phase lasted for 800ms.

2.3 Multi-touch displays

One of the next steps in the development of interactive displays after the invention and popularization of touch displays was to involve multi-touching. While traditional touch displays were designed for a single touch or interaction to occur at a time, multi-touch displays could admit several inputs at the same time. These multi-touch devices opened new possibilities and ways to interact with displays, the interaction was not restricted to one thing, it was possible to involve more interactions and therefore more ways to communicate with users. Nowadays, multi-touch displays are a convenient tool for collaborative work, multi-user interactions and several more things. Many environments have enhanced their work with the use of multi-touch displays.

2.3.1 Multi-touch display history

After the introduction of touch interaction technique, researchers came up with new technologies that could support multi-touch interaction on a larger display. In 1976, Massachusetts institute of technology came up with a keyboard that could support multi-touch senses [Kaplow & Molnar, 1976]. This was counted as the first multi-touch surface to be invented. Later on, in 1982, MIT developed one of the earliest multi-touch displays. Light was projected on a glass and the glass recorded the touch point after detecting the pressure exerted by the finger. Several users could use the display for basic tasks like drawing. The drawings were then projected on a different display for viewing [Mehta, 1982]. In 1982 more research on implementation of multi-touch was carried out in university of Toronto and the first human-touch input was realized. A camera was placed behind a glass and whenever users touch the glass a dark point is formed, and this was counted as an input [Buxton,1982]. In 1984 the first multi-touch tablet was developed by

Buxton [1984]. This was said to be thinner and less bulky and cumbersome as compared to the previous version which was using camera and glass.

Krueger [1985] introduced multi-touch gestures e.g. ("Pinch-to-zoom") which are still being implement to date. During the same period, DigitalDesk came up with multi-touch gestures that worked the same way as Krueger's. It supported multi-touch and the "pinch-to-zoom" multi-touch gesture [Wellner 1991].

In the twenty first century many companies began the actual implementation of multi-touch interaction as a new mode of screen interaction. For instance, iGesture [Westerman et.al, 2001] and TouchStream keyboard [Shanis & Hedge, 2003] were developed by Fingerworks which were later bought by Apple.

Other millennium multi-touch system included; DiamondTouch, the first multi-touch system that could differentiate users point of touch. As explained earlier, user's seats were connected to the screen and it could sense the pressure exerted by the user during interaction [DiamondTouch, 2001]. Dohse et al. [2008] introduced a multi-touch system which could sense user's interaction points. A camera was mounted on top of the screen and it could track the hands of the user during interaction in order to know the actions by different users. As earlier discussed, [Peltonen et al., 2008] is one of the systems that supported multiple fingers at the same time. The fingers could be used for zooming and rotating bjects. Kim et al [2010] created a system that supports multiple touch at the same time on a tabletop screen. This mainly enhanced collaborative work and improved usability through direct manipulation of objects.

2.3.2 Territoriality

Several studies have been carried out in the recent years concerning user interaction on large displays. In these studies, territoriality has been an important focus area in large displays. Presence of interactive screen in public spaces has raised questions with space sharing. As technology keeps changing new techniques are being utilized to enable ease of use, space sharing and ease of access of screen icons**.**

In order to understand territoriality, we will first introduce screen orientations which brought about the question of territoriality. Large displays research has been further narrowed down to horizontal and vertical orientations. Horizontal displays for instance has been used in offices as a table top mainly for collaborative work. For example, Liveboard, an interactive display for group meetings [Elrod et al., 1992]. BlueBoard a touch enabled plasma display that supports collaborative work between colleagues

[Rusell, Drews & Sue, 2002]. Research on collaboration on tabletop [Scott et al., 2004]. Horizontal displays have also been used in tourist information office for walk-in tourists [Marshall et al., 2011]. Vertical displays have been the main orientation for traditional desktops. Currently they are on shop windows for example WaveWindow [Perry, 2010], in universities [Hardy et.al, 2011].

Display orientation has brought about the question of territoriality. Kruger et al. stated that tabletop orientation and positioning of items on the screen enabled users to maintain their personal and group space [Krueger et al., 2003]. Screen partitioning has also been used as a form of defining user territories on both horizontal and vertical orientation [Scott et al., 2004]. When it comes to vertical orientation, users are more cautious to invade other users personal space in a public display [Azad et al., 2012].

Proxemics zone interaction has also been studied as a form of determining territoriality. Proxemics interaction is a term that was introduced by Ballendat et al. stating that position, orientation and movement can be used as an interaction controller on displays [Ballendat et al. 2010]. Anthropologist Hall came up with four proxemics zones (intimate, personal, public, social) that explain how individuals define interpersonal space [Greenberg et al., 2011]. Scott et al. also defined three zones (personal, group and storage) from their research on using tabletop for collaborative work [Scott et al., 2004]. Little research has been carried out on proxemics zone definition on vertical orientation. At this point it is unsure to say that horizontal orientation proxemics zone findings can be implemented on vertical orientation [Azad et al., 2012].

Social interaction has also been studied when defining territoriality. CityWall is a large multi-touch screen that was deployed in one of the busy streets of Helsinki. Users attracted passerby's and they were drawn to use the screen. This curiosity led several users wanting to use the screen at the same time, thus creating personal space tension. Turn taking was considered to be an effective mode of interaction to avoid invading other users' personal space [Peltonen et.al, 2008].

When it comes to orientation preferences, horizontal display has been considered to be comfortable for collaborative work since users are able to sit around the display and for longer period without getting the fatigue from standing. It also had less demand on physical movement. Dragging of item on a horizontal orientation is considered faster with low error rate. [Shen et al. 2003; Pedersen & Hornbaek, 2012]. On the other hand, Vertical orientation was more preferred for short and fast tasks. This orientation enabled users to reach a bigger area of the screen. It also caused the honey pot effect hence drawing other users to a public display. Tapping on a vertical display was also considered faster as compared to horizontal screen. [Li et al. 2000; Ardito et al., 2015; Pedersen & Hornbaek, 2012].

Wallace et al. questioned the use of territoriality and proxemics zone when it comes to defining interaction and personal space on public displays. He stated that the size of the screen is the actual determinant of interaction and definition of personal space. He concluded that further research needs to be carried out on whether the size of the display affects personal space [Wallace et al., 2016].

Other researchers came up with new concepts of space sharing and definition of private interactive areas. Elhart et al. [2015] came up with a concept that supports space sharing and applications selection by multiple users on public display. Users stand in front of the screen and their shadow is projected back on the screen which in turn becomes their personal interactive area. Users could drag and drop applications into their private area. This also supported the use of same application concurrently by multiple users. Dynamo system is a system that also supported space sharing. The platform was developed to support socializing and sharing among high school students. Users needed to attach an external device (pen drive, camera) where they could retrieve their media for sharing. The system allowed users to create caves which became their private owned area where they could interact and share with their close friends [Brignull et al., 2004].

2.3.3 Menu accessibility

Increase in display size means items (e.g. menu) will be beyond arm’s reach an issue that was never experienced in traditional desktops. Menu sharing mechanisms have been studied in order to support and improve collaboration on large displays.

In earlier multiple user touch displays, menus were locked to only one users at a time. Zeng and Zhang [2014] decided to provide every user their own context menu to avoid conflict during menu demand. Leftheriotis and Chorianopoulos [2011] came up with a chorded menu that would work well on a multi-touch display. Users place multiple fingers on a specific section of the screen and the menu would move to the point of touch. Therefore, users could access the menu at any point of the screen.

Hesselman et al [2009] implemented a half-pie menu for an interactive tabletop. They opted for a half-pie since a full-pie menu have been said to occlude users’ interaction areas. The half-pie menu was hierarchical, once opened it had deeply nested list of items. This in the end still occluded sections of users’ interaction areas.

There is limited research on menu accessibility and sharing on large displays. Researchers have raised questions concerning menus containing adequate applications that meet the needs of a public display and multi-touch screen that support easy and quick menu accessibility for collaborative work.

Over the years, large screens have been produced in high numbers making them less expensive and easily accessible. Increase in screen sizes led to the introduction of new ways of interaction and role of the screen in different sectors. Touch interaction was one of the earlier interaction modes used on these large screens and they are still the most widely used mode of interaction on large screens compared to gestures. For instance, “drag and drop” interaction has been used in touch enabled smartphones and screens for panning, scrolling and moving items around the screen. Large displays also brought about the multi-touch screens to support multiple users and collaborative work. Multi-touch displays brought about space sharing and territoriality concerns. Proxemics zones and territoriality is a concern that needs to be defined especially in multi-touch displays. A couple of multi-touch screens have partitioned screens as a way of defining different territories of interaction. Screens without partition force users to create their own territories this has often led to personal territory invasion. Further research and development need to be done to address space sharing concerns especially with the increase of multi-touch displays in public spaces. Menu accessibility has also been brought up in a multi-touch display. Increase in large display make it difficult to reach items e.g. menu that are beyond arm's reach. Menu should be readily available to all users in a multi-touch display.

3. Smart campus

Habitat III is the third United Nations conference that focused on housing and sustainable urban development. The conference's main focus was on drastic expansion of cities without better planning which has led to environmental degradation and heightened chaos for example physical risks like air and transportation deteriorating [Nam & Pardo, 2011]. This pushes for the urgency of creating smart ways of managing these challenges [Clos, 2017]. This Chapter introduces the smart campus concept. We will start by explaining what smart campus is all about and some prior implementations of smart campus.

Some researchers preferred the term "smart" technology rather than "intelligent" technology saying that they considered smart technology to be more user-friendly while "intelligent" is seen as having a quick mind and being responsive to feedback [Marse-Maestre et al., 2008]. Therefore, smart technology adapts itself to user needs and provides customized interface. According to some marketing researchers, the term "smartness" is centered on user perspective. "Smartness" in technology context implies to the automatic computing principles for example self-configuration, self-protection, self-recovery and self-optimization [Spangler et al., 2010]. This leads to sustainable development, economic growth and better quality of life for people as some of the aims of smart technology [Center of Governance, 2003].

According to Abuarqoud et al, [2017] smart campus originated from the idea of having smart cities. Technologies and implementation methods used in smart cities was used to develop smart campus with the thought that a campus is a small town [Smart Campus, 2014].

