Constructing Smart Cooperative Working Spaces Based on Multiple Displays

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Submitted to the Graduate School of
Systems and Information Engineering
in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering
at the
University of Tsukuba

March 2013

Abstract

We propose a novel spatial concept to support the collaboration in the multi-display environment. We call it the Smart Cooperative Working Spaces. The Smart Cooperative Working Space is the space which allows all devices to connect with each other intelligently and all users to have the collaboration rapidly and smoothly. And the Smart Cooperative working Spaces focus on the local collaboration based on multi-display.

In order to establish the connection and commence collaboration rapidly and smoothly in the local collaboration, the Smart Cooperative Working Spaces are constructed by peer to peer technology. In addition, according to the characteristics of the local collaboration, we propose more intelligent connection and more perfect interaction mechanism for supporting local collaboration. The proposed methods can simplifies collaboration initialization and ensure the security of the proposed spaces. And after constructing it, we develop a presentation application based the Smart Cooperative Working Spaces. According to the characteristics of the specific collaboration, we design two modes for the presentation application, speaker mode and audience mode. The two modes can make users have more efficient collaboration according to their roles. And the developed application will be used to evaluate the usefulness of space.

Finally, we conducted experiments to analyze the commonality of collaboration. In addition, we analyze the collaboration efficiency comparing with current environment.

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Chapter 1

Introduction

1.1 Background

When people found single display is not enough, they tried to take advantage of multiple displays. And this approach indeed improved the efficiency of work. In the past, the popularity of multiple displays is limited by technical difficulties and high prices. However, with the development of technology, multi-display has been widely applied to our lives and work. And it can be roughly divided into two situations depending on the number of users. The first situation [Figure 1-1] is that multiple displays are used by single user. The second situation [Figure 1-2] is that multiple displays are used by multiple users. In the first situation, using multi-display to manage multiple tasks can frequently be found in the laboratory or in the office. In the second situation, multiple users using their own computer to have the coordination can be found in the conference or group meeting. In our work, we focused on the second situation, multiple to multiple.

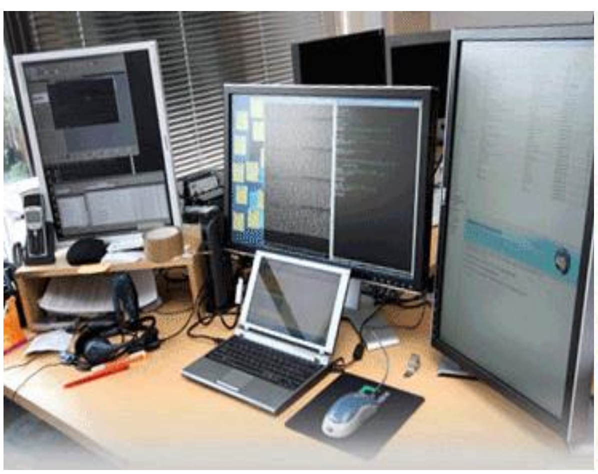

Figure 1-1 One to Multiple

Figure 1-2 Multiple to Multiple

Nowadays, we have enormous opportunities to utilize multiple displays in life and work, especially in the group work. And in the multi-display environment, the large display is also widely used now. The main problem in the multi-display is that the information of the multiple displays is dispersed and it can only be used by themselves. The most approaches adopted large display or network technology to integrate all the information. However, the current approaches cannot solve the problem fundamentally. The large display can only show one computer's screen generally. If we want to change the content which the large display is showing, we have to re-connect the large display and another computer. As one of the solutions, using the KVM (Keyboard.Video.Mouse Switch) can solve this problem incompletely. The lack of KVM is that we need connect the computers which we want to show through the large display to KVM in advance. We have to re-connect, when the other computers are needed.

Another approach is to integrate all the information in the multi-display environment by network technology. This approach can make all devices share their information among the group by network. However, this approach need network initialization just like creating the room and setting the password. It limits users cannot commence the collaboration rapidly and smoothly. Users have to pay more attention to establish the connection, not collaboration. So the current approaches cannot solve the problem fundamentally. Based on the above, more intelligent interaction approach based on multi-display environment has a high research value.

1.2 Purpose

Through the above, we can know that the research about collaboration in the multi-display environment is extremely meaningful. So in our work, we proposed a novel spatial concept to support the collaboration in the multi-display environment. And we focus on the local collaboration.

The purpose of our research is to construct the smart cooperative working spaces which can make all users in the same spaces have the collaboration with few restrictions. All information terminals can join the group and commence the collaboration rapidly and smoothly. In addition, we will construct the proposed spaces based on characteristics of the local collaboration in order to better performance. More intelligent connection and more perfect interaction mechanism will be defined and implemented in the local collaboration. After constructing the proposed spaces, we will develop applications based on the proposed spaces and evaluate the proposed spaces by applications. And we will also discuss the characteristics by the results of the questionnaires about collaboration in the multi-display environment.

1.3 Approach

To achieve this purpose, we construct the Smart Cooperative Working Spaces by peer to peer technology in order that multi-displays can establish the connection and commence collaboration rapidly and smoothly. And in order to achieve more perfect interaction mechanism, we will adopt a fast image transmission which splits image into many units and transfer units by identifying the position of the image change. Finally, as an application example, we developed a presentation system based on Smart cooperative working Spaces in order to evaluate the proposed smart space.

1.4 Organization

In chapter 2, we introduce the related works in detail and compare them with our researches. In chapter 3, the construction of the smart cooperative working spaces is introduced. It consists of discussion section and construction section. In chapter 4, we introduce the application we developed based on the smart cooperative working spaces. In addition, the implementation and the system structure are also explained in detail. In chapter 5, the evaluation experiment is introduced and the analysis based on the experimental results is explained in detail. In chapter 6, we summarize our research and propose future research plans in the smart cooperative working spaces.

Chapter 2

Related Work

With the popularity of multi-display, how to improve the efficiency of multi-display became a great significance research. Until now, there are many meaningful researches in multi-display field. And in this chapter, we will introduce some representative researches which are divided into two situations. One is one user to multiple displays. And another is multiple users to multiple displays. In the following article, we call them one to multiple and multiple to multiple. Finally, we will compare our research and the introduced researched with the respective characteristics.

2.1 One to Multiple

Kim presents VIWORD [Figure 2-1] [4] which is a multi-display collaboration support system. It shows multi-screen on the virtual workspace and users can deal with multi-display screen on the virtual workspace. VIWORD allows cross-platform operation. And user can use the information of screens which are collected on the virtual workspace to have more flexible screen operation. On the virtual workspace multi-screen can be combined and the combined screen can be shared to the others. VIWORD also offer file-sharing function. User can just drag a file from the desktop to the virtual workspace directly and in this simple method the file can be utilized among the group. And the virtual workspace will use the line to connect the file and screen in order to show that who shared the file. And if anyone utilizes the file, the virtual workspace will also use the line to connect the file and screen in different color. In this research users can share operated information of screens with the members of group. And everyone can join the group interaction simply by VIWORD. This research is suitable for a single user to operate multi-display. However, for multiple users, users will interfere with each other because of uninterrupted synchronization. And the system shows all screens on the virtual workspace no matter whether you need it. In the research, users can obtain the file from the other user. This operation led to some security issues. In our research, we focus on the multi-user interaction. And we not only offer the uninterrupted synchronization information, but also offer unsynchronized information. Users can utilize the information of multi-screen more adequately. Another difference is that we just show the icon of multi-screen. And if necessary, users can choose screen from icons to watch it with a large size. We can reduce communication traffic in this way in order to obtain a smoother user experience.

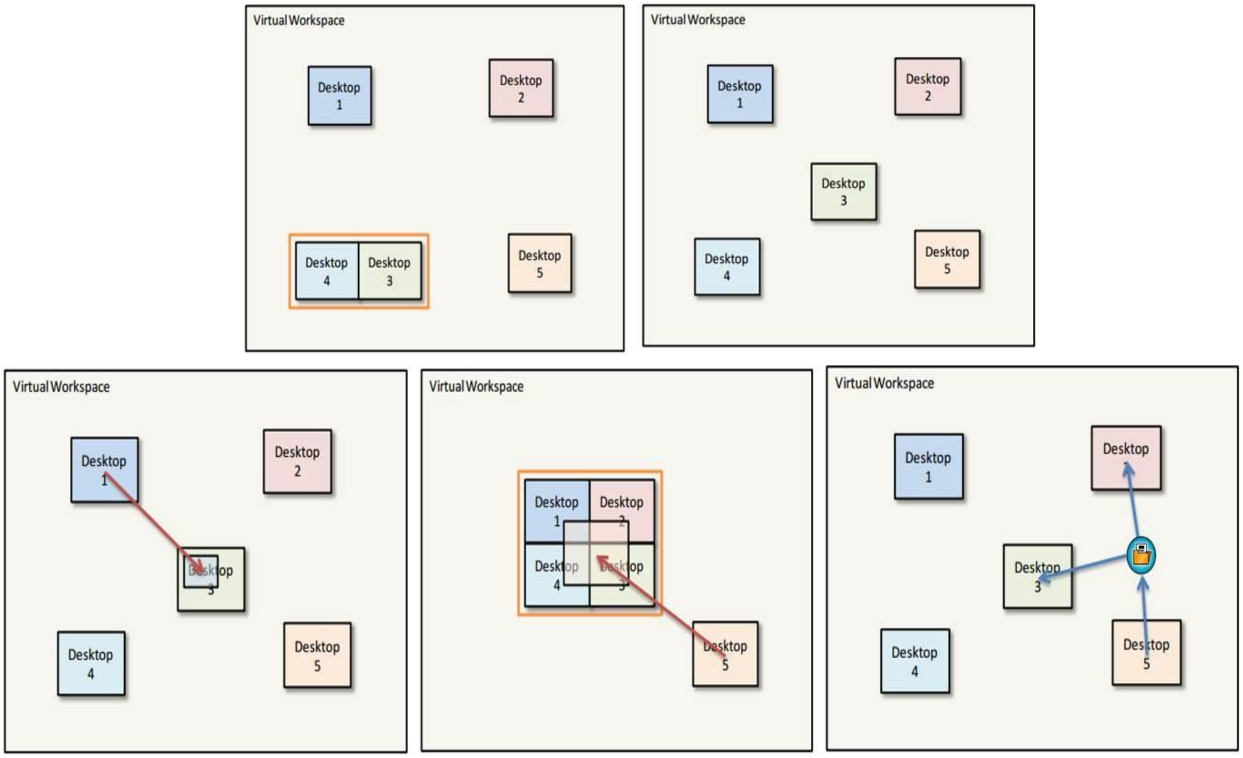

Figure 2-1 VIWORD

Miura presents comDesk [Figure 2-2] [17] which is designed to share the system to the other users using the Peer to Peer network. comDesk enables users to share the desktop with the others which is connected into Peer to Peer network. And users can control the hosts of the other users by operating the shared desktop. And Miura also designed the interface for the users. It shows every desktop which is connected as a window. The users can control the other desktops through drag and drop operations from one operating window to another operating window. The simple interface and operation method allow users to control the multiple displays more efficiently. One of the advantages is that the conDesk do not need the server to establish a connection. The comDesk allows the users to control the other desktops, so it is more suitable for one to multiple than multiple to multiple because of interfering with each other.

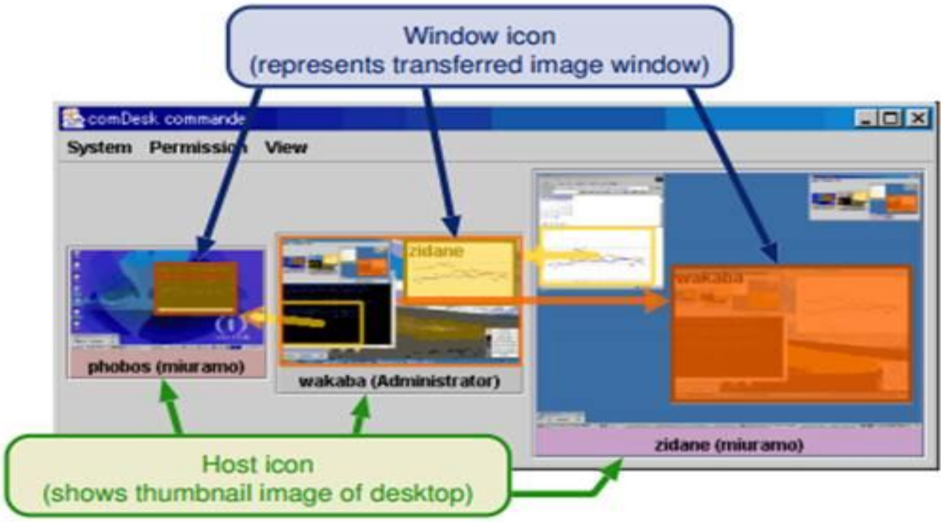

Figure 2-2 ComDesk

2.2 Multiple to Multiple

Microsoft SharedView allows users to have remote collaboration. And it allows up to 15 users from different places to do cooperative work. Users can join the group work by invitation from others. When the connection is established, users can share their screen information and control the others' screen to have the cooperative work. Parliamentary documents and files can be broadcast to anybody who joined the cooperative work. The creation of the cooperative work can be completed by windows live ID. And now SharedView can be used into the Microsoft Office and Windows Live Messenger. This function makes it more practical. When users modify word documents which have the SharedView function, the action will be reflected in the other person's screen. And if users have sufficient permissions, they can modify the others' documentation using their own computer. This research focuses on the remote collaboration and our research focus on the local collaboration. The remote connection needs more steps to maintain the confidentiality of communications. However, in our research, we construct smart cooperative working spaces by local area network. The use of local area network itself can improve security. Because Laboratory or office has its own network in general and outsiders cannot use it without password. According to this feature, we present that construct the smart cooperative working spaces by peer to peer technology. And we simplify the connection procedures. Users just need to start the application. Then the application will connect automatically. This design allows users to collaborate more quickly.

