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A Proxemic Interactive Platform for Sociable Public Zones in the Smart City

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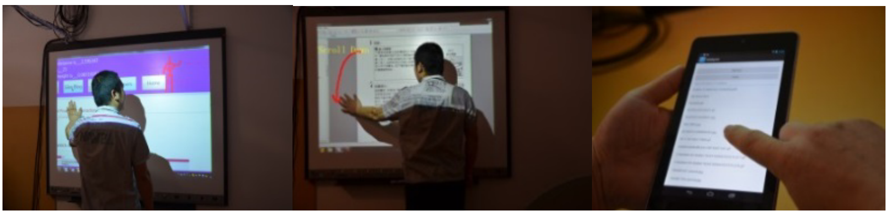

Figure 1 Proxemic Platform (Left: hand cursor control, Middle: scroll by hand glide, Right: file migrator)

Abstract. Public Screens are widely used in modern cities in the fields of public transportation, commerce, education and advertising. They respond to users' inputs passively rather than spontaneously interacting with them. Therefore few screens are sociable. This situation has started to change with the progress of interaction technology. In this paper we present an application independent proxemic platform, which includes a sociable public screen together with a file migration toolkit. The sociable screen displays information according to user's distance, orientation, posture, location and identity. Moreover, via the toolkit we can exchange resources easily and safely between various ambient devices with the screen. The platform works as a public sociable medium connecting citizens and providing new opportunities for them to communicate with each other. We describe the platform application using a bus shelter scenario before demonstrating the usability of our work through user study.

Keywords. Proxemic interaction, Public Screen, Smart City, Mobile Interaction

Introduction

With the prospect of ubiquitous computing, more and more large public screens will be deployed in future smart cities. These screens are used to display information, to advertise, as well in many other domains closely related to daily life. Public screens will play a key role in the future smart city. Screens presently deployed in the city mostly take the form of an interactive digital appliance rather than a "sociable" object. They only display contents according to users' inputs, rather than proactively communicate with users. Researchers have produced some instructive works about public display, such as Timo Ojala et al. [20] who placed the public display in the wild for three years, and studied the use of public display in real word application. They proposed to explore the link between mobile phones and public screens, which is also the problem we try to respond to in this paper. In addition, in order to build sociable

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public screens, we have studied the principles of proxemic interaction, which applies psychological terminology to human-computer interaction to study the interaction modality on a large screen. Saul Greenberg introduced proxemic interaction as a new kind of ubicomp [10]. He identified five key elements of proxemics: orientation, distance, motion, identity and location. And he described the indoor proxemic media player to explain this new interaction. Marquardt et al. presented a proximity toolkit, which supports rapid prototyping of proxemic interaction based on the Vicon motion tracking system and Kinect [16]. Compared with the indoor application, the public screen scenario is more promising. Proxemics has extended traditional plane interaction to space interaction by classifying different interactive zones in front of the screen, thus allowing it to discover and attract the user before he/she directly touches the screen. Along with the user's identity recognition, we could build a sociable public screen, which supports more diversified proactive interactions.

Furthermore, the screen is not isolated, but serves as a hotspot for info communication among various digital devices (tablets, smart phone and smart watch, etc.). Future public displays are individual nodes of an open display network, as Nigel Davies et al. [4] described. They envisaged that open public display networks will emerge as a new communication medium for the 21st century, and are open to applications and contents from many sources, including users' devices. Nowadays if someone wants to download the bus schedule from the screen installed in the bus shelter, he/she needs to take a picture or scan the QRcode by camera. This may be time consuming and not viable if the surrounding light is not appropriate for taking a picture. Assume we could just shake the phone in our pocket for the relevant contents to be downloaded to the phone automatically, without needing to take a picture.