Smart campus is an emerging trend [Abuarqoud et al, 2017] that is already being adopted by several universities. For instance, Birmingham City university spent $260 million dollars on the implementation of smart campus [City, 2016]. They were able to make energy cost savings of £140 thousand. University of Glasgow is making plans to invest £800 million on smart campus [Ginty, 2015]. They also aim at making the university a sustainable environment. Pakistan government announced that thirteen universities will be converted to smart campus by the end of 2017 [Riazul, 2016]. The government has started by ensuring that every university dweller has access to Wi-Fi around campus. The next phase will be to use available resources in order to control energy consumption.

When compared to traditional campus, smart campus aims at providing information at a fast rate, with less effort and at a low cost. This is made possible by using advanced technology that monitor and control campus facilities. Furthermore, this has increased the efficiency of the campus, better space utilization and decision making, thus improving student experience. University of Brescia [De Angelis et al., 2015] started a project on constructing smart buildings that aim at energy efficiency through use of smart grid management, controlled systems and automation. Aalto university developed "AaltoWindow" (figure 2) multi-touch interface as one of the projects for smart campus learning hub [Aalto, 2011]. The main aims of the interface were to provide a virtual interactive window for the different geographical locations of the campuses and students, to increase collaboration, interaction, and support learning by providing course works, lecture and workshops.

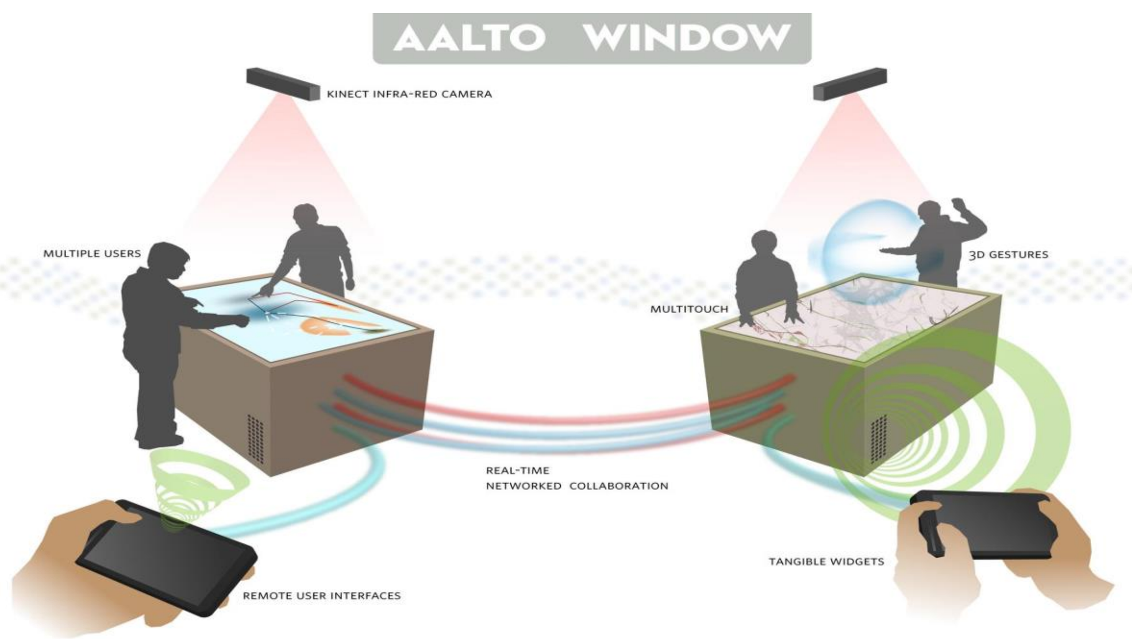

Figure 2: AaltoWindow interactive displays interconnected to support collaborative work.

Smart campus has been said to have some impact on the learning and teaching quality in universities [Aionet al., 2012]. Both smart and intelligent technologies have helped improve operations in the university. It was discovered that smart/intelligent campuses have provided easy access to support learning and research. According to one of the research [Jameson & Riedl, 2011], an intelligent system is one that is capable of performing tasks that have been traditionally done by human for example ability to learn, perceive, interpret, use language, reason plan and decide.

With reference to Malatji [2017], smart campus has to have characteristics and key performance indicators which include; smart education, smart environment, smart people, smart mobility, smart living and smart economy. Smart education is where the campus provides smart solutions that improves the learning ability of the students and improve performance of researchers. This is also made possible by creation of online platforms that aid in course delivery. Smart environment, where the campus utilizes smart technology that will aid in efficient use of resources. Smart people will be able to interact with the smart technology and together with the smart campus they form a smart community. Smart mobility, in a smart campus setting public transport is more encouraged to conserve the environment. Smart living is where the living premises of students is well monitored for example through internet of things where all gadgets are connected. Smart economy, where the campus is able to commercialize its research as a way of generating income.

Smart learning environment was said to provide a learning architecture that connects, interacts and share three major learning dimensions; learning collaborators, contents and services [Kim & Yoon, 2009; Zixue Cheng et al., 2005]. These learning collaborators, content and service can be made possible through public displays which are easily accessible by university dwellers. For instance, History-Puzzle is an example of large vertical display that was used by children to learn history [Ardito et al. 2013]. The children were given a set of incomplete sentences which appeared as a set of tiles on top of the puzzle (as shown in Figure 3). There were other sets of tiles on the left and right side of the puzzle where students were asked to select in order to complete the sentences. Once all the incomplete sentence was completed the puzzle piece is revealed. Several students could collaborate together towards solving the puzzle. The results showed that the system stimulated the student to get involved in playing and in the end, they learnt some history.

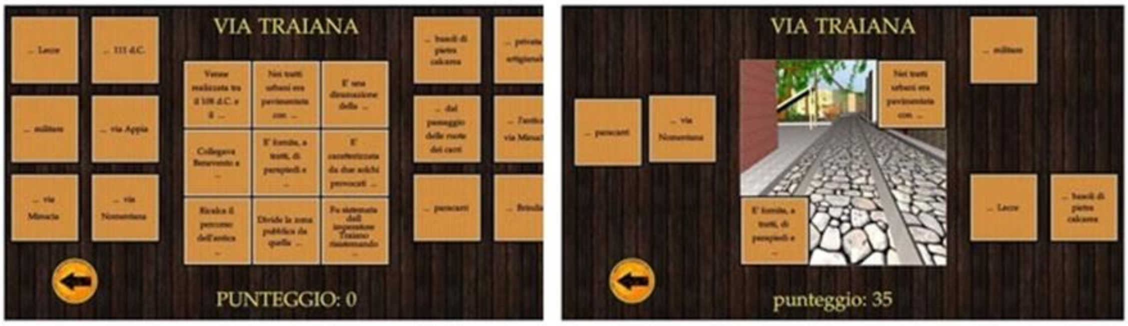

Figure 3. History-Puzzle; left image covered puzzle to be resolved by completing the sentence, right image puzzle revealed after sentences have been completed.

BlueInfo is an example of a public display deployed in Oulu University campus where users could search for information and transfer it to their mobile phone through Bluetooth [Kukka et al., 2011]. The displays were placed in busy locations of the university for easy access for instance cafes, restaurants and corridors. Users' were required to switch on Bluetooth on their devices, they would then navigate through the screen and once they found information or articles that they would like to continue reading, users selected their device from the list of devices found and the information was transferred to their phones.

In recent years, studies have shown that interactive surfaces have worked effectively for students with a short concentration span, which is a common problem for university students in this technological era [Smart, 2007]. Students are presented information given in a digital form for example use of images from interactive screen, computer monitors, television screens. In the study, students that used interactive surfaces for learning were more enthusiastic and more interested in the course than students who were taught the traditional way.

In the age where smart technology is being applied in all sectors, it comes as no surprise that universities are embracing the idea. New ways of utilizing smart technology keep coming up daily, and for our case we wish to apply the idea on public displays in a university setting. In the meantime, current public displays face a competitive advantage over similar models and in meeting smart campus needs.

4. Design of My AppCorner.

This chapter focuses on the design of My AppCorner and its objectives in order to produce a satisfactory smart campus system. My AppCorner was developed to breach the gap left by multi-touch displays in public spaces. It was born with the idea of building an interface that would support multiple users, ensure menu accessibility for all users, provide screen territoriality, use of same application concurrently and at the same time provide a sense of ownership to the users. There were interface implementations focusing on different public spaces. The initial interface was focused on a mall public space with the aim of providing mall information e.g. mall map and advertisements.

4.1 Previous version of the interface

The first version of My AppCorner [Fabregat et al., 2016] was developed and published in 2016. The first version had the goal of providing information in a general public setting and supporting multiple users. This version was made using MT4J (Multi-touch for Java). The components were made using OpenGL for drawing. The interface was compatible in any platform that uses WM_TOUCH (Windows 8/Windows 8.1). Touch was the main interaction techniques. The user drew a diagonal line on the screen using one finger and a rectangular outline was created on the edges on the diagonal line. This rectangular area became the private window. There was a circular menu which was mobile, and it contained applications disposable to the user (as shown in Figure 4). The user dragged and dropped the application from the menu to the private window. The private window could be moved to any section of the screen by dragging. The user could also touch a specific section of the screen and the menu moved to the point of touch. The menu could also be dragged to any section of the screen. The private window could be rotated to different directions of the screen. Screen rotation was mainly applicable on a horizontal orientation.

The system was tested on a 72” and a 62” multi-touch screen in a vertical and horizontal orientation. The interface initially utilized five applications: ice hockey game, 3D car manipulation, puzzle, two apps for creating shapes and colors. Through these applications, it was possible to test the functionality of the interface.

The initial interface was designed with the idea of public space in general [Fabregat et al., 2016]. The main targets were shopping malls, tourist information booths, and train station waiting lobbies. These public spaces are often occupied by different users.

The decision to incorporate games was to appeal both kids and adults. The shopping mall interface included a mall map, ongoing sales, news feeds about mall and information about the different shops. Tourist information offices contained maps on the city and information about attraction sites of the city. As for the train station, the interface contained train and bus timetables, information about the city, map of the city and nearby shops and restaurants. The new interface was redesigned with considerations of a smart campus environment.