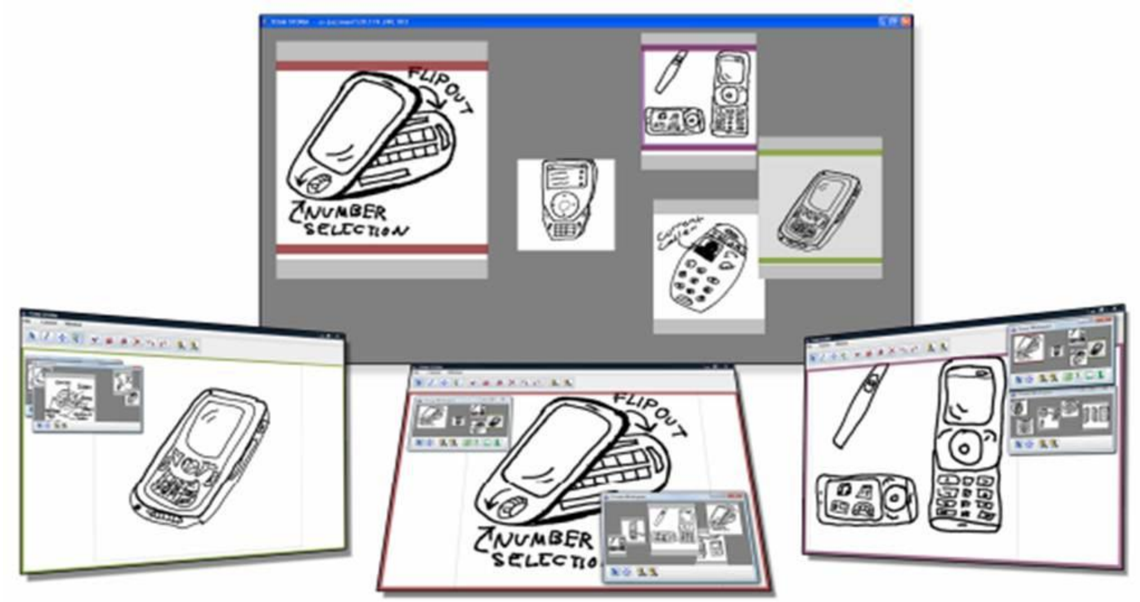

Figure 2-3 TEAM STORM

Hailpern presents TEAM STORM [Figure 2-3] [5] which is designed for creative team. The TEAM STORM makes all information of information terminals at the studio together in order that designers can share their ideas with the others to have the co-located collaboration. The designers can share their own ideas on the large display and the team can have the collaboration through these ideas. One of the advantages is that the TEAM STORM makes the dispersed single idea in the past can be integrated into an idea collection. The designers can share design concept and find out the best design rapidly in the idea collection. One of the differences between the TEAM STORM and our worker is that we do not show all information in the proposed spaces to all users. We just show the information which is necessary to the corresponding user. The method can reduce the waste of resources in order to obtain the faster running speed.

And the research like Impromptu[1] allows users to show the others' application windows on their own desktop. In addition, the system makes the Common Window to show the keyboard and mouse. And it is possible to redirect them on their own desktop. iLand[2] propose a new interface which is different from the traditional interface for smart space which is composed by the space and furniture.

In addition to the above, there are many other relevant studies, such as Swordfish[8] and PointRight[20]. They allow users to utilize the virtual workspace to operate the multiple displays. And the researches like CommunityBar[7] allows users to share their desktops to have the collaboration. The purpose of all these researches is to improve the efficiency of the collaboration in the multi-display environment. And the other researches like [6,9,11,12] also did the same work in the multi-display field. There are other researches which focused on the collaboration like [3,10,14,15,18,19]. In addition, Docking Window Framework[13] is the research which supports multitasking by docking windows. Another research about the multi-windows is WinCut[16]. WinCut allows users to replicate arbitrary regions of existing windows into independent windows.

Chapter 3

Construction of Smart Cooperative Working Spaces

3.1 Definition

The Smart Cooperative Working Space [Figure 3-5] is the space which allows all devices to connect with each other intelligently and all users to have the collaboration rapidly and smoothly. The Smart Cooperative Working Space is designed for the local collaboration in the multi-display environment. It focuses on interactive requirements of the local collaboration including the quick connection and smooth collaboration predominantly.

3.2 Description

The Smart Cooperative working Spaces focus on the local collaboration based on multi-display environment. So we must analyze its characteristics and requirements adequately in order to improve the performance of the local collaboration in the multi-display environment.

3.2.1 Local Collaboration

The local collaboration can be roughly divided into two situations. The first situation is the planned collaboration. The second situation is the unexpected collaboration. In daily life and work, we are to participate in a variety of planned collaboration almost every day. In the laboratory, we need to have research seminar constantly. And in the office, the workers need confirm each other's work by meeting. All these collaboration are planned in advance. We can know the number of participants and the meeting time. However, there are some uncertain factors. Their arrival time and departure time are not fixed. In most approaches, users' information terminal will be connected with each other before the collaboration. These approaches make users lack a smooth user experience. Users cannot join and leave the collaboration freely.

In addition to the planned collaboration, we also need to have some unexpected collaboration. The unexpected collaboration means that we do not know it will happen in advance. In this situation, we cannot predict the location, time and number of participants. And maybe someone will join the work, when it is in progress. So the collaboration spaces need more freedom and flexibility in order that users can have the collaboration more efficiently.

Through the questionnaire which will be introduced in the fifth chapter, we can know a few important requirements of the local collaboration.

- Establish the connection with others rapidly.
- Have the collaboration smoothly and rapidly.
- The participants who are having the collaboration do not allow the others to control their computer to obtain the collaboration materials.
- The places are not fixed.
- The large display is used in most situations.

In the local collaboration [Figure 3-2], the users pay more attention to the connection speed than remote collaboration [Figure 3-1]. In the remote collaboration, the users have to carry out a complex setting before collaboration in order to ensure communication security. However, we use LAN to establish the connection in the local collaboration. It lead that the users have to carry out twice setting before the collaboration. One is that the users need to connect to LAN by password which is not published to the outsiders. Another is that the users need to carry out the set to have to collaboration just like creating room and setting password. These settings lead that the users have to waste time to do some same things in order to have the local collaboration. So in our work, we are committed to commence the collaboration rapidly in the local.

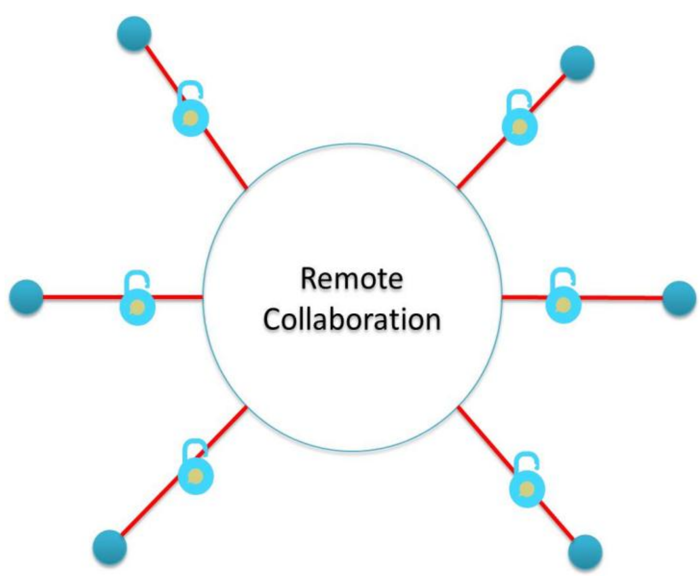

Figure 3-1 Remote Collaboration

First, in the local, the users must connect to LAN by password in order to communicate with each other. And the password is not published to the outsiders. In other words, the users can communicate with each other securely, not need to worry about the disclosure of information. So it leads that the next setting is becomes superfluous in the local collaboration because of the same function. In our research, we simplified the connection steps in the safe range. The users can commence the local collaboration without the second step which requires the users to create room and set password for the collaboration.

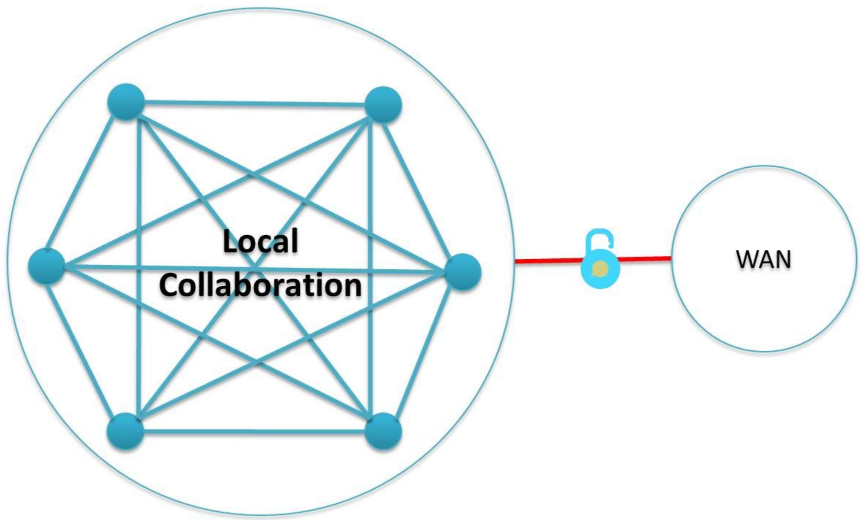

Figure 3-2 Local Collaboration

Then, in order to establish a remote collaboration connection [Figure 3-3] with others, the users have to know the others' IP address and Port number. It will waste considerable time to ask the others about the above information and confirm the related information. And it will become more trouble due to the increased number of the participants. In order to simplify connection further, we proposed intelligent connection [Figure 3-4] in the smart cooperative working spaces. The intelligent connection is that all devices in the proposed spaces can establish the connection with others automatically without knowing the others' IP address and Port number. The intelligent connection can save a lot of time which is used to ask and confirm the related information. And enhance the user experience further. The users in the proposed spaces can pay more attention on the collaboration, not connection.

Figure 3-3 Remote Collaboration Connection

Figure 3-4 Intelligent Connection in the Smart Cooperative Working Spaces

On the other hand, most of the users do not allow the others to control their computer in the collaboration because of the disclosure of information. However, they are willing to share their desktop to the others in order to have the collaboration more efficiently. Another problem about sharing control authority is that it will lead to low efficiency of collaboration. Controlling the other's computer will lead that the participant cannot have the collaboration at that time, because the computer is controlled by the others. The action like above affected that they cannot have the collaboration efficiently. According to the above analysis, no control authority sharing can ensure the information security and efficiency in the collaboration. So in our research, we will construct the smart cooperative working spaces based on these requirements.

3.2.2 Characteristics of the Proposed Spaces

Through the above analysis, we can know the characteristics and requirements of the local collaboration. So we make the smart cooperative working spaces have the two main characteristics.

- **Intelligent connection**： Information terminals in the proposed space will be connected into the collaboration group automatically by starting the application.

- **No control authority sharing policy**： The proposed spaces do not allow users to control the others' computers. In our research, we only support the collaboration by sharing the desktop information.

According to the above, we present that using peer to peer technology to establish the underlying communication in order to achieve simplified connection. And in our research, we will do not allow users to control the others' computers and access other users' files in any event. We stipulate that only the desktop information can be exploited. So this requirement led to high requirements of images transmission. To achieve requirement, we adopted smart image transmission method which can reduce the total amount of transmission. The smart image transmission method is that we will transfer part of image which changed intelligently, not the entire image. In the following section, we will introduce these technologies and how to use them to construct smart cooperative working spaces in the multi-display environment.