Our aim is to build a sociable public screen which acts like a person. It recognizes people, "talks" with them, as well as accesses people's digital devices. Then we try to study the role of the interactive public screen in future social life. In this paper, we first describe a proxemic platform comprising a sociable public screen and a file migration toolkit. In the remainder of the paper, we first introduce some related works. Next we explain the deployment of the proxemic platform. We then describe the bus shelter scenario of the platform application against the background of the smart city. Finally we present the user study and analyze the results, before proposing the future work.

1. Related work

The goal of our work is to transform a normal projection screen into a proxemic interactive screen, along with the data exchange solution among ubiquitous devices. With this we study the effect of the public interactive screen on social life in the city.

Marquardt et al. proposed a system called GroupTogether which could detect proxemics of users and their devices. It infers the user's group relationship by their relative positions. Moreover, people could share and send files via tilt mobile devices to orient devices. They emphasized the effect of people's group relationship while multi-users interact with the large display. Related research is also presented in another paper by the same author [18]. Vogel et al. [12] studied the principles for designing an interactive ambient display: the screen supported various interactions in different proxemic zones. They discussed privacy issues as well. Ju et al. [15] introduced their work on an implicit interaction electronic whiteboard, which is deployed in a lab for collaborative work. They used the simple distance based interaction modality. Vogel and Ju thought the large screen was isolated and did not consider communication between the screen and other devices. Belloti et al. compared human-human interaction with human-computer interaction in their paper, and proposed instructive questions for interaction research which are valuable for interaction design. Proxemic interaction could also be regarded as one application of HHI in the HCI domain. With respect to the public screen, Florian Alt et al. [9] studied the problems concerning advertising on public display networks. They underlined the importance of sensing the user to obtain information about passers-by. This factor is also considered in our work, for providing pointed contents to users. Murugappan et al. [19] designed an extended multi-touch table via depth data collected by Kinect. It was not only able to support multi-touch, but also to retrieve information from user's hand postures, identity and handedness. In this way, they extended more input modalities. Wilson et al [24] also probed touch interaction by processing depth data. They provided a good method for retrieving useful data from the depth image of Kinect. Compared to them, we used depth data to gauge the distance and position of users to the screen, and recognized the identification through a web camera which is more precise. Besides, we referred the fine-grained gesture interactions on screen. Wigdor et al. [23] presented a set of interactions, which augmented direct multi touch interaction with shape-based gestures. This improved the preciseness of direct manipulation and mitigated occlusion. Other researches such as [22] used a glove with color markers to carry out real-time hand tracking. Harrison [12] processed sound signal to explore more precise touches on tangible surfaces differenced by nail, pad, tip and knuckle to enhance touch interactions.

2. Sociable projection screen

Most public screens are currently un-interactive. In our work, we transform a normally projection screen into an interactive surface supporting 3-dimensional interaction. It accounts for user's posture, identity, orientation, location and distance as implicit interaction input, rather than simple touch interactions. By means of Kinect, it is easy to collect the above user factors if we locate the Kinect in front of the screen. This is feasible for most existing public screen interactions. However, if the user stands too close to the screen, he/she exceeds the range of the Kinect, and it is impossible to display personal contents to the user due to privacy reasons. As a result, in our platform, we install Kinect near the ceiling facing the user's back, as shown in Figure 2. The distance from Kinect to screen is about 2.5 meters. Then we mount a projector on the ceiling to project a screen on the wall. This deployment ensures Kinect can detect users regardless of their position.

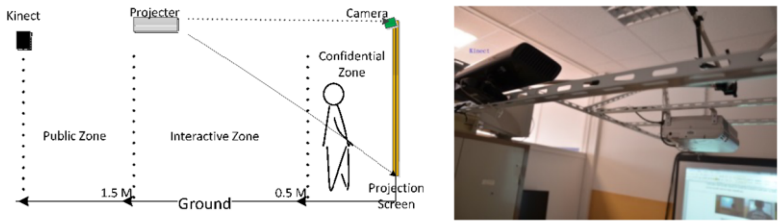


Figure 2 Deployment of proxemic platform

We divide the space in front of the screen into three zones:

Confidential zone (CZ): from 0 to 0.5 m in front of the screen. Users in this zone have maximum authority to interact. Also, the screen displays personalized and private contents to them;

Immersive zone (IZ): from 0.5 to 1.5 m in front of the screen. Users in this zone can browse and zoom in the contents on screen by gestures. Nevertheless, they have less priority than users in CZ;

Public zone (PZ): the space beyond 1.5 m. Users in this zone can only skim the current interfaces roughly and select the relevant one by simple gestures.