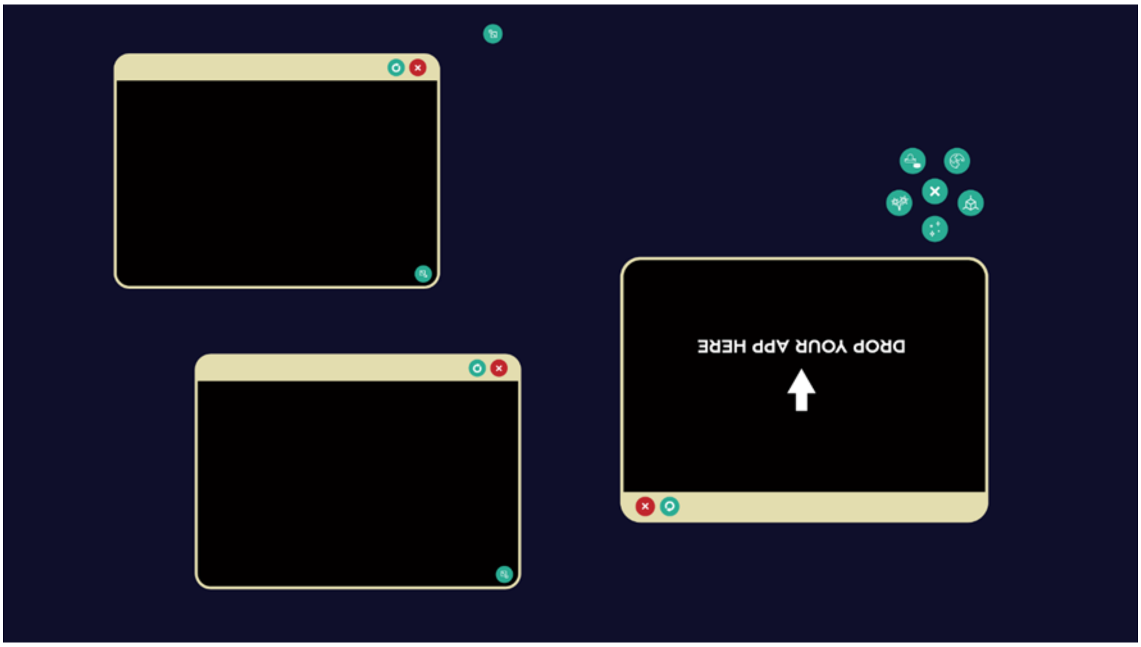

Figure 4. Appearance of the first version of My AppCorner Interface showing active private windows and a circular menu containing five applications.

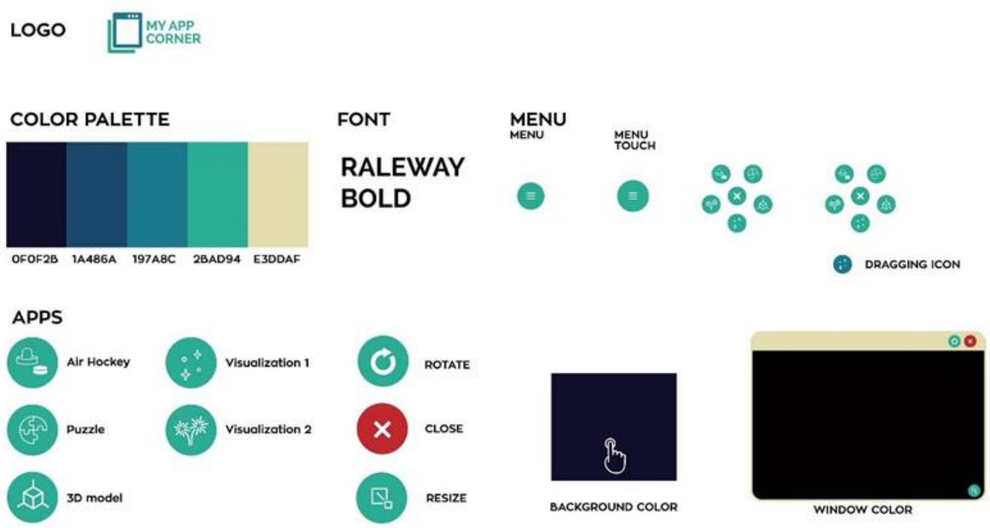

Figure 5. UI Style sheet of the first version of My AppCorner.

4.2 New version of the interface

A new My AppCorner interface was redesigned using HTML. It still carries out the same functions, where users are able to create their own private windows and drag and drop applications into the private window. However, the applications were changed to meet the needs of a smart campus environment which was the main focus. From a smart campus perspective, the system mainly focuses on using an interactive public display to provide information to students, university visitors and university staff

My AppCorner aims to contribute to smart campus technology which is gradually being introduced to the university. The display shifts from the main purpose of advertising to unresponsive audience to providing information that is relevant to university occupants. Thus, the new system was redesigned with action design in mind.

The general objective of the system is to provide a multi-user public interactive screen where users can access campus related information.

Specific objectives:

- Several users can interact with the screen, while using different applications concurrently.
- Users can create their own private window on the public screen thus giving them a sense of ownership.
- The private windows can be created anywhere on the screen depending on user's preference.

- Users can access campus related information

When the objectives of the interface are achieved, the interface will have the following expected outcomes:

- Offering a sense of ownership through creation of own personal window.
- Creating their private windows anywhere on the screen.
- Providing access to university related information.
- Supporting multiple users at the same time.

4.3 Applications used in My AppCorner

Three applications were selected for My AppCorner, these applications were hand-picked in order to meet the needs of a university environment; bus timetable, university newsfeeds and campus map.

4.3.1 University newsfeed

Through the newsfeeds application, students are able to quickly access news concerning the university. They are also able to check various types of course information for instance course content, teacher responsible for a specific course, in which period the course will be offered and course enrolment.

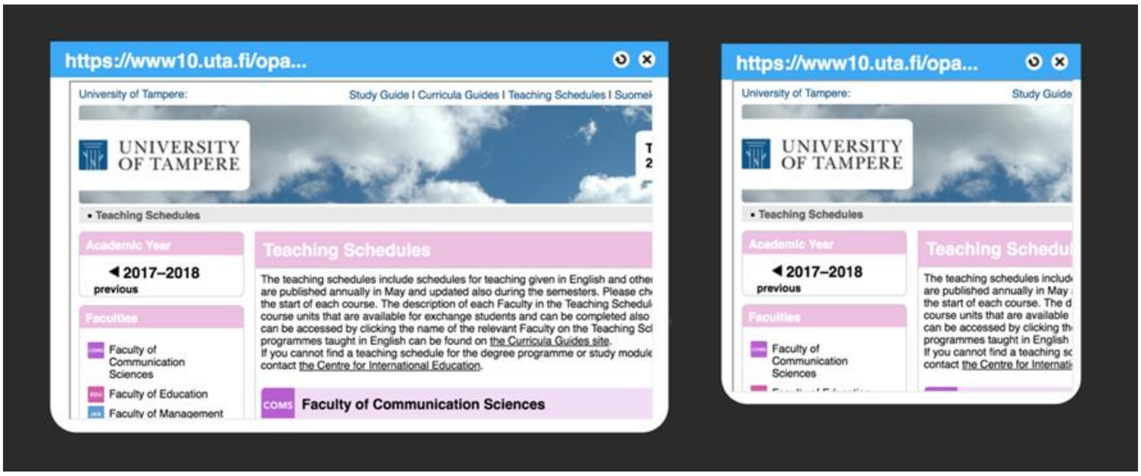

Figure 6. Private window containing University news feeds application.

4.3.2 Campus map

Navigating through the university can be challenging especially for newcomers. Through using the map, students and university visitors are able to locate different areas of the university and also find their way out. The applications include a full Portable Document Format of the university campus.

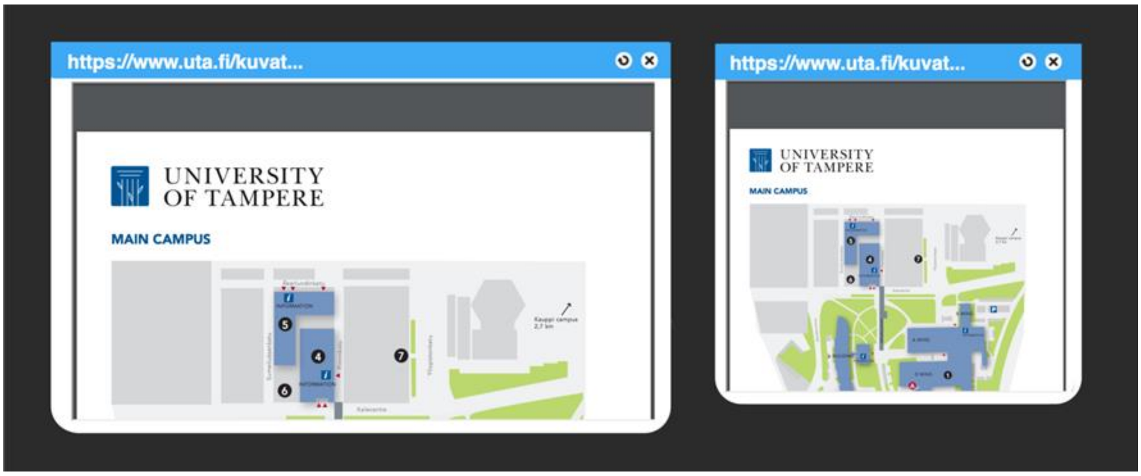

Figure 7. Private window containing Campus map application.

4.3.3 Bus timetable

Most students commute using buses therefore it is important to provide a platform where they can quickly check the bus number, stop and time in respective locations. The bus timetable application redirects to the local transportation website, which includes a service where the user can look for the bus timetables in Tampere.

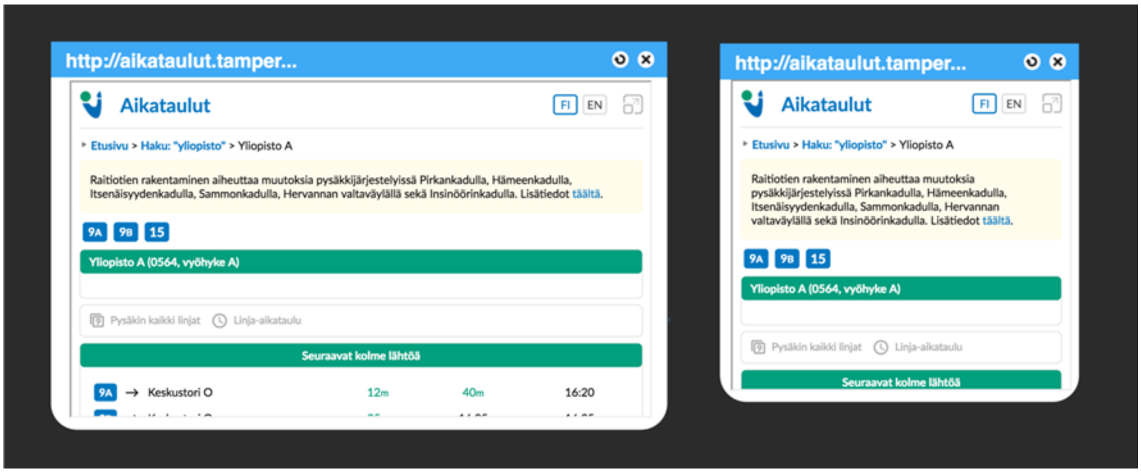

Figure 8. Private window containing Bus timetable application.