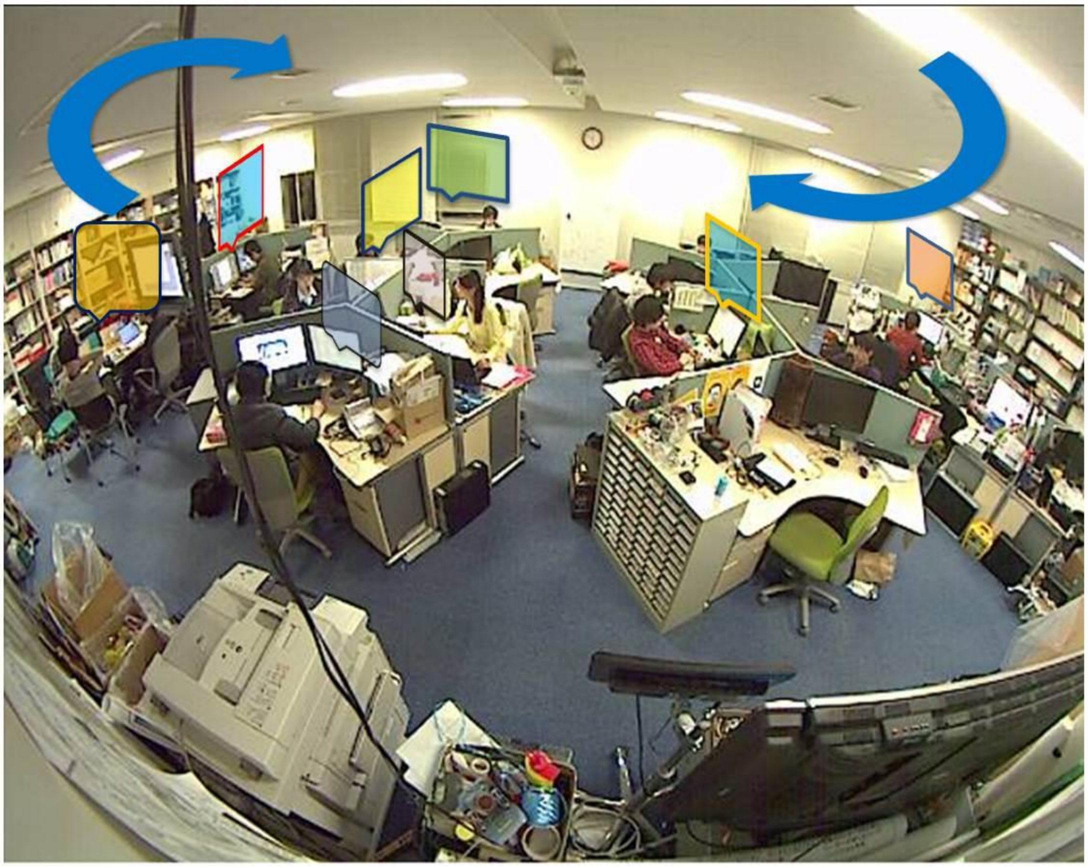

Figure 3-5 The Smart Cooperative Working Spaces

3.3 Connection of Smart Cooperative Working Spaces

In our research, we decided to use Peer to Peer technology as the underlying communication because of the unique advantages. In the following section, we will introduce peer to peer technology, its advantages and the established method in our work chronologically.

3.3.1 Peer to Peer Technology

The Peer to Peer Network [Figure 3-6] is that every information terminal in the network is equal and all of them can be treated as server or client. And it allows all information terminals to share resources without a central server. Peer to Peer technology can be set up within a variety of field, such as laboratory or Internet. When Peer to Peer technology is set up, all of the information terminals are required to install a compatible program in order that they share and obtain resources in the network. It can be applied to share all resources which are in digital format.

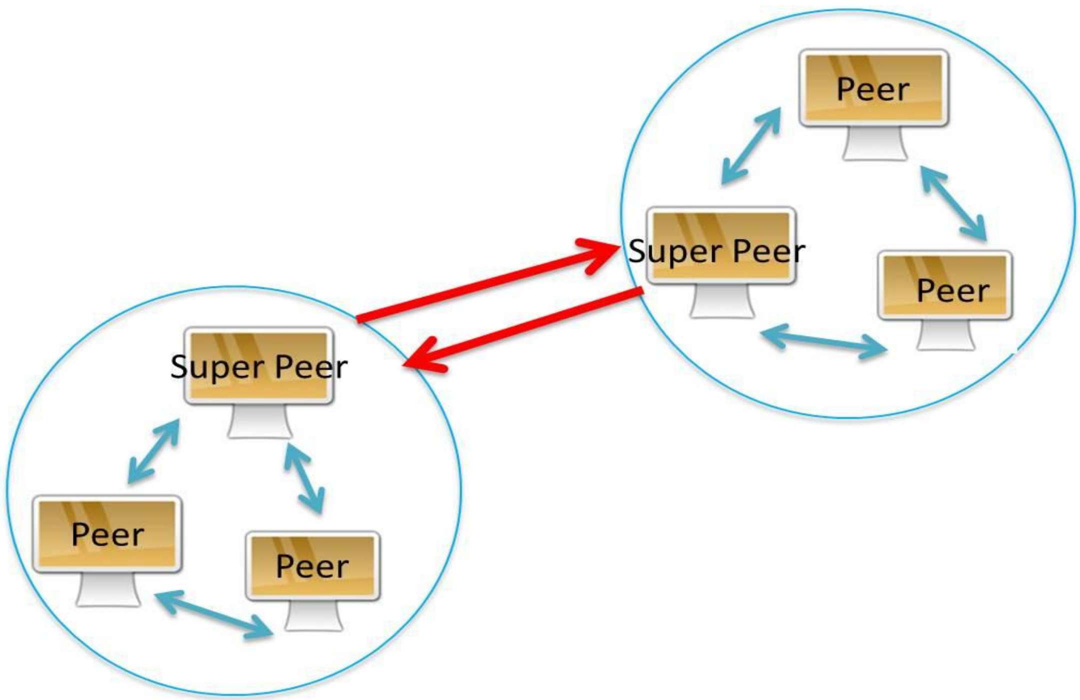

Figure 3-6 Peer to Peer Network

Following is the characteristics of Peer to Peer technology.

- All of peers are the equal in the network.
- Database and computation are dispersed.
- The connection of peers is unstable.

- Properties:
  - no central coordination
  - no central database
  - no peer has a global view of the system
  - global behavior emerges from local interactions
  - all existing data and services are accessible from any peer
  - peers are autonomous

3.3.2 The Advantage of Peer to Peer Technology

The advantage of Peer to Peer network is that it is easier to set up and use than a network with a dedicated server. In Peer to Peer networks, all nodes can act as server as well as client therefore no need of dedicated server. When demand on the system increases, the total capacity of the system also increases. Robustness of the Peer to Peer network increases when duplicate data arrive on multiple peers. Here are some points that describe that the Peer to Peer network is less expensive. Peer to Peer network is easier to set up and use means that you can spend less time in the configuration and implementation of peer to peer network. It is not require for the peer to peer network to use the dedicated server computer. Any computer on the network can function as both a network server and a user workstation.

In our research, the reason why we adopted Peer to Peer technology is that it can allow users connect and interact more flexibly and rapidly. Users can establish a connection to have the collaboration without server. In the above, we discussed the requirements of the local collaboration. In the local collaboration, one of important points is that the spaces must allow the users join or leave the collaboration flexibly. And the Peer to Peer technology can meet this requirement.

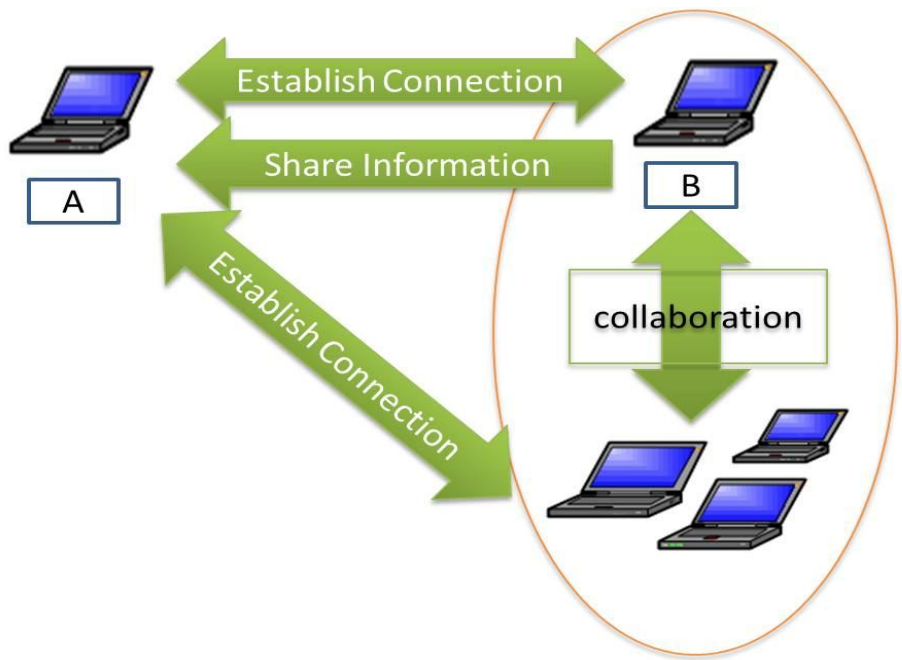

Figure 3-7 Intelligent connection

3.3.3 The Established Method in Our Research

In our research, we present the intelligent connection [Figure 3-7] method which does not require unnecessary certification procedures to join the collaboration flexibly and smoothly. In other words, users can establish the connection to have the collaboration more efficiently than before. When users start the application in the proposed space, the application will try to find the compatible programs which are installed in other information terminals to establish connection dynamically.

To achieve the proposed intelligent connection, six steps will be conducted gradually. First, when the application is started, the system will send the authentication messages [Figure 3-8] to every information terminal which is connected to the same local area network. The authentication message consists of three parts. They are confidential information, IP address and Port number.

Figure 3-8 Authentication Message

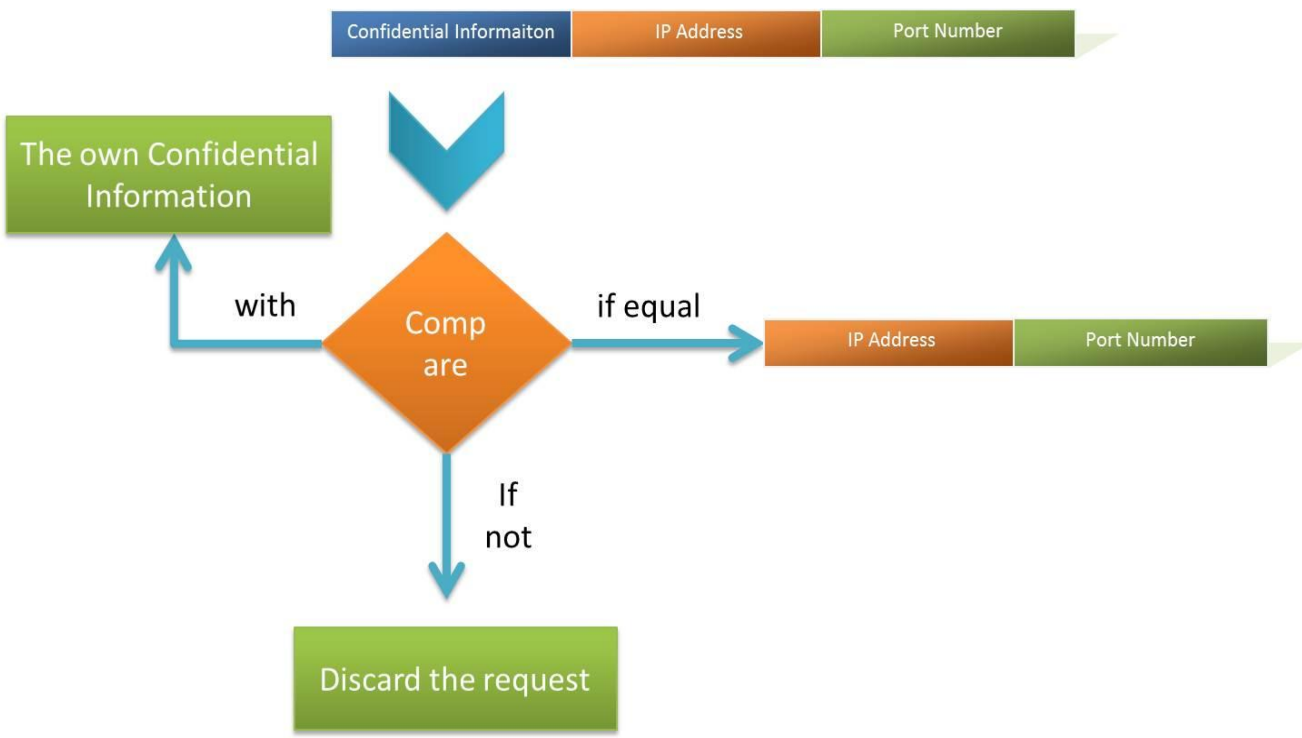

Figure 3-9 Connection Authentications

Following is the steps of intelligent connection Authentication [Figure 3-9].

- First, the authentication messages will be sent to every information terminal which is connected to the local area network.

- Secondly, when application receives the authentication messages which are sent by other users. The application must compare the confidential information with their confidential information to determine whether it is the information terminal which is needed to establish the connection with by the result of comparison.

- If the comparison result is consistent, IP address and Port number which are mothballed in the authentication messages can be obtained and exploited without restriction.

- Return the confirmation message to the information terminal source which sent the authentication messages by the IP address and Port number.
  Confirmation message = confirmation message+ IP address+ Port message.

- When the confirmation is returned to the information terminal source, the two information terminals will began to connect with each other by Peer to Peer technology.

- When the intelligent connection is established, they will share the information of information terminals which have been connected to the two devices. They will send the related information of these devices to each other. And they can connect these information terminals by accepted information. In this way, the group connection can be established and commence the collaboration rapidly and intelligently.