Based on this deployment, we build a proxemic platform with a sociable public screen as the center, which supports multi interaction modalities, as shown in Table 1. We use Kinect with windows SDK 1.7.0 for implementation.

Table 1 Interaction Modalities Supported by the Platform (√ supported, × not supported)

Interact Modality	C Zone	I Zone	P Zone
Left or Right Hand Cursor	√	×	×
Push or Wave to Click	√	×	×
Glide to Scroll	√	×	×
Presenter Position Interact	√	×	×
Browse and Zooming Gesture	√	√	×
Sitting Position Interact	√	√	×
Roughly Skim Gestures	√	×	√

In the following sections, we describe the different interactions in the three zones.

2.1. Interaction modality in the Confidential Zone

If someone enters the CZ, we infer that he/she intends to interact with the screen. Unlike the direct touch interaction of the traditional touch screen, the projection screen senses the user before he/she crosses the border between CZ and IZ, while the camera mounted on top of the screen also recognizes the user via face recognition. We define several interactions by gestures and postures in this zone, as follows:

Users could move their left hand to control the cursor for selecting the relevant contents. We obtain the user's skeleton info from Kinect, then scale the 3-dimensional coordinates of the hand joints to 2-dimensions via the built-in function of Kinect SDK. However, assignment of these scaled coordinates as cursor coordinates is not feasible, else, when the user directly touches the screen, the cursor position would have a large offset with the actual hand position. We need to mitigate the offset to avoid mal-functioning. We adjust the deviation by adding two empirical coefficients α and φ to the scaled coordinates.

$$CursorX = \alpha \times \frac{interfaceActualWidth - scaledHandX}{interfaceActualWidth} \times ScreenResolutionWidth \quad (1)$$

$$CursorY = \varphi \times scaledHandY \times \frac{interfaceActualHeight}{ScreenResolutionHeight} \quad (2)$$

In our deployment, screen resolution is 1600×900, while interface resolution is 1920 × 1080. We conducted many tests to calibrate the coefficients. After comparison of different pairs of the two coefficients, we found that the best values are $\alpha = 0.8$, $\varphi = 1.3$, with which we obtain a minimum deviation between the hand and cursor position. The deviation is amplified if the user removes his/ her hand from direct touching on screen. However, inside the border closer than 0.5 m, this offset is acceptable. For large displays, the user has difficulties reaching items out of hand's reach, so it needs to amplify the hand's cursor as well. In this case we set $\varphi = 1.3$ as the coefficient of the Y axis, to balance the two opposite requirements. The same problem is also present in the X axis, as it is hard for the user to reach the item on the right side of the body with his/ her left hand. As a result, if Kinect detects that the user wants to reach the item to the right with his/ her left hand by his/ her posture, it relates the coordinates of the right hand with cursor movement instead of the left hand. Thus the user can move the cursor with his/ her right hand.

We have devised two methods for the click method. Once the user has selected an object, he/ she could push his/ her hand straight forward to click and open it, as shown in Figure 3. Or, alternatively, the user could wave his/ her free hand to click the current items as well. The push gesture is more natural than the latter, while the latter is more precise. This is because, when the user pushes his/ her hand forward, hand depth is changed, causing sudden drifting of cursor coordinates. The user might click another item by mistake. To solve this problem, we save the previous cursor coordinates in the memory. Once Kinect has detected the user's push gesture, it reads the previous data from the memory and re-assigns the data to the current cursor to avoid cursor drifting.