4.4 User-Centered Design of My AppCorner.

User-Centered design methodology focuses on having the user as a main actor during the whole development process. The international Standardization Organization defines user-centered design as follows: “User-centered design is characterized by the active involvement of users and a clear understanding of user and task requirements, an appropriate allocation of function between users and technology; the iteration of design solutions; multi-disciplinary design”.

There are different steps that can be adapted to a specific project but, in general each process that involves User-Centered Design should cover these sections:

- Context of use
- Requirements
- Design solutions
- Design Evaluation

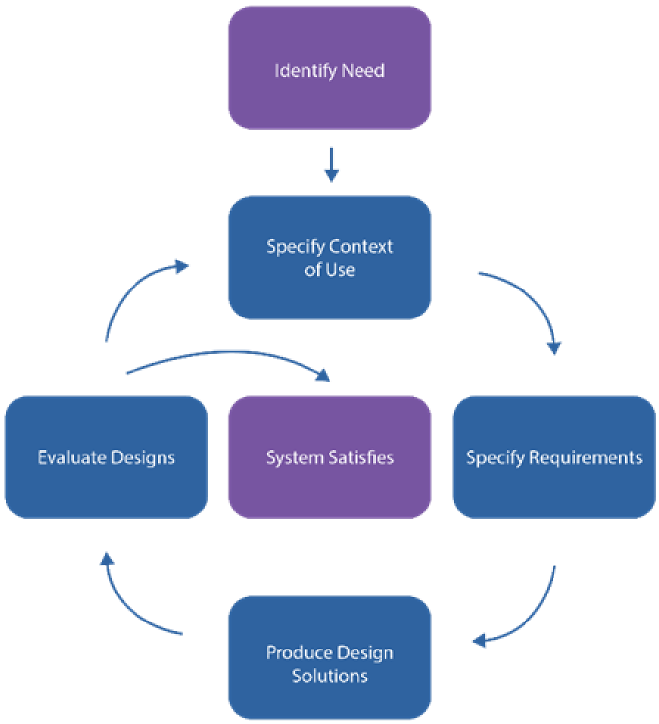

Figure 9. General overview of the User-centered design process.

4.4.1 Process

This section shows an overall image of the process and show the key steps that were important for the evaluation of the system.

We mainly focused on how to organize and present information on the interface for easy usability and findability. For instance, minimalistic visualization of icons was used to represent the different applications.

4.4.2 Context

Environments play a big role in any kind of development. If the target group is not clear from the beginning, the project can easily derail and end-up not achieving the right goals. The university environment has different kind of users, therefore many targets.

There are around 20,000 students at the University of Tampere and around 3,000 staff members, each one of them has different needs. My AppCorner tries to tackle the main problems that students and staff have around the university. We focus our efforts on new students and visitors that need quick and easy way to find information about the university.

4.4.3 Personas

A persona is a fictional character that represents the different types of users that might use the system. A persona is created with the goal of having a realistic representation of the users.

Based on an analysis of the different kinds of users that the university has, two personas were created. These personas cover the main characteristics of the target users.

Figure 10. Persona number 1

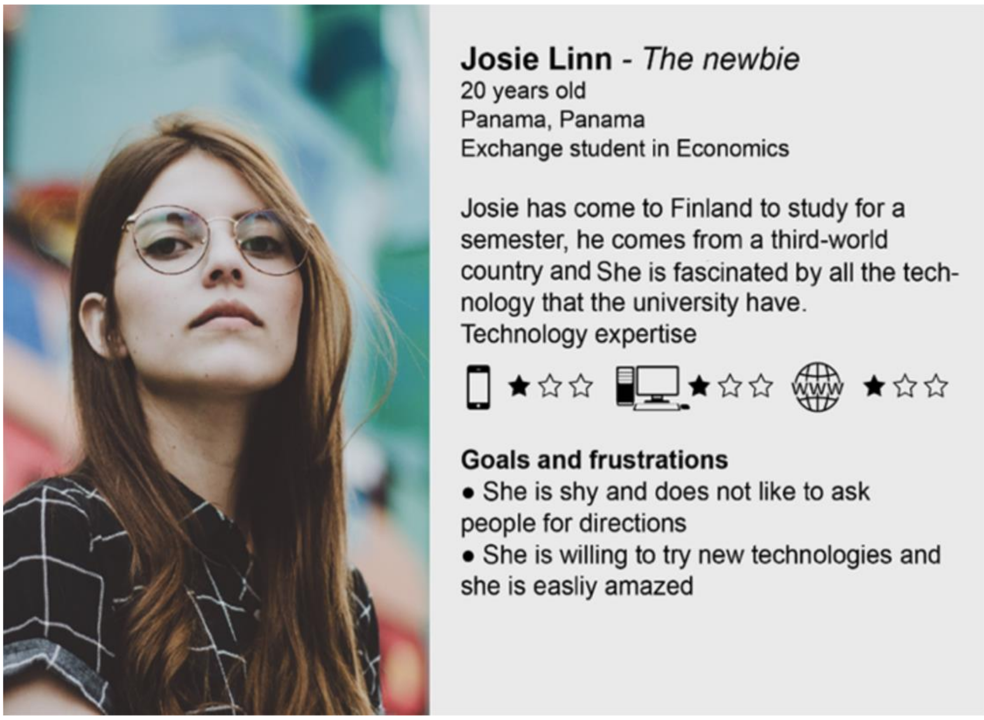

Figure 11. Persona number 2

4.4.4 Scenarios and Use Cases

Scenarios: They are assumptions made by designers. A persona is selected, and a story is told about the problems experienced by the persona and how the system developed will work towards solving them.

Use case: They are a set of steps carried out in order for the persona to achieve a certain goal. They are usually the interactions and actions being carried out between the user and the world. This is usually displayed inform of a table or list with short descriptions of actions being carried out. The “Actor” column represents the actions done by the user and the “World” column represents actions performed by the system.

Scenario Jakko

Jakko is visiting the main building at the University of Tampere for the first time. He is running late, and he has forgotten to check the room of the course that he needs to take. He realizes that a multi-touch display can help him to find the information that he needs (see table 1).

Use case

Intent: Find the classroom

Step 1: User activates the system by tapping the screen

Step 2: User reads the printed instructions that are next to the screen

Step 3: User proceeds to create a window by dragging his finger in a diagonal way

Step 4: User clicks on the menu button

Step 5: User drags the courses icon to his window

Step 6: User releases the icon inside his window

Step 7: User proceeds to find the course that he needs

Scenario Josie

Josie is going home after a long day at the University of Tampere. She lives in Hervanta and does not know where to find the timetables for the bus. It is really cold outside, so she prefers to find out the correct time before going to the bus stop. She finds out that the interactive display at the lobby can help her to solve her problem (see table 2).

Use case

Intent: Find information about the bus routes and times.

Step 1: User reads the printed instructions

Step 2: User clicks on the menu to see what happens

Step 3: System opens the menu

Step 4: User clicks on the menu again and the system closes the menu

Step 5: User drags her finger across the screen and tries to create a window

Step 6: System recognizes that the user is creating a small window and does not allow her to create it.

Step 7: User finds out that the minimal size of the window is color coded. She makes it bigger and the window is created

Step 8: User drags the bus icon to her window

Step 9: User proceeds to find the right bus

Actor	**World**
User activates the system by tapping the screen	
User reads the printed instructions that are next to the screen	
User proceeds to create a window by dragging his finger in a diagonal way	
	System presents a created window
User clicks on the menu button	
User drags the courses icon to his window	
	System provides visual feedback of the icon being dragged
User releases the icon inside his window	
	System shows the course contents within the created window
User proceeds to find the course that he needs	

Table 1. Scenario of persona 1 (Jakko).

Actor	**World**
User reads the printed instructions	
User clicks on the menu to see what happens	
	System opens the menu
User drags her finger across the screen and tries to create a window	
	System recognizes that the user is creating a small window and does not allow her to create it.
User finds out that the minimal size of the window is color coded. She makes it bigger and the window is created	
	System creates window
User drags the bus icon to her window	
	System displays bus timetable on the window
User proceeds to find the right bus	

Table 2. Scenario of persona 2 (Josie).

4.4.5 Interface map

An interface map shows the organization of the elements and all the options and steps that users need to make to achieve all the possible goals of the interface.

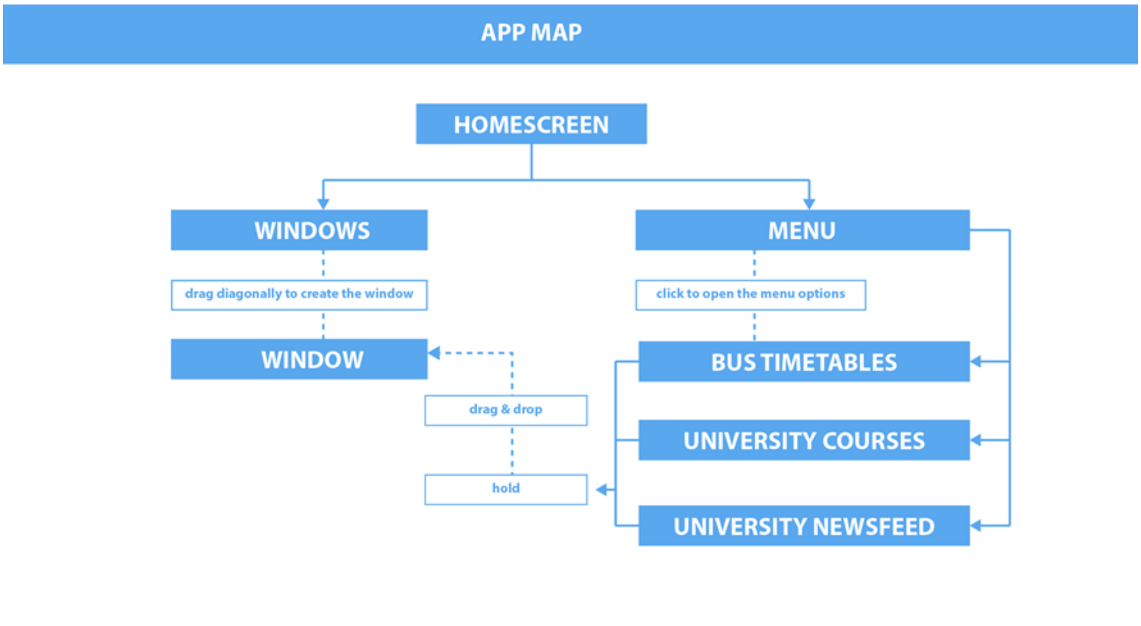

Figure 12. interface map of My AppCorner.