The above is the method that we establish the intelligent connection which was proposed in our research. Our Approach allows the connection to be established rapidly and intelligently without a central server in the local collaboration. If necessary, users can join or leave the group randomly without disturbing others and location restriction. Another advantage is that all connection procedures are automatic. The connection can be completed without artificial settings. The intelligent can make users to pay more attention on collaboration, not the connection settings.

3.4 Image Transmission

In most approaches, accessing to files and controlling the screens are authorized. But these approaches are usually accompanied by security problems and mutual interference. First, these authorizations may lead that files on the system may be obtained unconsciously. Undesirable illegal utilization will occur. And another situation is that controlling the others' screens without restriction will interrupt others and make them cannot work. Thus, it will disrupt the work of the entire group, not just individuals. In order to avoid these problems, we stipulate that only the desktop information can be utilized in our research. This provision led to high requirements of image transmission. So we adopt the smart image transmission method to achieve it. The smart image transmission method is that we will just transfer part of image which changed intelligently, not transfer the entire image constantly. The proposed method can optimize the communication status of the Smart Cooperative Working Spaces. In the next section, we will introduce the specific mechanism of the image transmission.

3.4.1 Message Digest Algorithm 5[21]

In our research, we adopted Message-Digest Algorithm 5 to judge whether to transfer image unit in order to avoid the waste of resources and we call it MD5 in the following.

MD5 is an algorithm that is used to verify data integrity through the creation of a 128-bit message digest from data input (which may be a message of any length) that is claimed to be as unique to that specific data as a fingerprint is to the specific individual. And it was developed by Professor Ronald L. Rivest of MIT.

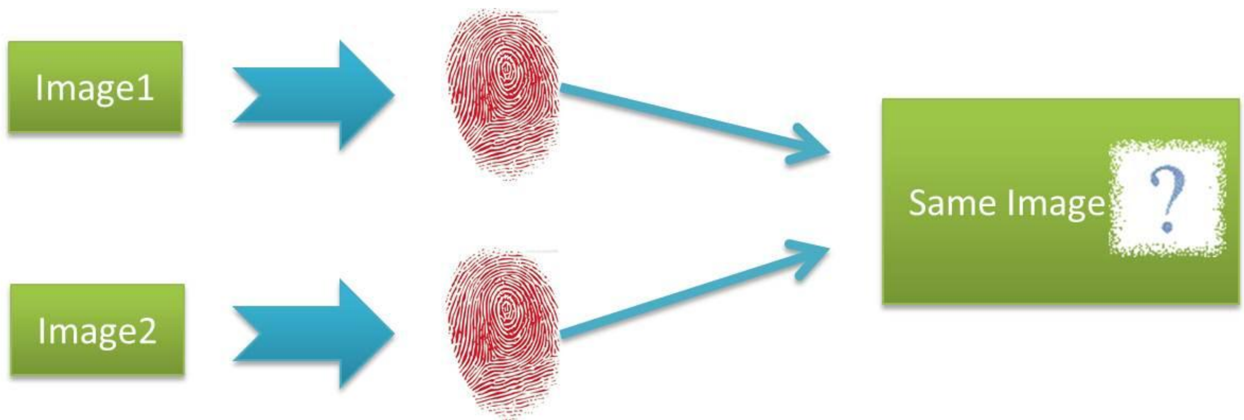

Figure 3-10 Message Digest Algorithm 5

3.4.2 Mechanism

In this section, we will introduce the proposed image transmission. It can be roughly divided into six steps. We can know from the above that image transmission is an important part in our research. The efficiency of the image transmission affects system performance and experience directly. So we will do some processing before transferring images in order to obtain faster transmission speeds.

Following is the steps of the image transmission [Figure 3-11].

- Before transferring the images, they will be divided into a number of image units according to the size of the image.
- Then, all image units will be obtained and be used to judge the image change. And only the image units which changed will be transferred to the others .
- In order to judge whether to transfer the image units, the MD5 values of all image units will be calculated by the Message Digest Algorithm 5 [Figure 3-10].

- The MD5 value of an image unit will be compared with its last MD5. If the result is not the same, the transmission will be canceled.

- And if the result is the same, the image unit will be transferred to the specified information terminal. In order to obtain faster transmission speed, the image unit will be compressed into a small size.

- When the above processing is completed, image unit transmission will start.

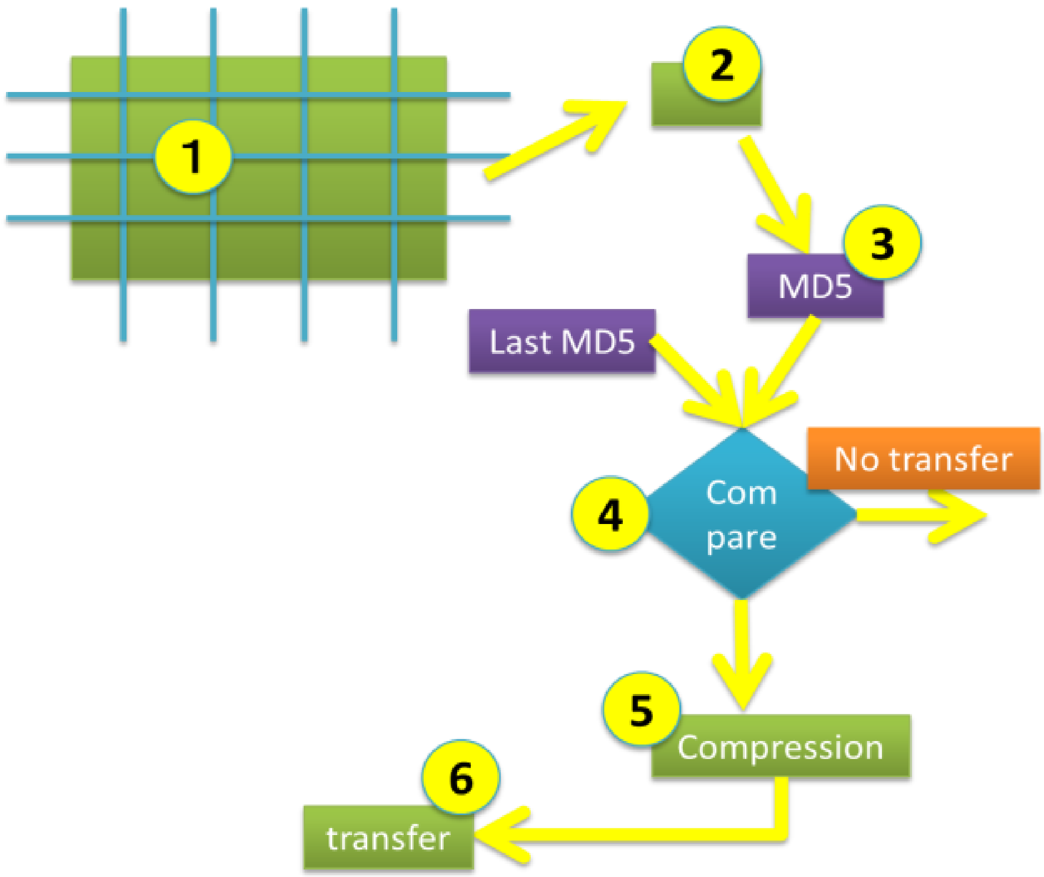

Figure 3-11 Image Transmission

In our smart cooperative working spaces, all the image transmission will be conducted using this method. The proposed image transmission method reduces unnecessary waste. And it can control the transmission delay effectively.

3.5 Interaction

In most researches about multi-display, they only provided the synchronization information of others' information terminals. It means that users can just obtain the information which the others' users are using. However, the information disappears in a flash. In our research, our provision [Table 3-1] is that users cannot control the other information terminals to obtain any information which they want. We can just use the desktop information of the others to have the collaboration. Based on above, we present axis structure [Figure 3-12] to deal with the desktop information in order to improve the efficiency of collaboration. Through the axis structure, the participants can use the synchronization and non-synchronization information flexibly and smoothly in the proposed spaces.

Table 3-1 The Interaction Characteristics

Connect	Control Share	Desktop Share	Situation	Synchronization Information	Non-synchronization Information
P2P	No	Yes	Multiple to Multiple	Yes	Yes

3.5.1 Axis Structure

The proposed axis structure consists of screen axis and timeline. The vertical axis is the screen axis. And the horizontal axis is timeline. We utilize the information of the screen axis and timeline to build the collaboration information archive in order that users can utilize all the information adequately in the proposed spaces. The screen axis shows all information terminals which are connected in the smart cooperative working spaces. We use the small icon to represent the information terminals which are connected in the proposed spaces. The small icons are made by screen thumbnails. They change with screens synchronously in order to understand the working state of the other members. And users can select one of the screen icons to obtain its timeline. The timeline will be calculated until one of icons is selected. We present that using the similarity of the images to build the timeline. Each frame of image will be compared to the last frame of the screen images. And if the result shows that they are the different images, the current image will be put into the timeline. In addition, in our research, we adopt the image perceptual hashing algorithm to calculate the similarity of the images. Through image perceptual hashing algorithm, we can calculate a fingerprint for each image. And these fingerprints will be used to compare the similarity of the images. The similarity of fingerprints will determine the similarity of the images. In our research, when the similarity is more than 83%, the images will be judged to be the same. And if the similarity is less than 83%, the images will be judged to be the different. We carried out repeated experiments to determine the value which can be used to judge whether the image is the same because of image transmission noise. By the above method, we can build the timeline for every user. The significant advantage of the timeline is that the past information which is published by other users can only be obtained. Users do not need to worry about unpublished information. It makes that proposed space has a higher level of security.

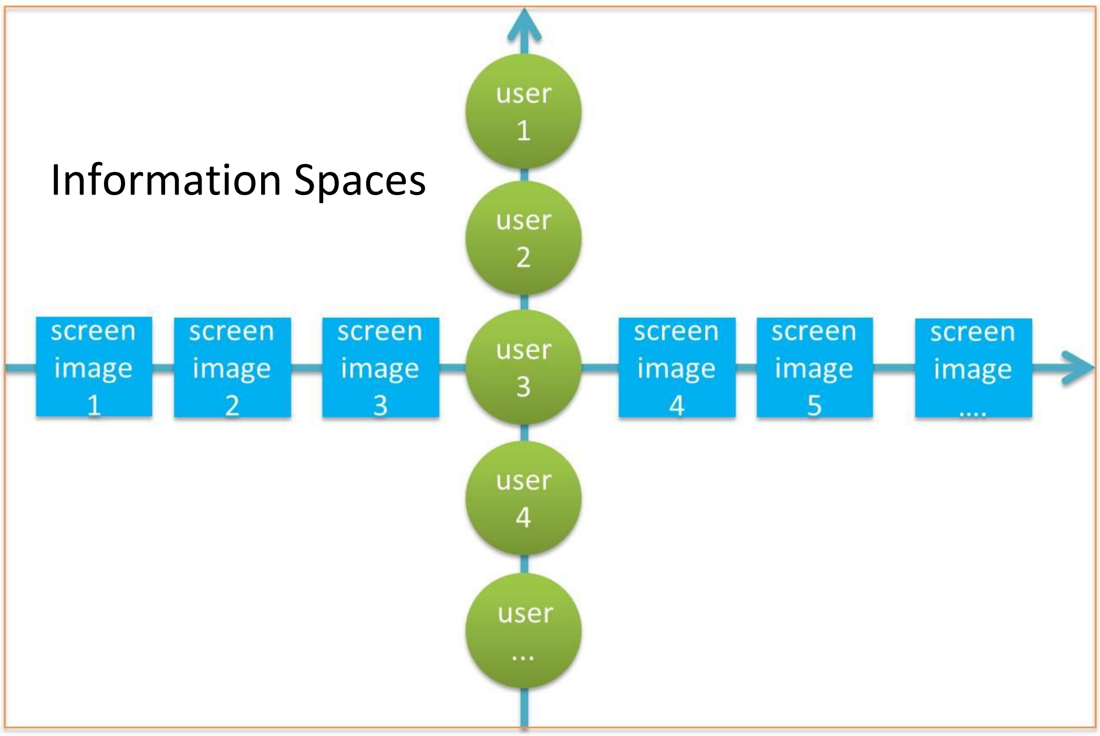

Figure 3-12 Axis Structure

Chapter 4

Application of Smart Cooperative Working Spaces

4.1 Presentation Application

In chapter 3, we introduced the construction of smart cooperative working spaces. And in chapter 4, we introduce the presentation application [Figure 4-1] which is developed based on the smart cooperative working spaces.

In the daily life and work, we have a number of opportunities to participate in the conference in the multi-display environment. Sometimes we need to have a presentation. Sometimes we need to hear the presentation and give constructive comments back to the speaker as an audience. It requires us to utilize the information of the multiple displays which is shown in the same spaces adequately.