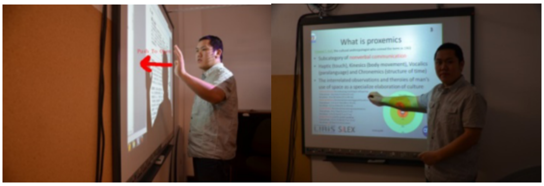


Figure 3 Left: push to open, Right: user interact with the hand close to screen

Normally the user scrolls the contents on the screen to check details. During our previous investigation via Wizard-Of-Oz [13], we found that the user always moves his/ her hand on the screen from top to bottom to scroll down the contents. We adopt this spontaneous behavior for contents scrolling. The user glides his/ her hand from top to bottom quickly, and the current page scrolls down. Similarly, if the user glides his/ her hand from bottom to top, the page scrolls up, as shown in Figure 1.

In the CZ, we sense the user's orientation as well. If the user wants to present something (such as a photo, slide, etc.) to others, he/ she turns back and faces the others standing in front of the screen. We detect the change in orientation, allowing users to control the contents using the hand close to the screen. The other hand is used to assist. as shown in Figure 3. The tester raises his/ her left hand, then moves his/ her right hand to cause rapid skimming over the current interface. If he puts his/ her left hand down, his/ her right hand will only control cursor movement.

2.2. Interaction modality in the Immersive Zone

In the IZ, users have limited possibilities to interact. They cannot interrupt the current interactions of the user standing in the CZ unless the CZ is available. Instead, they can browse the contents by waving their right or left hand, to control the last and next page.

In this zone, users stand at a large distance from the screen, and we need to let users zoom in on the content for easy reading. In our previous work [13], we tried to set the zoom in action by the user's intuitive movement such as walking towards the screen. However, test results showed that users easily triggered the zoom unconsciously. Therefore we have defined several explicit gestures for zooming. When the user raises his/ her right hand, this means zoom in on the current contents, otherwise, if he/ she raises their left hand, it means zoom out, as shown in Figure 4.

Figure 4 Gesture Interact of user in IZ (scroll up, down, zoom in and out)

The screen also senses the user's sitting position. In our prototype, if the user takes a seat, we infer that he/ she wants to read the current contents in full screen mode, and the screen displays the current contents on full screen. The user can control the next and last page by waving his/ her hands. The full screen mode exits once the user stands up.

The sitting position is especially helpful to detect disabled people in wheelchairs. For example, in metro stations, if a disabled person approaches the screen, it displays the position of the entrance with an elevator.

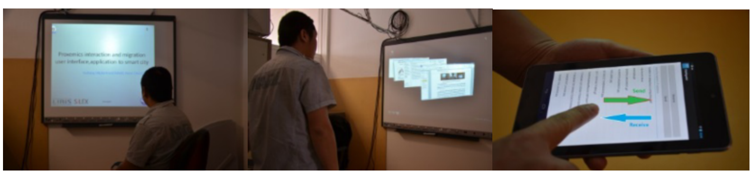


Figure 5 Left: user's sitting position in IZ, Middle: skim interface in PZ, Right: file migrator operation

2.3. Interaction modality in the Public Zone

In the PZ, users can only skim the current running interfaces, by waving their left and right hands to select, as shown in Figure 5. Unless the user steps into the inner zone, he/ she cannot engage any further interaction. If no users are present in the work space, the screen clears the contents and waits for the next user.

As aforementioned, the platform supports resource exchange among different devices. Users, public screens and ambient mobile devices are aware of each other and can "communicate" seamlessly. Using the WIFI module widely embedded in mobile devices, we have built a file migrator toolkit, which has a mobile version implemented on Android 4.0 or higher, and the desktop version in Java.