4.4.6 Sketching

We initially did low fidelity sketches mainly for brainstorming, discussions and testing the concept and we were able to explore multiple ideas. Nielsen [2003] stated that it is cheaper to make changes on a sketch than on a fully coded system. Concepts taken into account for the sketching process: minimalistic, simplism and consistency.

We decided to have a rectangular shape private window since it would be easy to create. Items and online pages will also be easily visible in this shape since most online sites have information displayed in this manner. The rotate and closing buttons were placed on the top most far right corner which is the usual position for closing buttons on laptop and computer windows. This was mainly to ensure consistency and standards.

We opted to have a small circular menu that would easily move around the display. This will ensure that it is easily accessible by all users and it does not occlude other user's interaction areas. The Initial menu the user could tap it and it would open to show the various applications available but the current menu there is no option on tapping to open it. The menu is small enough thus there is no need for closing it. When it is open users could easily see the applications present without the worry of knowing how to open the menu. Unlike command driven systems, users do not have to remember the items they need they only need to recognize them (recognition rather than recall [Nielsen, 1995]). For this reason, we selected icons, that represent the applications, that are self-explanatory. The icons were big enough to be easily selected by a finger.

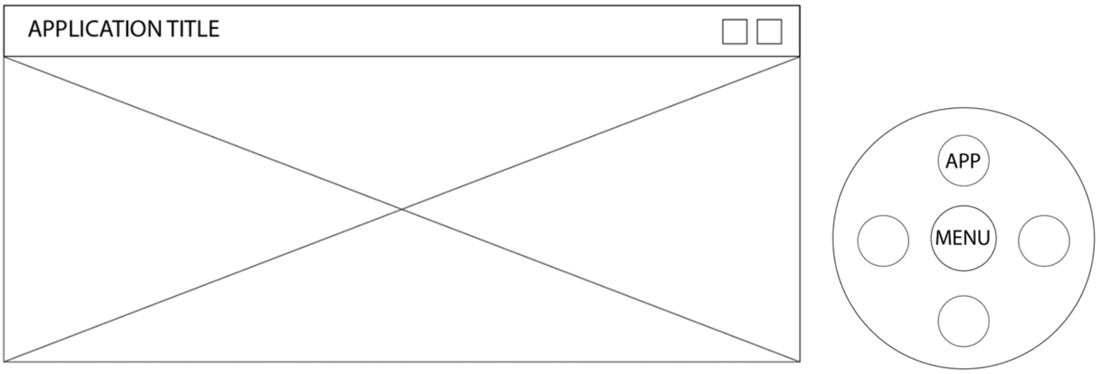

Figure 13. Window and menu sketch.

We sketched the final appearance of My AppCorner with the menu in the middle and an active window. When the interface is run, this will be the initial appearance. A created private window showing the application title and rotating and closing buttons. An open menu with all the visible applications.

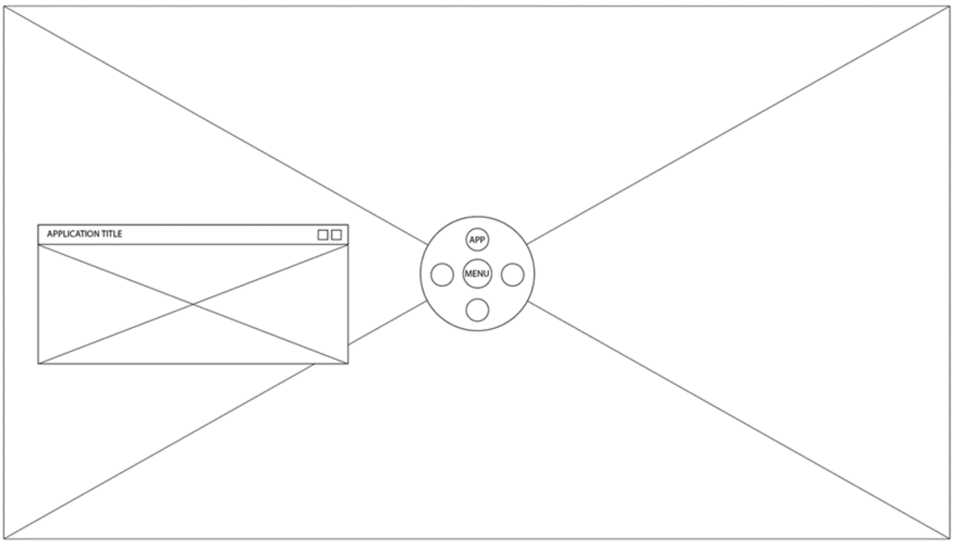

Figure 14. Full-screen sketch.

4.4.7 Prototyping

Prototyping aids in detecting usability issue in an interface [Hosseini-Khayat et. al, 2011]. We made a draft version (high fidelity) of the final product from the sketches to confirm that we are designing the right product.

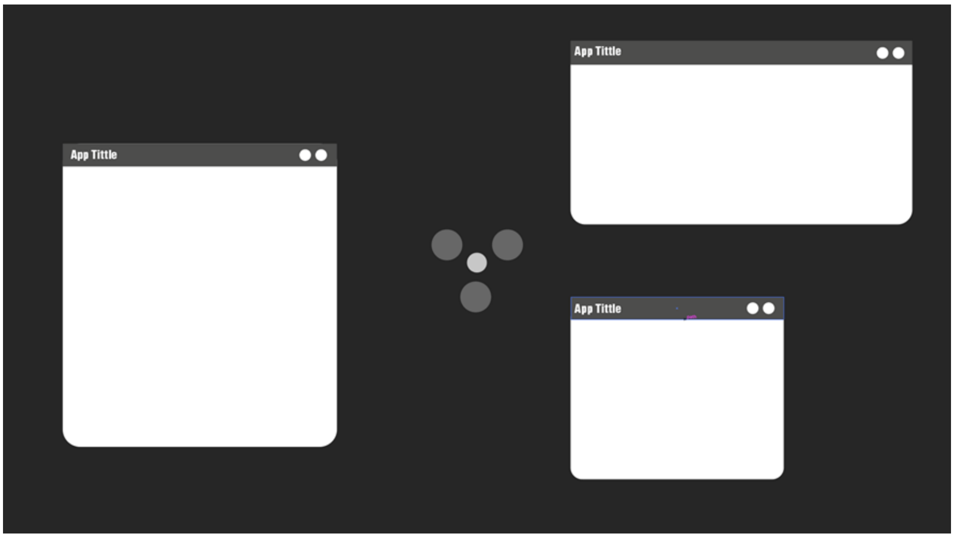

Figure 15. Final prototype of the interface.

4.4.8 Interaction Design of My AppCorner

Interaction design focuses on how the users can interact with the interface. Touch interaction technique was the defined interaction mode on My AppCorner through use of “drag and drop” and “hold” interaction techniques. Clues were issued through the use of shapes and colors during window creation and when dragging applications.

4.4.8.1 Window creation

User creates the private window by touching down on the screen with one finger then dragging it diagonally forming a diagonal line. A rectangular outline is drawn on the edge of the diagonal line which in turn becomes the private window. The minimum size of a private window is predefined, following Fitt´s law [Fitt, 1954] where the objects on the interface need to be of a reasonable size to allow interaction. That is, when a user is drawing the diagonal line, there is a blue outline and once the user goes beyond the minimum defined size, entire rectangle is blue.

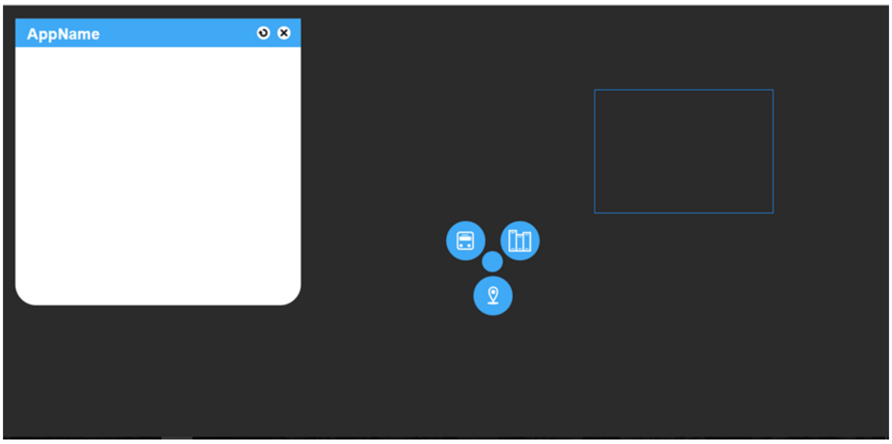

Figure 16. Blue outline for a window in the process of creation

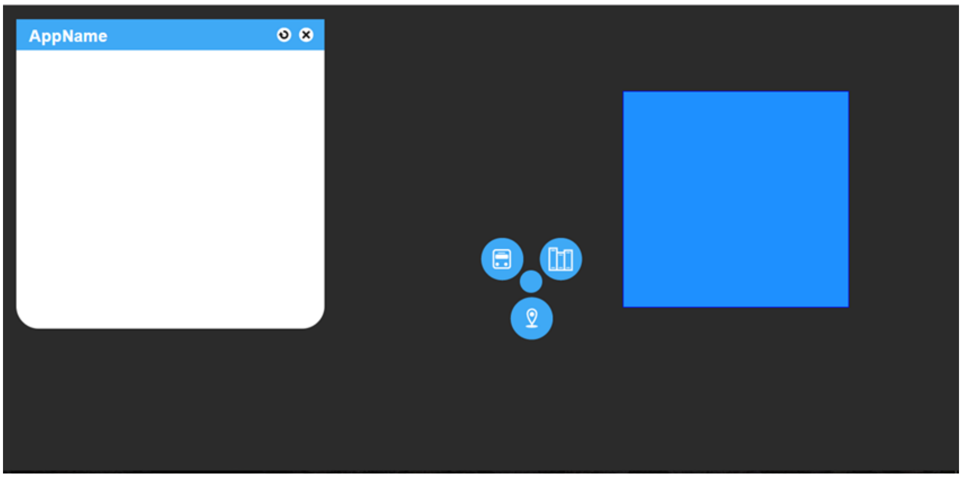

Figure 17. Private screen that has passed the minimum predefined size of a private screen.