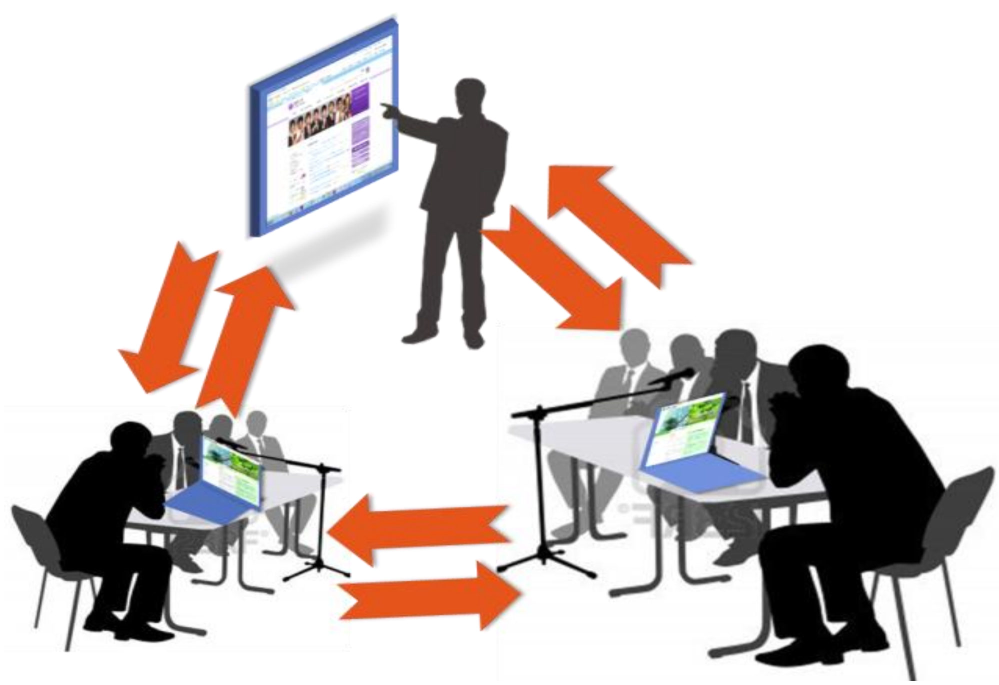

Figure 4-1 Presentation Application based on the Smart Cooperative Spaces

- The first situation is that the user is speaker. As a speaker, the user has to share the presentation material to the other users in the same spaces. And the speaker also needs more information to make have a good presentation, such as serif. It can remind him the key points of each page and make him have a good presentation.

- The second situation is that the user needs to give the constructive comments back to the speaker as an audience. As audiences, they need to obtain the presentation material of the speaker and give their own comments back to the speaker or other audiences.

And we also present to use the large display to share the information together in the multi-display environment. The speaker can share the presentation material using the application based on the smart cooperative working spaces and large display. Content which is shown to the speaker and the audience is different in order to achieve customization. The audiences can only obtain the content which is published by the speaker. In addition, audiences can build the axis which consists of the screen axis and timeline by the information of speaker's screen. And audiences can annotate screen image which they are interested in and have questions on and put them into the image archive in order that audiences can present the high quality questions and comments later.

4.2 Mode

According to the above description, we present two modes in our research. One is speaker mode [Figure 4-2] and another is audience mode [Figure 4-3]. We developed these modes based on the characteristics of the presentation scene in the multi-display environment with large display. In the local collaboration, users can change the mode according to their roles in order to improve the collaboration efficiency. And we designed the different interfaces for two modes because of the respective responsibilities.

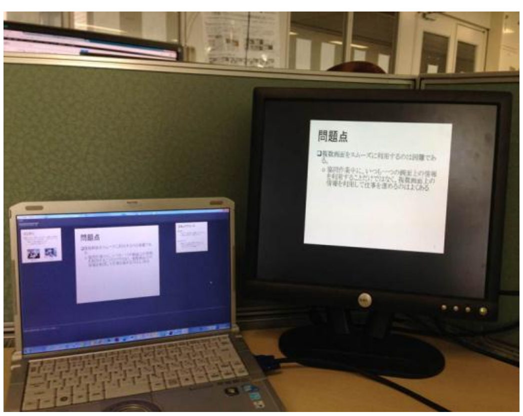

Figure 4-2 Speaker Mode

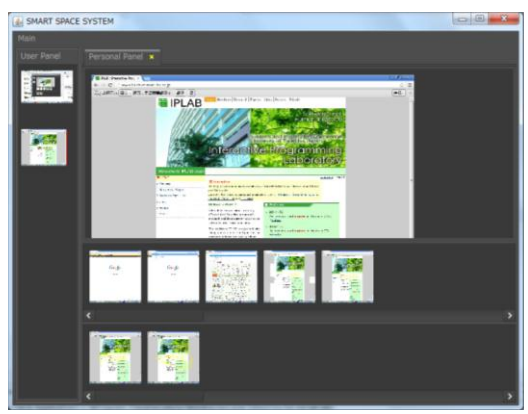

Figure 4-3 Audience Mode

4.2.1 Speaker Mode

We designed four parts for speaker mode [Figure 4-4] [Figure 4-5] including user panel, personal panel, serif panel and large display panel. We will achieve the above-mentioned demand of speaker through these panels.

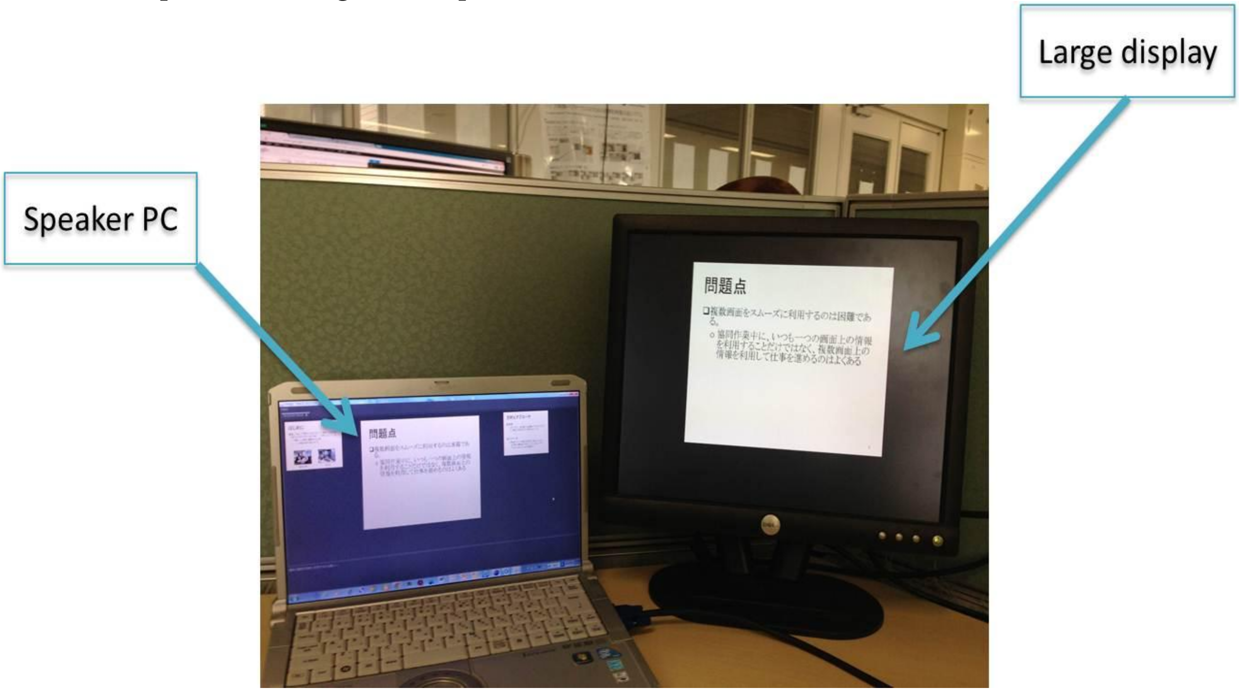

Figure 4-4 Hardware of Speaker Mode

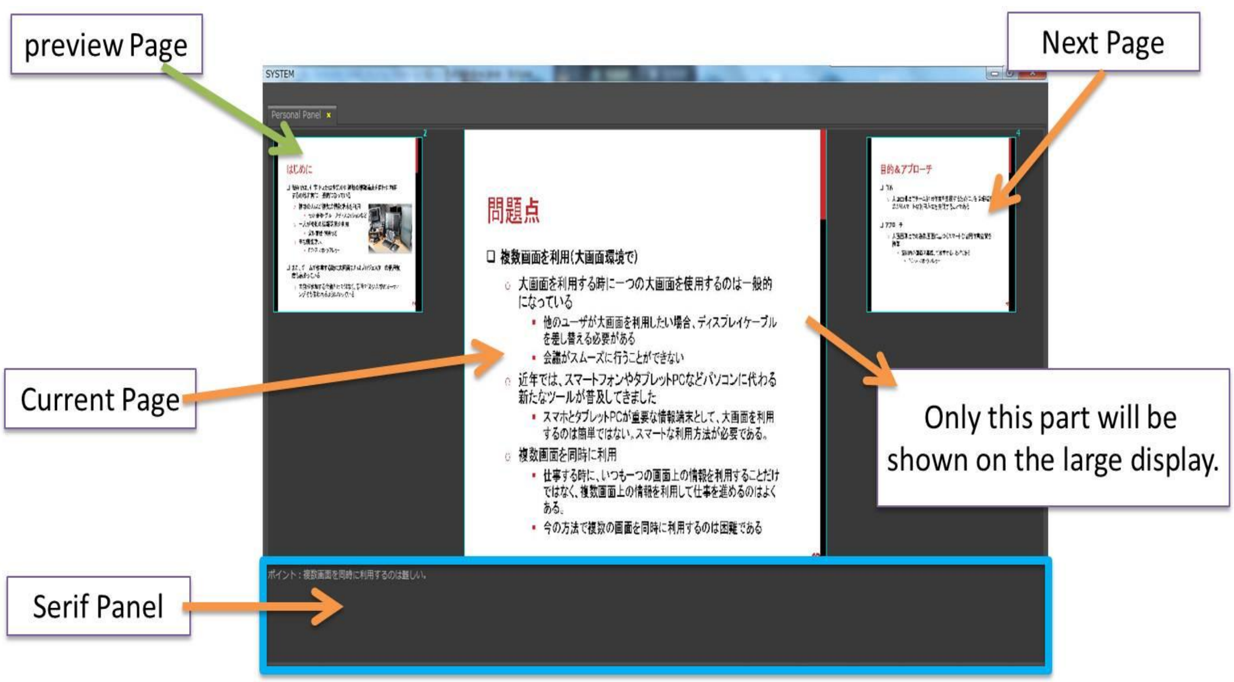

Figure 4-5 Interface of Speaker Mode

First, speakers need to import PowerPoint file before having the presentation in order to obtain the related information. We designed the user panel to show the information terminals which are connected to participate in the collaboration. When the speaker is having the presentation, he can know the participants who are hearing his presentation. But sometimes user panel may interfere with the speaker, so we designed that the speakers can set it visible or invisible.

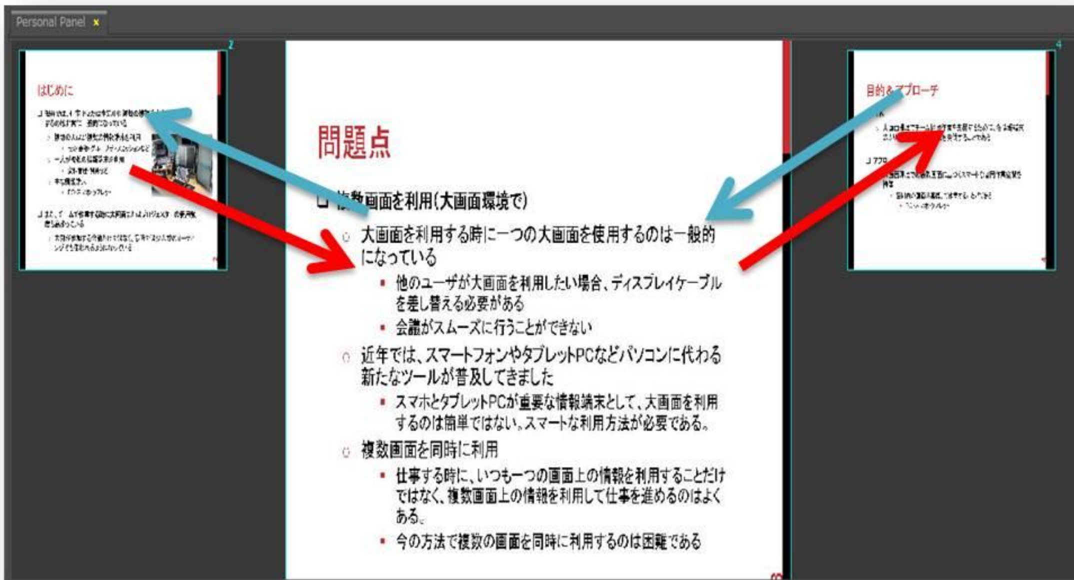

Figure 4-6 Personal Panel of Speaker Mode

And another part is personal panel [Figure 4-6]. We designed this part for showing the personal information to the speaker. The personal panel can be roughly divided into two kinds of information panel, public and non-public information. The public information is that everyone in the collaboration can utilize it without restrictions. The non-public information is that only the speaker can utilize it and it is hidden to others. Two parts of the personal panel are the current page and preview page. We set the current page as the public panel and the preview page as the non-public panel. The current page is the page we are illustrating. The preview page is the next page and previous page of the current page and it can make presentation more relevance because of three-page information. The current page will be shared to the audiences by Peer to Peer network and shown on the large display as the public information. Contents which are utilized by speakers and audiences are different. This kind of design makes the speakers don't need to worry about leakage of personal information. The system will provide users with customized information according to their roles.