3. File migrator

Compared to file transmission by Bluetooth or maker based, WIFI is a more practical and quicker way for exchanging resources: it is not limited by devices and the surrounding environment, and is easy to configure. Although there are many tools for share files with computers via WIFI, they are not suitable for application with public screens. Most tools configure the mobile device as a hotspot, and users access the files via the web explorer in computers. They can read and modify all the files in mobile devices. However, this method generates privacy problems if it is used with a public screen. The user connects his/ her mobile devices to the hotspot of public screen, he/ she might just want to share a single file, but has to publish all the files in the public network. Regarding this problem, we have developed a highly efficient file sharing tool based on client/server structures. It is designed to transfer resources naturally among all ambient devices in the vicinity of the public screen.

3.1. Flick to send

Users naturally explain “send out” intentions with a flick gesture: specific to the case of mobile devices we consider that if the user glides a finger from screen bottom to top, he/ she wants to send out a file, as shown in Figure 5. First the user selects a file from the list, and glides a finger from bottom to top, and then the file is sent out. Public screen users expect to get instant feedback from the screen to verify whether the file has been successfully sent. Thus, after the file has been accepted, it will be opened instantly on the projection screen. This is useful if one user wants to present something, such as photos, slides or files stored in his/ her mobile devices to others.

3.2. Draw or Shake to receive

Compared to the send action, users could “draw” a file from the screen by selecting and sliding a finger from top to bottom. Alternatively, we employed the embedded accelerators of mobile devices to produce the “shake to receive” effect. In our vision, users do not need to take their phone out for downloading a file from the screen, they just shake the mobile phone in their pocket and the file will be downloaded automatically. This means users no longer bother to scan the QR code, or take pictures.

The file migrator is a lightweight toolkit oriented to the ad hoc resource-sharing requirement in public spaces. It connects the user with the public screen, as well as the others’ devices seamlessly. This is convenient for daily social life: for example, if two friends meet in the street, they want to exchange their name card stored in their mobile phones. There is no need to manually input, one person just sends the card by flick and the other person receives it by shake, and the exchange is finished. Additionally, in local communities, several friends gather in the bus shelter to wait for the bus. While they wait, they could easily share their interesting topics, such as photos or videos with others by publishing the file on the screen. This extends the public screen as a sociable medium putting a variety of people in contact, and not merely a display for information.

4. Scenario Applied to the Public Transportation System

As aforementioned, the networked public screen will be pervasively used in the future smart city. Our platform provides a rapid and economic method for building an interactive and sociable public screen. We have envisaged application of this platform in several promising scenarios, such as for the public transportation system (bus shelter or metro station), and other public service screens for tourism, billboards or advertisements.

We take the bus shelter as an example to explain application of the platform in the public transportation system. Bus shelters are one of the most social occasions in the city. Passengers obtain information from the screen mounted on a bus shelter. Today they can only obtain information about bus schedules, and most screens are not interactive, let alone sociable. We should take advantage of the time while passengers wait for a bus, to make the screen work as a more useful medium than a simple bus schedule. Passenger mobility is another advantage of the public screen in the bus shelter, as various user samples mean more abundant interactions. Therefore, in our vision, we reform the normal bus shelter as the info island for passengers [6], as shown in Figure 6. It provides not only transportation information, but also shopping, culture and sport information, as well as local personal information.

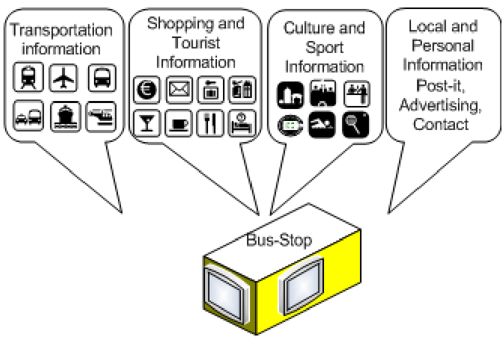


Figure 6 Bus shelter info island with sociable public screen

Passengers fall into two typical types in the bus shelter: local inhabitants and tourists. Each type has different concerns about the bus shelter. Compared to local inhabitants, tourists are concerned with the schedule, route map and connections, while inhabitants, familiar with this information, are more concerned with local community messages, such as entertainment, advertisements etc. We describe the different interact scenarios for the two kinds of users.