The lower area of the rectangle was smoothened out using curvy corners to create a smooth look. The created private window can be moved to any part of the screen depending on the user's preferences. This is made possible through using the "drag and drop" techniques. To drag the window, user touches down on the top section of the window then drags it to the preferred section of the screen. Users are able to navigate through the information on their private window through scrolling up and down. Zooming of the objects on the private window was possible through the use of two fingers dragged on the opposite direction. The typography on the windows were set in that when the window is created, the title on the window is "AppName". Once an application is dragged in the private window, the title changes to the URL of the applications for instance, “http://aikataulut.tamp...” that is if it is the bus timetable app being used.

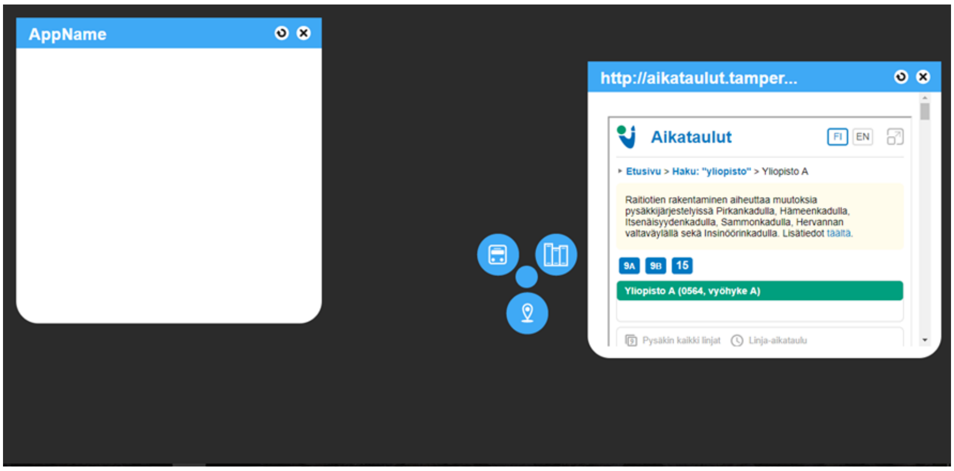

Figure 18. Two active private windows. Left window does not have an app running. The right has an app running hence the App name changed to the URL of the app to notify users which app is being used.

4.4.8.2 Circular menu

We aimed at providing, organizing, labelling and structuring information effectively in order for users to easily find their way in the system. We used the circular menu as an organization structure where users could easily locate the applications. The menu and application icons are circular in shape and they act as the buttons for the interface. Minimalistic visualization of Applications icon will work as a comprehensible symbol for the applications.

Figure 19. Menu icons Representing Bus App, News Feeds App and Campus Map App.

We opted to use a circular menu since it does not occupy a large space on the screen. In large displays, menu accessibility is a major challenge. As solution to this challenge, we defined a way that can make users access the menu no matter the distance. Users need to hold down on a specific section of the screen, where they want the menu to be. After one second of touch down, the menu will move to the point of touch. In our earlier design, we had the option of dragging the menu to desired location and the point of "touch techniques" but the "point of touch" technique seemed to be more effective. Drag and drop has been seen to experience challenges especially if the target is far, users always failed to reach the target hence why we settled for the "point of touch" techniques.

4.4.8.3 Drag and Drop of applications

The user also drags and drops applications from the menu into the private window. Users need to touch down on the application then drag it into the private window. When a user holds down on the application in the menu, all open private windows will be highlighted blue to show that an action is being performed. When dragging the application, a moving icon will be moving according to your touch gesture as a way of providing feedback to the user.

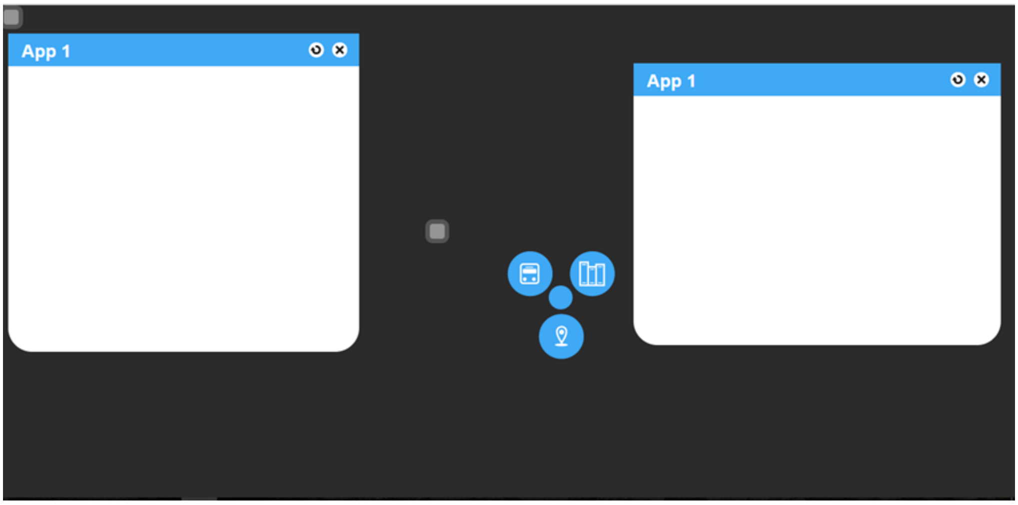

Figure 20. The small grey box is the moving icon providing a feedback for the drag and drop.

If the user fails to reach the target private window and drops the application on open display, the application is moved back to the menu. Several users can use the same application concurrently. They just need to create their own private windows and drag and drop applications. We changed the application to mainly meet the needs of a smart campus setting. The applications that we used include the Tampere bus timetable, the University of Tampere map and university newsfeeds.

4.4.9 Look and feel

In order to build interest of users and provide a valuable and efficient experience, we chose the colors, shapes and images that would give My AppCorner great aesthetics. Minimal design helped to minimize the cognitive load. For instance, the rectangular shape was used to define users´ private window. The textured background was black to ensure that the private windows stand out on top of it.

Figure 21. Final style sheet of the current version of My AppCorner.

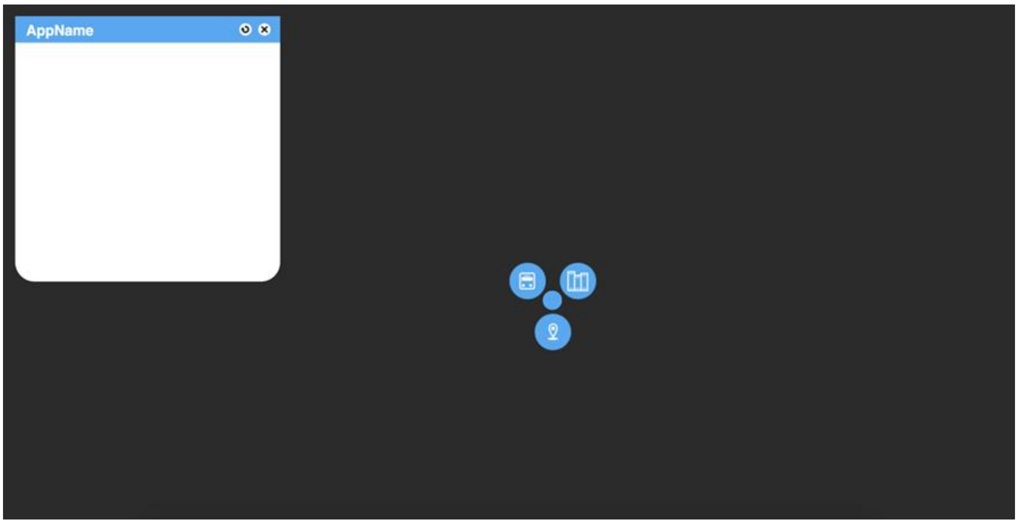

Figure 22. Appearance of the new My AppCorner Interface showing active private window and a circular menu containing three applications.

Improvements were made on the previous version of My AppCorner in order to meet the needs of a smart campus environment. This included the redesign of the interface and using relevant applications for a university setting. We used personas in the initial stages of design in order to understand the needs and expectations of our target users. Although, the system was later tested by target users in order to know their thoughts of the system. The results will be presented in the next chapters.

5. Evaluation

This section describes the experiment of design and the requirements for testing the system. We will first state the participant demographics of those who took part in system testing. Then explain the hardware and software required. The methods we used for information collection and a list of questions and attribute tested will be stated and explained here. The environment where we did the system testing will then be explained. Finally, an analysis of the evaluation will be explained.

5.1 Participants

We recruited 10 individuals between ages 23 to 40 to participate in the interface testing. They were recruited from both students and university staff fraternity since university students and staff will be the main users of the system. Three of the participants were ladies and seven were male. The participants were from the faculty of computing, engineering and languages. The students were all doing their master's degree at the University of Tampere. With reference to familiarity to interactive screens, four participants out of ten had used an interactive screen before our testing, the rest had not. small number of participants had used interactive screen before.

5.2 Hardware and software

A 65-inch CTouch display with a resolution of 1920 x 1080 was used for the testing of My AppCorner Interface [CTouch, 2017] at the University of Tampere. The touch screen has 10 touch points with a response time of 6ms. The interface runs on Mozilla Firefox and Chrome web browser. Due to the touch capacity, up to four users could interact with the interface at the same time without any interferences.