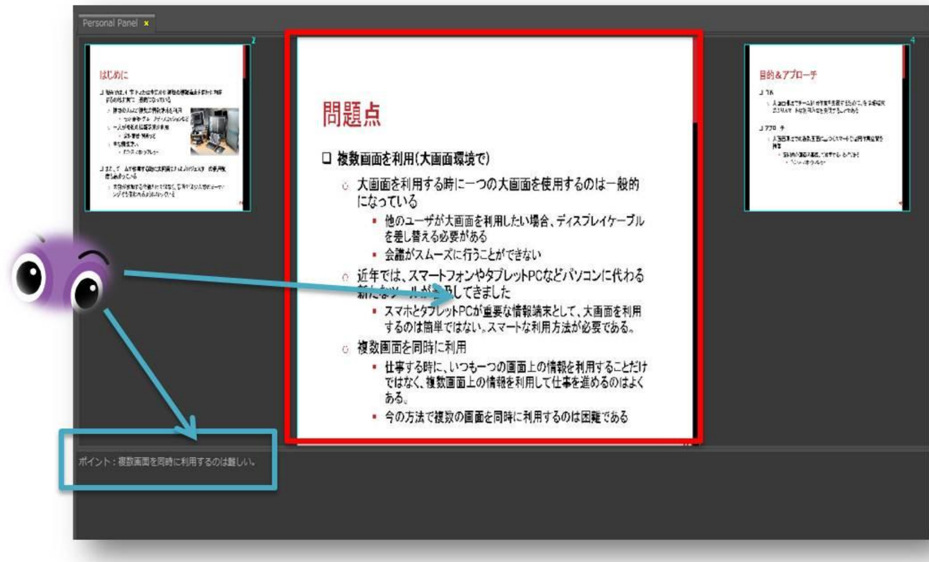

Figure 4-7 Serif Panel of Speaker Mode

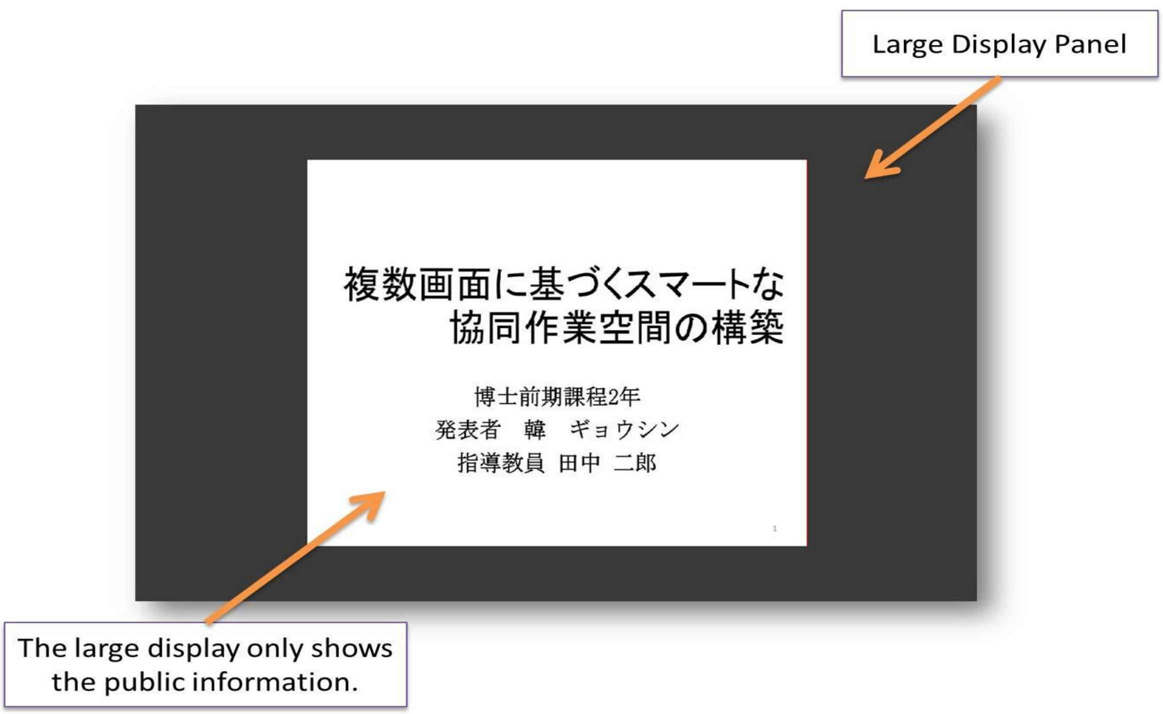

Figure 4-8 Large Display Panel of Speaker Mode

We also designed the serif panel [Figure 4-7] for speakers. When we make PowerPoint file, we always need to write some serif for every page in order to remind ourselves. And lot of speakers like watching the serif to have the presentation. However, the serif can just be watched by speakers and not be shared to any other users because of confidentiality. So we set the serif information as the non-public information based on this point. In our research, we present a fully customized interface for every user.

And the last part is the large display panel [Figure 4-8]. Nowadays, the use of a large screen has become a trend in the collaboration. So we add the large display to our system. The large display panel is designed for the audiences and just shows the information which is set as the public.

4.2.2 Audience Mode

We designed four parts for audience mode [Figure 4-9] including user panel, personal panel, timeline screen image archive and annotation image archive. These designs allow the users utilize the information in the proposed spaces flexible and adequately.

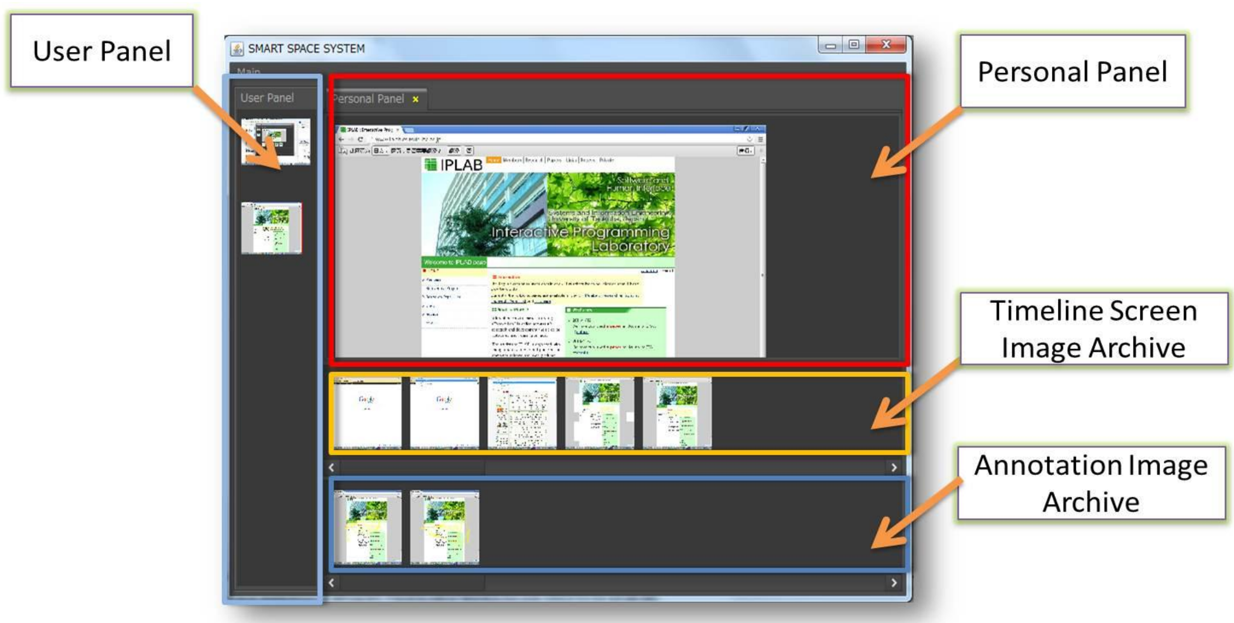

Figure 4-9 Interface of Audience Mode

First, we designed the user panel [Figure 4-10] like speaker mode for audience in order that audiences can know who are in the collaboration at any time. The user panel is designed to show the screen axis. It shows the screen icon which is made by the full size screen image. And they will change in real time in order to know the process of other users.

The personal panel [Figure 4-11] is designed to show the full size screen image of the others. Users can select one icon which is in the collaboration from the user panel. The full size screen image of the selected information terminal will be shown on the personal panel. And in order that audiences can record doubt about content of the screen, we also developed the annotation function for the personal panel. The audiences can mark on the screen image which is shared from other information terminal to remember the doubt point or interesting point of each page. And the marked screen image will be stored into the annotation image archive in order that the audiences can utilize the information again, if necessary.

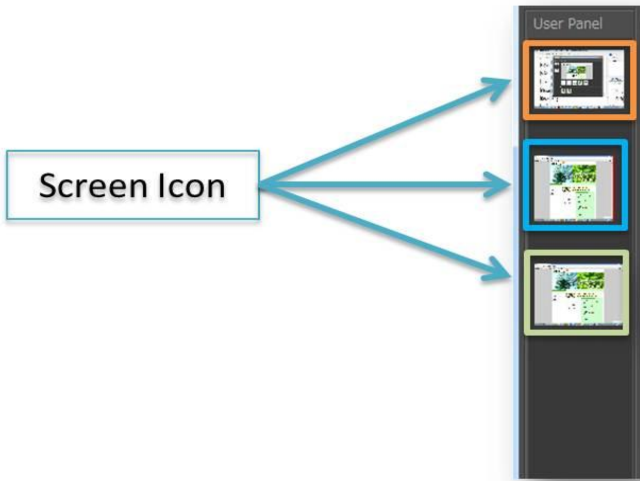

Figure 4-10 User Panel of Speaker Mode

Figure 4-11 Personal Panel of Audience Mode

The next part is the timeline screen image archive [Figure 4-12]. When the users select one icon from the user panel, the full size screen image will be shown on the personal panel. And then image similarity will be used to build the timeline screen image archive. The image which is shown on the personal panel will be compared with last frame. If it is determined as the different images, it will be put into timeline screen image archive. Timeline of axis will be built by this method and all previous information will be stored into the timeline. The users can utilize all screen images in the timeline screen image archive by clicking them and then the previous screen information will be shown on the personal panel. By this way, all information from past to present in the smart cooperative working spaces will be integrated and then users can re-use these information simple at any time.

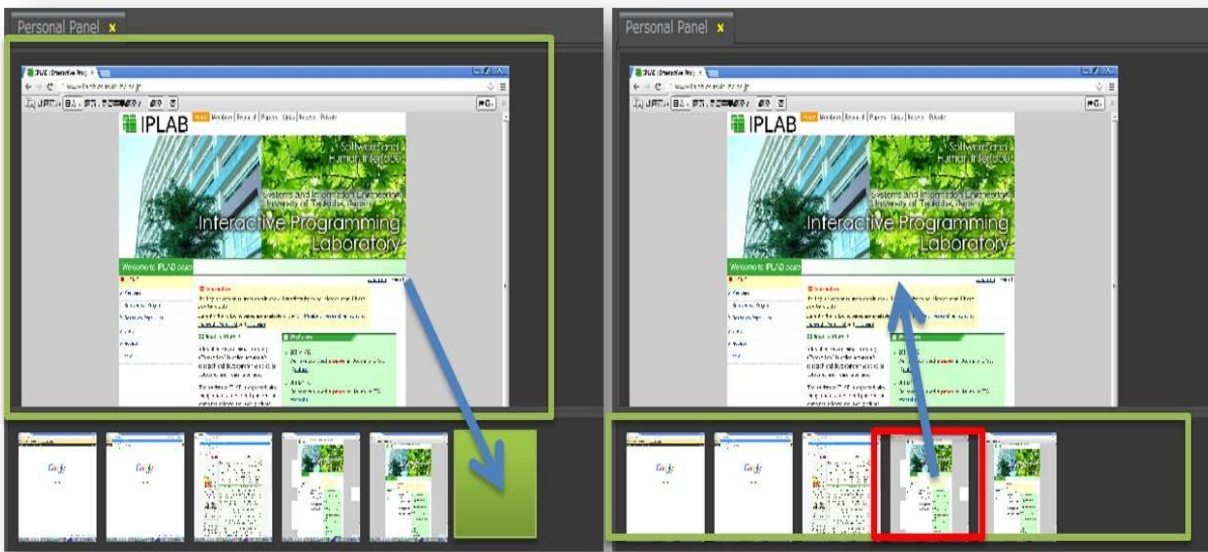

Figure 4-12 Timeline Screen Image Archive

The last part of the audience mode is the annotation image archive [Figure 4-13]. The annotation image archive stores images which are marked on the personal panel. In our research, we designed two kinds of the archives. They saved the two types of information, the integrated information in the spaces and the customized information. The annotation image archive shows the customized information. Users can annotate on the screen image of the other information terminals which are shown on the personal panel to make the information they need and the marked information can be stored into the annotation. Through watching the marked image in the annotation image archive can make users remind first thoughts. If the timeline screen image archive can be likened to objective spatial memories, the annotation archive can be likened to subjective individual memories. The two kinds of archives allow the smart cooperative working spaces have comprehensive information network in order to have highly efficient collaboration.