4.1. For Tourists

Tourists come to the bus shelter not only to take the bus, but also to check local information, and quickly find the tourist attractions, or restaurants. Normally, tourists standing in the public zone obtain general information such as bus arrival time etc. If he/she steps further into the immersive zone, two selectable boxes will appear, called “Tourist” or “Inhabitant”. He/she then waves his/ her hand to select Tourist, and the screen displays the categories specialized for tourists, such as “Museum”, “Restaurant” , “Hotel”, “City Bike”, “Emergency” and “Transport”. He/ she can select the category using the simple gestures mentioned above.

Tourists only need to click a button to display the relevant interface. They can use gestures to scroll contents, as well as zoom. They need to step further into the confidential zone if they want to check details. In the CZ, users can engage more abundant interactions. As tourists have no personal data stored in the public screen network, the camera will not recognize them, and no personal information can be displayed. Nowadays, tourists often want to search for a WIFI hotspot, as their mobile phone does not work in foreign countries. Therefore the screen displays their WIFI code and they can connect their phone to the local hotspot. They can then download files easily from the screen, such as tourist maps, restaurant addresses and transportation maps. Or they can share their favorite photo of a local monument in their mobile phone on the screen, and the photo will be published in the open display network, so that others can enjoy this photo from all the other screens in the network.

We have envisaged other interesting applications to build sociable connections between people. Under the museum menu, there will be special charts displaying the popularity of local museums. Tourists can rate their favorite museums based on their own experience, and check out others' comments, as well as add comments to others' views. Some museums always offer discounts for group visitors, individual tourists could create a note with their mobile devices to invite other sightseers to visit the museum together, then send the note to the screen. This will then be announced on the public display network, and other tourists can read this note from any bus shelters and accept the invitation. Not only is this a good opportunity to build a subtle relationship, but it is also a good way to introduce tourist-related business.

4.2. Local inhabitants

Unlike tourists, local inhabitants are familiar with the schedule, and thus less concerned with transportation information. The interface that the inhabitants see in the public zone is the same as for tourists. However, when someone enters the interactive zone, he/ she selects "Inhabitants" to display the various categories such as "Restaurant", "Cinema", "Concert", "Emergency" and "Community news". If they step into the confidential zone, the camera will recognize their identity. According to the favorites analyzed from their browse histories, and other records from their social web accounts (Facebook, Twitter or G+), the screen can display personalized information, such as recent news of their friends, greetings from others, etc. For example, if they have shared a video about a recently released film on Facebook, the screen can display when the film next shows in the nearby cinema. Moreover, it displays the local inhabitants interested in this film as well. They could invite someone to see this film together, though they might not know each other. The next time the other inhabitant accesses the screen, he/ she will be reminded of the invitation. By this means we enhance the social relationship among strangers. Furthermore, as the screen and user's devices are networked, local inhabitants could exchange their files in the mobile devices with the public screen, such as download a restaurant voucher, publish a Lost and Found ad., etc.

5. User study

We invited 10 volunteers for a user study (3 females, 7 males), with an average age of 26.5, and an average height of 172.7 cm. We asked them to carry out specific tasks, and recorded the total test time. They all use their mobile devices every day: 7 use IOS devices, while only 2 use android devices, and 1 uses a windows phone.