5.3 Procedure

Research approaches have been used over the years (e.g. qualitative, quantitative and mixed approach) for data collection and analysis. In our research, we wanted to focus on participants behavior and thoughts while using and after using the interface. Based on the nature of our research, we settled for qualitative approach since data was typically collected while participants were using the interface or immediately after using the interface. Therefore, we settled on using observation and questionnaires as our research methods.

5.3.1 Questionnaires

Post-test questionnaire were issued to participants for their response about the working of the interface. This was carried out in context after the testers has used the system. Reasons for using questionnaires;

- Immediate feedback was given regarding the interface.
- The moderator could easily request for detailed explanations, clarification and personal opinion regarding the interface.
- To get a clear understanding of participants´ mental model of the interface.

5.3.2 Questionnaire questions

We designed a set of questions to capture users feeling and cognitive perception on the working of interface and the ease of interacting with the interface. Questions 1 to 4 used Likert scale to rate users attitude towards a specific part of the interface. Questions 5 to 9 were Open-ended questions to encourage participants to provide further information concerning a specific section of the interface (see table 3).

	Questions	Attributes tested
Q1	You had to create your own private screen, how was it?	Difficulty/ ease of private window creation. Are there sufficient instructions of private window creation?
Q2	Having a private screen did it give you a sense of ownership?	Benefits of own private screen.
Q3	How was the experience while using the screen with other people?	Supporting collaborative work. Space sharing.
Q4	If you found such a screen in a public space would you use it?	Screen blindness and honeypot effect.
Q5	Have you interacted with both horizontal and vertical orientation? Which one was better and why?	Most preferred screen orientation in this public space, in order to have proper setting for that orientation (e.g. screen rotation on a horizontal orientation).
Q6	How was the menu and drag and drop technique?	Effectiveness of a mobile menu and the efficiency and usefulness of drag and drop.
Q7	What was best experience while using My AppCorner?	Wow-factor of My AppCorner. What was interesting while interacting with the system.
Q8	What features were difficult to use?	Area of difficulty in interface interaction.
Q9	What would you improve on My AppCorner?	User preferences and suggestions of improvements on specific areas of the interface.

Table 3. List of questionnaire and attributes tested in My AppCorner.

5.3.3 Observation

Observation are mostly important when assessing users behavior [Beyer, 2011]. We could easily observe the operations being carried out by the testers. In this way users behave naturally not knowing that they were being observed.

Reasons for using observation;

- Some actions that could not be addressed by the questionnaires were observed during system testing.
- through observation we could notice if there were any intense or cumbersome operations and processes on the interface.

5.4 Tasks

During the testing we requested the participants to perform six main tasks on the display: Window creation, moving the window to different sections on the screen, moving the menu, rotation of window on a horizontal display and work on it from the opposite side of the screen, scan through content of the window after an application has been dragged into the window and close the window at the end. The interface was tested on both horizontal and vertical orientations to see which one is more preferred by users and which orientation will be suitable for a university public space.

After performing the tasks, participants were asked to fill in some questionnaires so that we can get a feedback from the participants.

5.5 Environment

The interface was deployed at the university since it is the appropriate public space for this interface and students and university staffs are the main users of the interface. The testing took place in SimSpace at the University of Tampere which is often times frequented by members of the computing department.

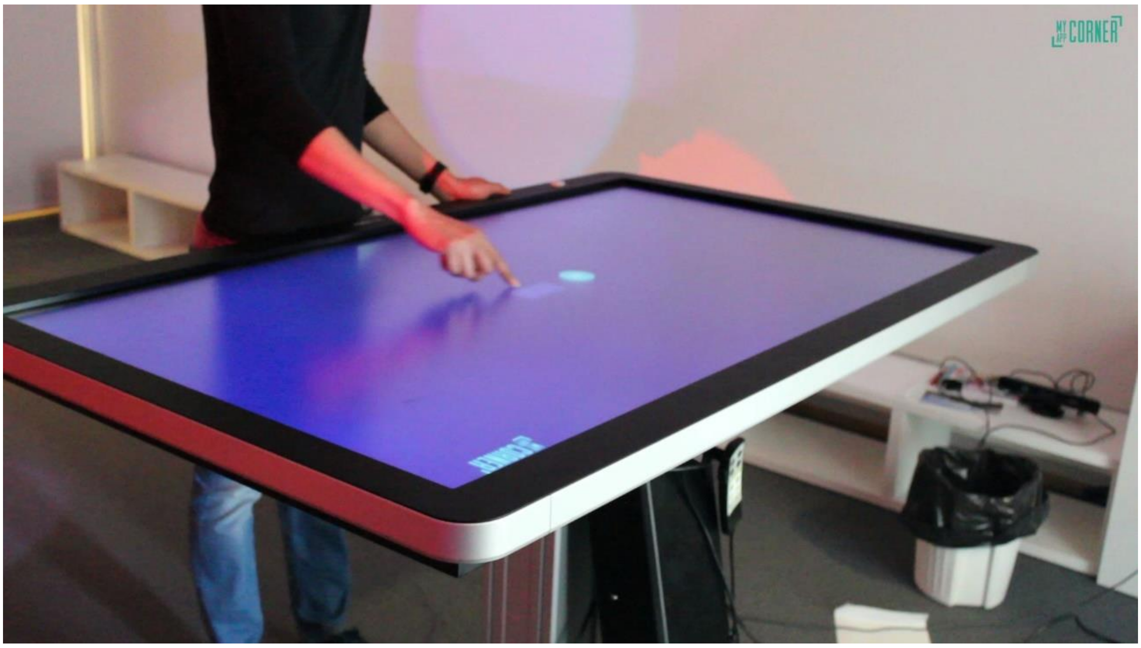

Figure 23. My AppCorner testing at the University of Tampere premises.

5.6 Analysis

We aimed at testing the working of the interface in the actual environment and with the main users of the system. We picked a section of the university that is often frequented by students and staffs in order to get satisfactory results. We recruited participants from students and university staff since they are our main target users. Participants were then given tasks to do on the interface. We observed participants action when they were doing the tasks and noted problematic areas of the system. Participants were later handed questionnaires to share their thoughts concerning the interface. The results from the interface testing will be reported in the next chapter.

6. Results

This section addresses questionnaire questions from Section 5 and a report of the results collected from the questionnaires that can be found in the appendices section. We will be basing our analysis on the results collected during testing. The evaluation of My AppCorner will be discussed in the next section and

As stated earlier Question 1 to 4 used Likert scale of 7 ordinal points to rate whether users agreed or disagreed with the statement regarding the interface (as shown in Figure 24). Q1 was concern about the ease or complexity of window creation (Scale of 1-very easy and 7-Very difficult). Participants affirmed that window creation was easy, although some users had difficulty in creation of private windows at first when we were explaining the concept to them. A couple of users expressed that they liked the idea of creating everything dynamically.

In Q2, we wanted to confirm if users felt a sense of ownership with having their own interaction window (Scale of 1- No sense of ownership and 7- had a sense of ownership). The results show that a couple of users felt they owned the interactive area and they could use that section for their own private interactions. Users could also create their own window in whichever part of the screen and the option to move the screen to whatever section that they preferred. However, 40% of the participants stated that the private window did not have any benefit nor difference with a screen which is not partitioned.

Q3 addressed the collaborative sense and support for multiple users interaction (Scale 1- Not comfortable and 7- Very comfortable). All the tasks involved interaction of multiple users using the system at a time and many users liked the idea of using the screen with other users. Several private windows could be created in different parts of the screen and the menu could be accessed by all users hence several users could use the same applications concurrently.

In Q4, we wanted to know if the interface suffers from interaction blindness and whether individuals could use it if they found it in a public space (Scale of 1- Not at all and 7- Very much). Often times when people see public displays they expect them to be unresponsive and playing commercial advertisements. Other times, users restrain from using the display since they do not know how to interact with the display, this is know as interaction blindness [Sorce et al., 2015]. 50% of the participants expressed that they were not sure if they could use the system in public. The other 50% stated that they would use the system in a public environment.

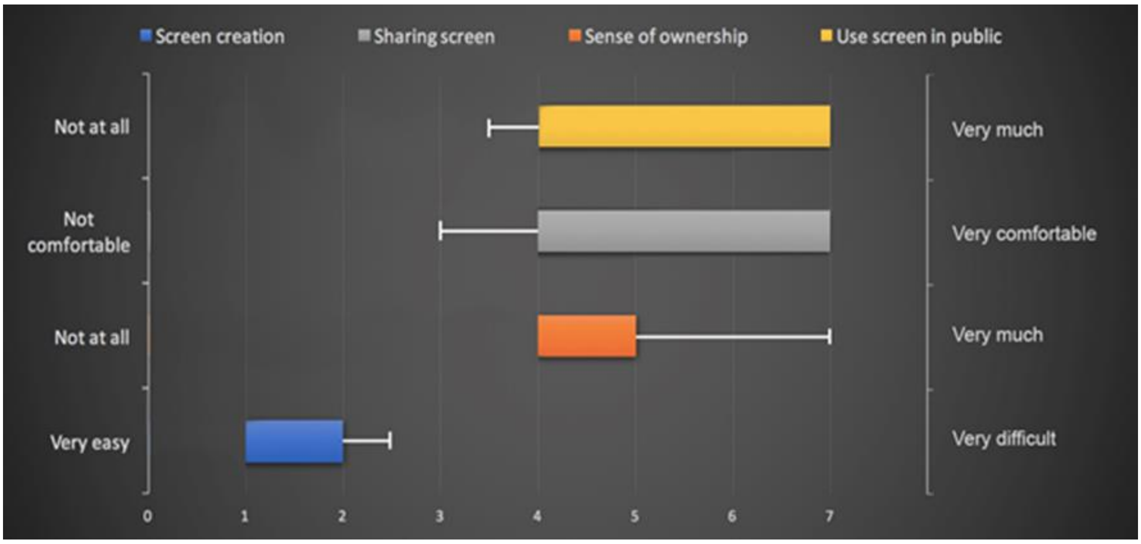

Figure 24. User experience score based on the Likert scale.

Both horizontal and vertical orientations were tested but horizontal orientation was more preferred to vertical orientation. There was a rotation button, where users could rotate their window in a horizontal orientation and use the window on the opposite side of the screen.

Drag and drop interaction technique was familiar to users. The interaction techniques were said to be smooth and natural although it was considered slow at some point.

The circular menu was readily accessible, and user could use different applications found in the menu although there were some delays when users tried to request for the menu. Users were able to scroll through the information in their private window by dragging their finger up and down their private window.