Figure 4-13 Annotation Image Archive

The above is the two modes which are developed based on the different user requirements for the presentation application in smart cooperative working spaces. The presentation application allows participants to have the collaboration efficiently according to their roles. And the application allows users to participate in and quit the collaboration dynamically. When the own information terminal is connected with the others, users can freely utilize the integrated information and the customized information within the space through their information terminal.

4.3 Implementation environment

In our research, in order to evaluate the proposed smart cooperative working spaces, we developed the presentation application based on it. In this section, we will introduce the implementation environment about the presentation application based on the proposed spaces including the development environment and the system architecture.

4.3.1 Development Environment

In the collaboration, it is almost impossible that all the information terminals use the same Operating System. Therefore, in order to enhance the robustness, we must make the smart cooperative working spaces allow cross-platform. In our research, we adopt the Java language to construct the proposed spaces and develop the application based on the proposed spaces.

- Compilation Environment： Java^{TM} Platform, Standard Edition Development Kit 7
- Development Tool： Eclipse Galileo IDE for Java Developers
- Runtime Environment： Java Runtime Environment 7
- Development System： Windows 7

Through development based on the above, the proposed spaces allow to have the collaboration with the cross-platform. And it is an important difference, comparing with the most of the researches in the past. The cross-platform made that users do not need to worry about whether their system are compatible with the other information terminals in the smart cooperative working spaces.

4.3.2 System Architecture [Figure 4-14]

The modules of the presentation application are divided into five parts including of main module, interface module, connection module, image transmission module and function module.

The main module consists of system initialization, other modules invocation and specific functions invocation.

The interface module consists of the speaker interface, the audience interface and respective function listener. When the application starts, the main module will invoke the audience interface of the interface module. And users can change the mode to the speaker mode by self-invoke.

The connection module consists of network initialization, connection operation and information terminals filing. The main module will invoke the connection module to initialize the network configuration and information terminals, when the application starts. And the application will invoke the connection module to have the connection operation. All information of the connected information terminals will stored in order to be able to use at any time.

The image transmission module consists of the image Segmentation, the MD5 value calculation, the image compression and the image transmission. The image transmission can be invoked by the connection module and the function module. When the image transmission module is invoked, the correlation function will begin to calculate the corresponding content.

The function module consists of user panel function, personal panel function, serif panel function, timeline function and annotation function. These functions can be invoked by the listeners of the interface module and the main module. When these functions are executed, the stored information of all information terminals will be invoked from the multiple information terminal information stubs at the same time.

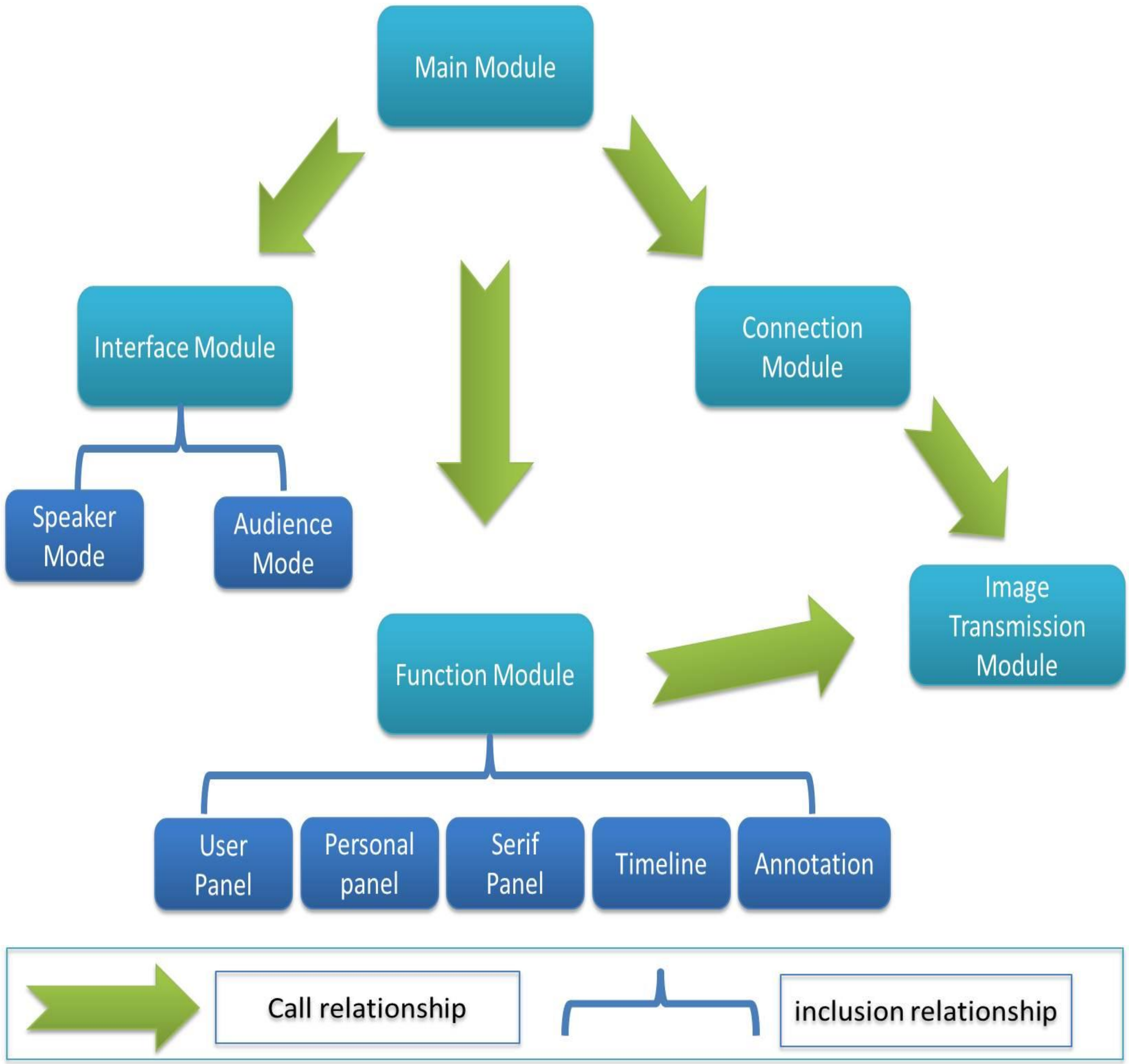

Figure 4-14 System Architecture

4.4 Scenario

We assume that the scene is the presentations of the conference. The speaker does not need to print presentation material and distribute them to the participants in advance. The speaker just need to start the application to join the collaboration and then the audiences can obtain the presentation material without hindrance in the safety range by the presentation application.

And when the participants arrive at the venue, they start the application to connect to the smart cooperative working spaces and then they can freely utilize all information in the spaces. In addition, if some participants are late, they can also join the collaboration and obtain the conference material without disturbing others.

- The speaker has the presentation using the speaker mode based on multi-display environment with large display. The speaker can utilize the preview information, current information and the serif information to make the presentation high quality. The pubic presentation materials will be shown on the large display as well as the public information which is shown on the personal panel. So in this way, the audiences can obtain the current information from the personal panel and the large display. And in order to avoid missing any important matters, the speakers can have the presentation with watching the serif which is shown on the serif panel. The speaker can share the presentation materials to the audiences and do not need to worry about leaking the content of the presentation.

- And when presentation starts, the audiences can obtain the presentation material and watch the presentation by selecting the icon from the user panel. The timeline of the presentation will be built after selecting the icon of the speaker. And they can also annotate the screen information on the personal panel in order to record the focus and save memory. Through this approach, the proposed spaces can collect important information automatically during the collaboration. And when the presentation finishes, the audiences can utilize the information which is collected by the proposed space automatically and made to record the focus and memory to help them to look for the constructive problems and have the collaboration.

Through the information archive which is made by the proposed spaced automatically, the users in the proposed spaces can have the collaboration more efficiently. And when the collaboration finished, the information collected by the smart cooperative working spaces can be stored into all information terminals which are connected into the collaboration automatically as the recording of the conference in order to archive the conference.

Chapter 5

Validity Questionnaire

In the last chapter, we will evaluate the smart cooperative working spaces through some questionnaires. And we focus on evaluation of user awareness in the multi-display environment and the effectiveness of the proposed spaces.

5.1 User Awareness in the multi-display Environment

In this section, we will analyze user awareness in the multi-display through questionnaires. The first important thing we must prove is that whether to allow the others to control your computer in the collaboration. And we conducted a questionnaire in order to know this problem.

The experimental participants were required to answer three questions in the questionnaire I according to their awareness.

- Q1: Do you allow the other users to control your computer in the collaboration? If yes, go to Q2. If no, go to Q3.
- Q2: Do you allow the other users to get your documents from your computer without making you aware of it?
- Q3: Do you allow the other users to view collaboration material which are shown on your desktop in the collaboration?

The result [Figure 5-1] is shown below. We can know that most of the people (71%) do not allow the other users to control their computers, even in the collaboration. And although the rest allowed the other users to control their computers in the collaboration, all of them do not allow the others to get their documents from their computers without making them aware of it. It means that all experimental participants were worried about disclosure of information. This result is very representative. And it is important for us to evaluate the proposed spaces.

If the proposed spaces allow users to control the other users' computers, it will be difficult to ensure that the other users do not obtain your documents without making you aware of it. So in order to ensure the information security, the best approach is that do not provide the function which can allow users to control the others' computers.

80% of the people who do not allow the others to control their own computers allow sharing their desktop screen to the other users in the collaboration without control functions. And the rest of the people do not want share their desktop screen to the others unless it is absolutely necessary. It means that most of people think sharing the desktop screen is a relatively safe approach.

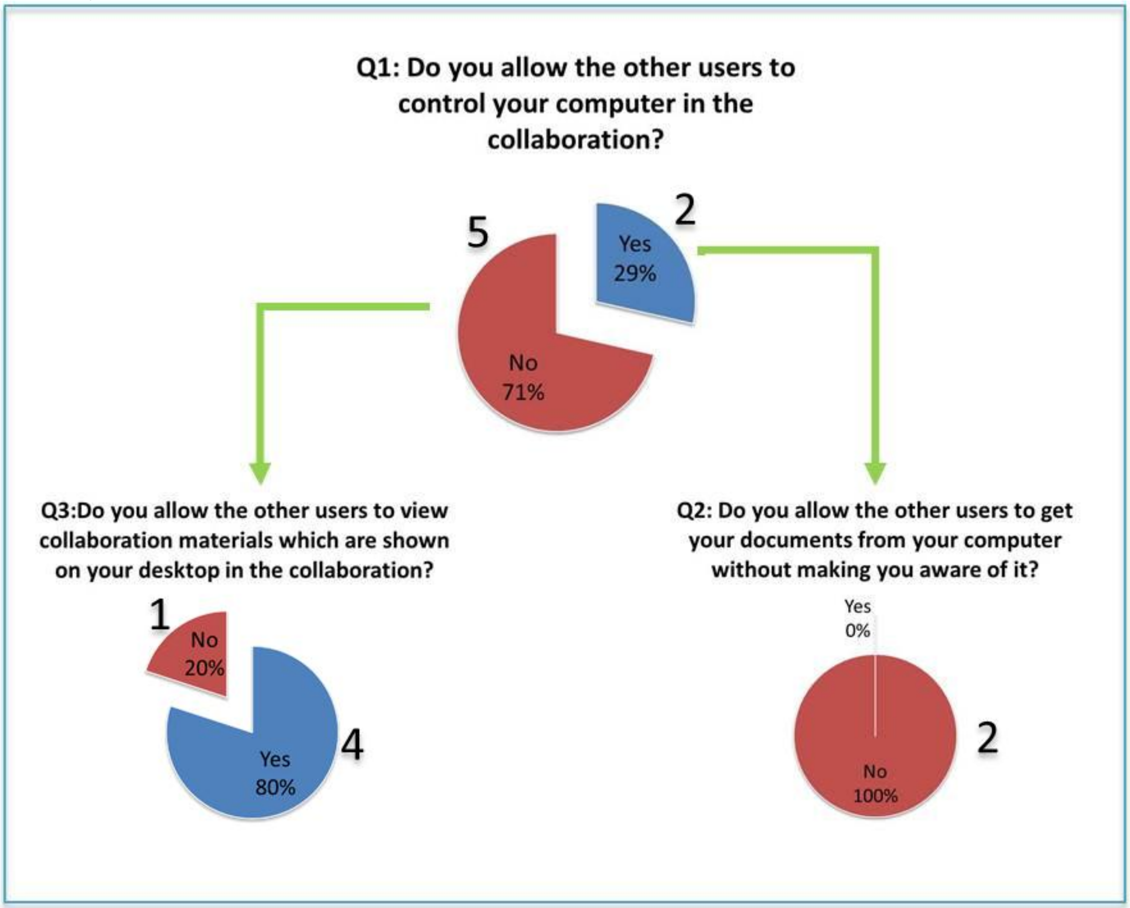

Figure 5-1 Results of the Questionnaire I

Through the above questionnaire, we understood user awareness about sharing the information which is saved into their computers to the others. And in the next section, we will introduce the questionnaire about the multi-display environment in order to find commonality of local collaboration.