5.1. Sociable screen interaction task

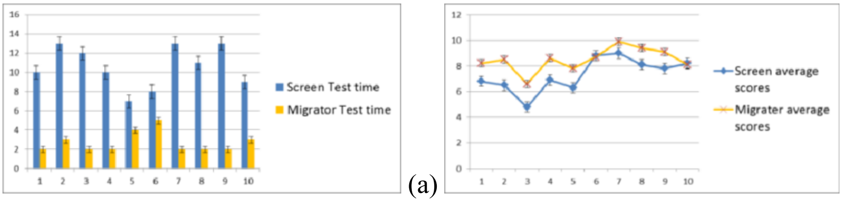
We explained and demonstrated the interaction process to participants, and asked them to interact with the screen in three different zones. First they stepped into the **public zone**, and skimmed the current interfaces running on the screen, then they chose one open web page about the "Transportation common Lyonnais" and entered the **immersive zone**. Once in the IZ, they tried to control the scroll and zooming operation of the current interface. After successfully finishing these actions, they stepped into the **confidential zone**, the screen displayed them with personal information, and reminded them to control the cursor with their left or right hand (depending on user position). Participants were asked to click the button by one of two methods: wave the other free hand, or push the current active hand. We compared the efficiency of these two gestures. Finally, the user turned away, and the screen returned to neutral state.

5.2. File migration task

We uploaded the Android app file (.apk) in the local server, and asked the participants to download this apk file from the local server and install it in the mobile devices. They could either use their own android devices or we offered them the Sony ST18i mobile phone and Nexus 7 tablet. There are user's instructions in the app interface. Participants were required to send a jpg, pdf and ppt file to the public screen and another mobile device respectively, and they tried to receive the file from other ambient devices by shake mobile phones and glide finger.

5.3. Test results

We recorded the total test time that the 10 participants took to complete the two tasks. As shown in Figure 7a, participants needed on average 10.6 minutes to finish the first task, and 2.7 minutes for the second. They spent more time in the learning process of screen interaction, and needed time to adapt to the various gestures, especially in the confidential zones. However, once they practiced a little, they adapted well to the gestures. The migration toolkit is easier to learn and use. All the participants were able to finish the required tasks successfully. Only one person accustomed to IOS devices initially had some problems with the UI of android devices.



(a) (b)

Figure 7 a: Total test time for each user (minutes) and b: Scores of satisfaction

We asked users to evaluate the usability of our prototype by grade, from 0 to 10, the higher scores being positive and vice versa. We asked them 12 questions for screen interaction, related to experience of learning, gesture interaction and proxemic interaction, etc. We then listed another 8 questions concerning the file migrator. We calculated the average satisfaction of the ten users, as shown in Figure 7b. Comparing these two charts, it is obvious that satisfaction is low if they spent more time on the required task.

Through analysis of the questionnaire and conversation with participants during the usability test, we found that users complained mostly about the two parts of screen interaction: click selected items and alter control between left and right hands. For example, the user naturally stretched his/ her left hand to the right if he/ she wanted to click an item in the right side of the screen, rather than changed to his/ her right hand to select. Besides, when the surrounding light is too weak, cursor position had a large offset with hand position. Another problem raised is that if the user's hand is occluded by his/ her body, Kinect cannot detect the hand, thus causing malfunctioning. Regarding the file migrator, most users are happy with the instant and natural migration of files, and find it practical for satisfying resource exchange requirements on the public screen.

6. Conclusion and future work

In this paper, we presented a proxemic platform consisting of a sociable screen aware of user's proxemic attributes, and a file migrator for ad hoc resource exchanging among ambient devices. The sociable projection screen attracts users by discovering them proactively. Users interact with the screen implicitly by a 3-dimensional position relationship and explicit gestures, rather than plain multi-touch interaction. The screen functions as a sociable medium rather than a merely interactive surface. We also demonstrated the file migration toolkit oriented at social life in the public zones of the smart city, increasing the efficiency of resource exchanges between different devices. We envisaged the application scenario of the platform in the future bus shelter, and discussed its effect on connecting citizens and enhancing the social relationship between people. We did the preliminary user study to demonstrate the usability, as well as the possible problems. We found that the platform is a practical way to build sociable and intelligent public zones in the smart city.

In future work, we will substitute the single Kinect deployment with multiple Kinects environment, to solve the occlusion problem with one Kinect, and design parallel interaction for multi users.

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