Participants stated some of the best experiences they had with the interface. They appreciated the idea creating their own private window on whatever section of the screen they preferred. They also liked the idea of creation of several private windows since it ensured that multiple users could use the display at the same time. The interface allowed interaction by several fingers especially during zooming of objects on the private screen. Users acknowledged that the mobile menu was very handy in such a large screen and for a system that supports multiple users. The menu was also said to have a potential of having multiple applications. Users could easily scroll through content within their private window. Window rotations was regarded important especially in a horizontal orientation. The window could also be easily dragged to whatever part of the screen. We also observed that participants rotated their windows to the side of other users so that the other users could interact on them.

Figure 25. Word cloud on the best experiences on My AppCorner.

Nonetheless, Participants experienced multiple difficulties on the system. We explained how the system works but since it was a new system to the participants they had some initial difficulties especially in window creation. Participants wanted to move their private screen to other parts of the screen and in the process, they overlapped other private screens. Screen rotation, dragging of the private window and menu movement was too slow at certain times. A couple of participants stated that they needed further instructions on how to add content into their private window.

From these drawbacks, we wanted to know what improvements should be made on My AppCorner. Participants wanted the menu to be easily accessible by every user on the screen. Decrease latency on menu movement, Window dragging, and window rotations should be avoided. Users requested for the opportunity to resize the window creation to avoid closing it and creating a new window. Creation of duplicate windows should be made possible to save on the time spent creating a private window. Window overlapping should also be prevented to avoid obscuring other users' working area. One participants requested for the possibility of customizing their own private window and incorporating bookmarks.

Figure 26. Word cloud on the improvement to be made on My AppCorner.

7. Discussion

In this chapter we will focus on the results presented in Chapter 6. We will explain how the system worked, in terms of what worked effectively, the challenges we faced in the system and where the challenges resulted from. We found out that we had to first explain the working of the system to users and this posed some difficulties to the first participants who used the system since they were still getting used to the system. For this reason, at first, some users had challenges in window creation, but they later discovered it was quite simple. A large number of users reported that the window creation process was very simple. Participant were then able to create their own window in whatever section they wanted and drag and drop application.

The “drag and drop” technique was easy to use, and users found it to be natural and familiar since it is one of the techniques used mostly in current smartphone. However, there was a lag during “drag and drop” of applications and menu movement across this screen. This was as a result of the screen that we were using [Ng et al., 2012]. The screen [CTouch, 2017] has a ten-touch capacity and when the capacity is surpassed the lagging happens or the system crashes. We experienced this in the initial testing of My AppCorner and had to limit the number of private windows created. In order for the system to work effectively and support more users a larger screen with more touch capacities will be more appropriate. From our observation, “drag and drop” had lower error rate on a horizontal orientation than on a vertical orientation [Zeng and zhang 2014]. This was visible when users opted to “drag and drop” applications when the menu was far from the private window.

Users were able to scroll material within their private window, through drag and drop technique. This allowed them to access full information in their window especially when reading the articles in news feeds. Users could also zoom items on the private window by using two fingers.

Both horizontal and vertical orientation were tested, and most users preferred the horizontal orientation as was also preferred in [Pedersen & Hornbaek, 2012] [Shen et. al, 2003] since they also agreed that it was more comfortable and less physically demanding. Horizontal orientation supported collaborative work with other users and would be more applicable in long task. Vertical orientation would be more suitable on short task, for instance when checking the bus timetable [Ardito et al., 2015]. When it came to personal space and territoriality, we observed that users respected other users personal space when the display was in a horizontal orientation. This proved that horizontal orientation was more effective, and it would support collaborative work [Krueger et.al, 2003]. During vertical orientation interaction, users using the screen on the lower section of the screen were obstructed by other users. Scott et al. [2004] stated that screen partitioning was a form of defining territoriality. In My AppCorner, users create their own personal interactive windows as a way of defining territoriality and to provide them a sense of ownership.

Users had the freedom of creating their private window in whatever part of the screen. They could also drag the window to whatever section of the screen but there was also some lagging time due to surpassing touch capacity of the screen. The window also moved out of the screen boundaries when users tried to move it to their preferred location on the screen. This also made it impossible for users to close the window since the closing button was no longer visible. To avoid this, screen boundary should have been defined to avoid this problem and it would constrain users [Shingo, 1989] and such errors would be prevented. Private windows also overlapped each other when dragged on top of other window, this obstructed other users from using their windows. A boundary could also be set to prevent windows overlapping each other.

Participants wanted the option of resizing their private window after creation to adjust it to their preferred size. In the previous version of My AppCorner, users had the option of resizing their private window which we disabled in this current version due to the screen size which was 65´inch. We noticed that users enlarged their private window size and this took up other users' space. The resizing of the private window would work better in wall size screen where there are no risks of overlapping other private windows. The private window also contained a rotation button which was more applicable on a horizontal orientation. Participants were able to rotate their window and use them on different sides of the screen. Rotation delays were also experienced due to limited touch capacity.

With increase in size of screen, users have difficulty of reaching items beyond their reach [Doeweling & Glaubitt, 2010], for this reason, we decided to use the "hold" techniques for the circular menu. Users touched down on the screen and the menu would come to the point of touch. This was to ensure that users had easy access to the menu. However, this also experienced a lagging time due to the limited touch capacity.

The interface supported multiple users interacting concurrently. Several users could create their own private interactive area. Users could use multiple fingers to interact with the system for example during zooming.

Interaction blindness [Ojala et al, 2012] will be one of the challenges faced by users since some users expressed that they would not be able to use this system in public space. As we stated earlier, we had to first explain the working of the system to users and user first had problems of creating the private window this is as a result to interaction blindness. Studies have also proven that people are reluctant to use public displays to avoid social embarrassment [Buerger, 2011]. This could be as a result of users believing they do not have the knowledge of how to go about the system. Often times, users do not have the patience and time to learn how a system works especially in a public environment.

Overall, users were impressed by the possibility and ease of creating their own private windows. They were able to use any application they wanted and to move the window to whatever section of the screen. As earlier stated, increase in display sizes makes it difficult to reach items beyond arm's length, hence the option of having a mobile menu. It should be noted that the menu worked accordingly despite the slowness of the screen. Applications used were good examples of applications needed in a university environment and users appreciated the fact that they could easily access university information. Furthermore, they could share this information with other users using the same screen by rotating or dragging the window to the position of other users.

However, we faced some limitations on My AppCorner interface. As earlier stated, the screen had limited touch capacity causing system crash and increase in latency while dragging the window and menu movement. Standard touch screen usually has a latency of between 50 to 125ms. Increase in latency decreases user performance hence poor user experience [Jota et. al, 2013]. The testing environment was controlled since it was mostly frequented by individual from the IT department who are familiar with interactive displays. We had a couple of participants from other departments, but we would have collected better and varied results had we placed the screen in an actual public lobby and for a longer period. Screen deployment in a public space for a longer period would have also helped us have better judgement on interaction blindness. Further research and development of the interface need to be carried out to perfect on the actual needs of a smart campus for instance use of collaborative applications and sharing of information within the screen. Our current work can be seen as an initial innovation and contribution to smart campus through use of public displays. Although further improvements and research need to be carried out.

8. Conclusion

This thesis presented My AppCorner, a multi-user interaction interface where users get to create their own private screens on a public display and giving users a sense of ownership. In this chapter, we summarize the thesis by explaining our findings and answering the research question:

How can an interactive public display support multiple users but still offer a sense of ownership and at the same time play a part in smart campus?

From the testing results, the system was able to support multiple users where several users could create their own private window at the same time and use the same applications concurrently. The interface also supported the interaction by multiple finger during zooming of items on the private screen. The private window provided users a sense of ownership since they could interact with whichever applications they want, and they could create and move the window to whatever part of the screen. In the private window, user could "drag and drop" applications and manipulate the information within their window. The screen was mainly redesigned for a campus setting as a smart solution in education [Malatji, 2017], that aims to improve the learnability of student through collaborative work and quick access of campus related information. The applications used included: bus timetable, campus map and university newsfeeds.

Overall, we can say that the system was "actually" useful as with accordance to the definition by [C. MacDonald and M. Atwood. 2014] since it was able to perform the required tasks efficiently, effectively and with satisfaction. My AppCorner successfully supported multiple users and at the same time offering a sense of ownership to the users through use individual interactive areas. The system will be a huge contribution to a smart campus by providing applications that offer information to the university occupants. However further research and improvement should be done on the system to successfully meet the needs of a smart campus university.

8.1 Future work

The interface has a lot of potential and possibilities, more service can still be added to make it even smarter. In a smart campus setting, public displays have been mainly used for class collaborative work. As of now, our interface provides a platform for collaborative work, but further modifications and additions need to be done to perfect collaboration for instance applications for collaborating can be installed. There has been research on location-based map that show the physical location of a user, the map application that we used needs to be updated. The applications relating to a smart campus can be added for instance, class attendance application, room booking. Interface may suffer from interaction blindness when placed in an actual environment. A video explaining the working of the interface should be playing on the screen when it is not being used and the same video can be accessed upon user request. Another option is to use proxemics interaction where systems sense body cues [Ojala et al, 2012]. Since the interface is for multiple users, it can be run on an even bigger screen with more touch capacity. Window constraints should be put in place to prevent users´ overlapping other users´ windows and to prevent windows passing the physical size of the actual screen. Following Poka-Yoke principle [Shingo, 1989], constraints will make users adjust their actions and continue performing correct actions, this will in turn prevent errors from occurring. The results and work done in this thesis is a step towards contributing to smart campus environment. The system offers potential improvements that can be made to provide satisfaction to users in a smart environment.

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Appendices

Questionnaires

Thanks for taking part in this test. Now I will request you to fill up this questionnaire in order to get feedback concerning the interface.

1. You had to create your own private screen, how was it?

Very easy Very difficult

1 2 3 4 5 7

2. Having a private screen did it give you a sense of ownership?

Not at all Very much

1 2 3 4 5 7

3. How was the experience while using the screen with other people?

Not comfortable Very comfortable

1 2 3 4 5 7

4. If you found such a screen in a public space would you use it?

Not at all					Very much
1	2	3	4	5	7

5. Have you interacted with both horizontal and vertical orientation? Which one was better and why?

6. How was the menu and the drag and drop technique?

7. What was the best experience while using My AppCorner?

8. What features were difficult to use?

9. What would you improve on My AppCorner?