The experimental participants were required to answer the questions below in the questionnaire II.

- Q1: Is the place which you have the collaboration in fixed?
- Q2: Do you think connection speed is important in the multi-display environment?

- Q3: The number of participants in the collaboration which you participate in generally?
- Q4: Do you want to know the list of participants in the collaboration?
- Q5: When you have the collaboration、do you summarize the key issues and take notes in advance in order that do not forget any key issues?
- Q6: when you have the collaboration, is the large display used?
- Q7: In the multi-display environment, do you think it is very troublesome to connect the PC and large display frequently?
- Q8: Do you want to use the collaboration materials which are saved in other users' computers in the collaboration?

Through the results [Figure 5-2] below, we can draw a few common points. First, the places which we have the collaboration in are not always the same. So establishing a connection rapidly in any environment is a very meaningful element. And in our research, we made the proposed spaces can establish the connection rapidly and smoothly by Peer to Peer technology. Another is that most of participants in the collaboration want to use the others' materials. And they think it can make everyone work more efficiently. In addition, most participants want to obtain immediate list of the participants in order to know the collaborative participation at any time. And in the collaboration, the large display will be used to share the information in most instances. But most of people think it is very troublesome to connect the PC and large display frequently. It will lead to waste a lot of time.

Another meaningful result is that most people think the connection speed is more important than security to the local collaboration. In the local collaboration, the complicated connection set makes most people feel trouble and unnecessary. They hope to commence the collaboration rapidly.

In addition, the collaboration which consists of 5~10 people is very common through question of average number of participants in the collaboration [Figure 5-3]. And the experimental participants said the team which consists of 5~10 people has a higher efficiency than the team which consists of other number. The detailed data will be shown below.

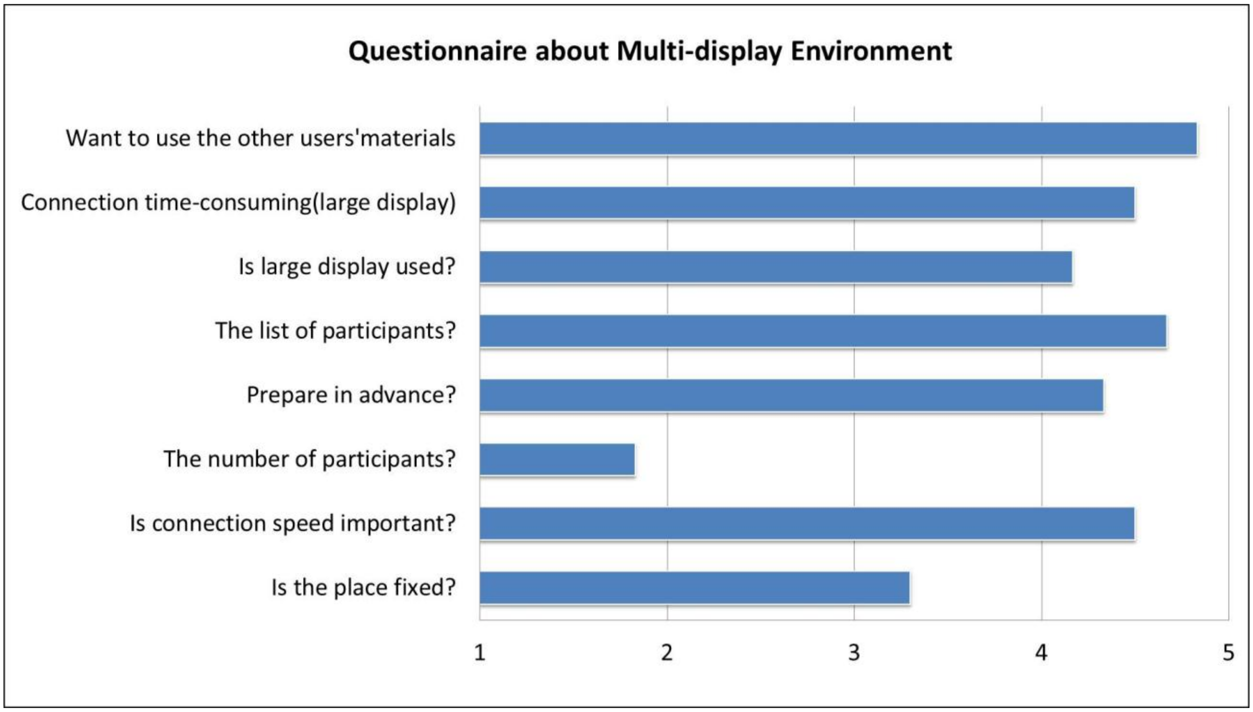

Figure 5-2 Results of the Questionnaire II

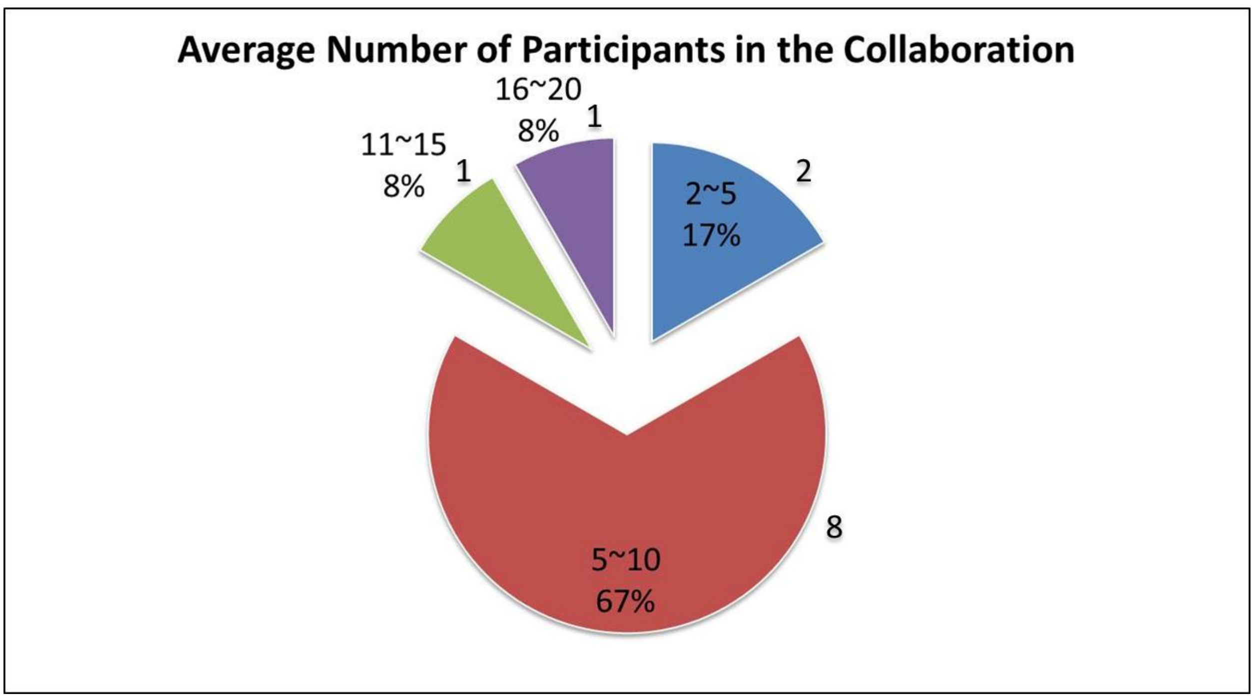

Figure 5-3 Average Number of Participants in the Collaboration

5.2 Collaboration Efficiency Optimization

In this section, we will analyze the collaboration efficiency optimization by the time which is saved by the proposed spaces. Nowadays, the participants have to waste some time to deal with the multi-device and multi-participant. In the multi-display environment with the large display, the participants have to connect their computers with large display frequently. During the period of the connection, the participants may use the time to start other topic which has nothing to do with the collaboration. And when the connection is completed, perhaps the new topic is not over yet. It will lead to waste more time.

In addition, the speakers need to print the PowerPoint documents before the collaboration. And when the collaboration begins, they need to distribute these printed documents to the others. The time will vary according to the number of participants. When the number becomes large, it will lead to waste more time.

Another problem is no printed documents environment. Sometimes we have no time or no place to print the documents sometimes. Sometimes we cannot know the specific number of participants in advance. It will lead that though print the documents, they are not enough. Some participants have to have the collaboration without the printed documents. So in the no printed documents environment, the participants have to remember every question which they want to ask to the speaker. It may lead to forget the questions and the participants need some time to think about them. Sometimes they need to confirm the content with the speaker in order to make themselves to remember the question. Through the above analysis, we summarize three factors which lead to waste the effective working time in the collaboration.

- Connect the PC and large display frequently. And it may lead to start other topic which has nothing to do with the collaboration.

- Distribute the printed documents to the other participants mutually.

- Think about the questions which they want to ask to the speaker. And confirm the presentation content with the speaker in order to make them remember the questions.

In this section, we only consider the impact of the above factors and analyze the collaboration efficiency optimization. We collect experimental data from the daily collaboration. And we mainly collect experimental data from 2-people collaboration, 5-people collaboration, 10-people collaboration and 11-15 people collaboration because of representativeness.

The experimental data which is collected from the daily collaboration including non-effective time [table 5-1] and collaboration efficiency optimization [Figure 5-4] is shown below.

Table 5-1 Non-effective Time Statistics

Collaboration (25 minutes per person)			
The Number of Participants	2	5	10
The Connection Time	36.1+3	36.1+6	36.1+7
The Distribution Time	5.5	17.28	23.9
The Question Time	12*1	12*3.5	12*4.8
The Wasted Time	3.64%	6.34%	7.67%

The connection time= connection time + other topic time.

The distribution time =distribute the printed to the participants.

The question time=think about and confirm questions * the number of askers

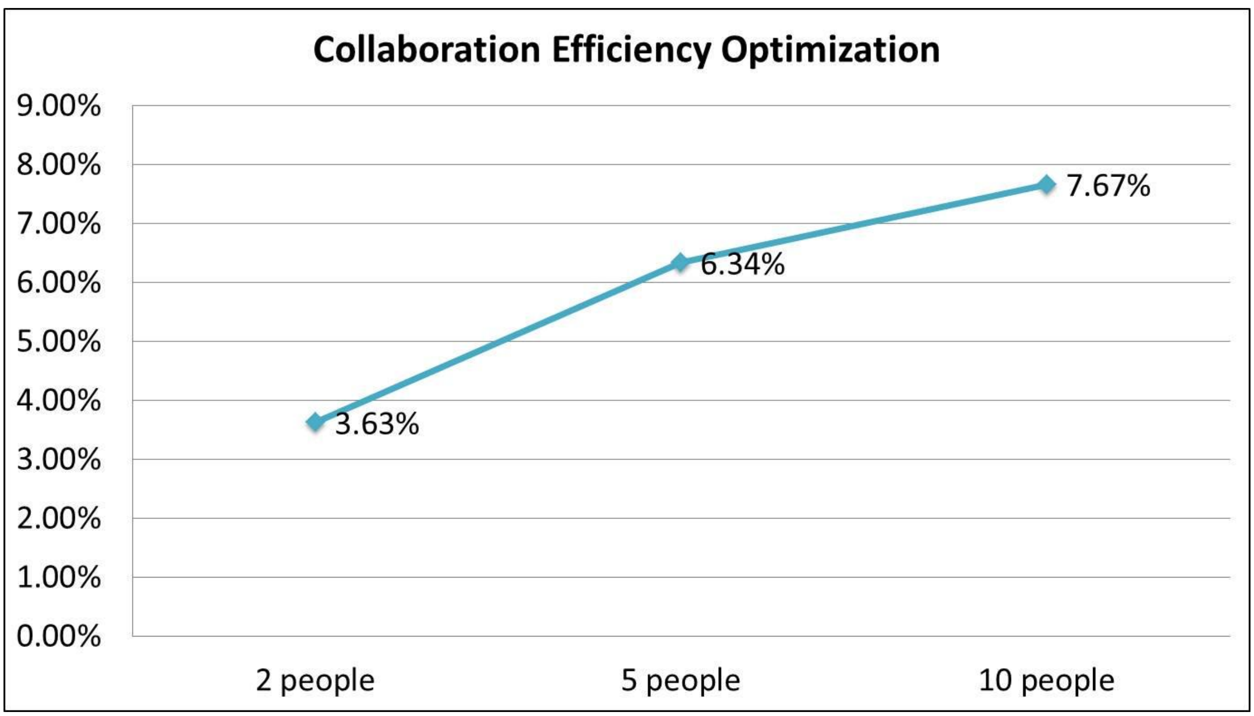

Figure 5-4 Collaboration Efficiency Optimization

The result shows that collaboration optimization curve rises steadily. And it is quite consistent with our previous experiments. The collaboration which is less than 10 people has a highly efficiency. And through the above questionnaire, we can also know that 84% of the experimental participants often participate in the collaboration which is less than 10 people. And we can know from Figure 5-4, the proposed spaces can optimize collaboration efficiency obviously. It proved that our proposed spaces can effectively improve collaboration efficiency in the multi-display environment.

In our research, we adopt Peer to Peer technology to establish the connection in the proposed spaces. When the participants increase, the amount of space communication also increases. The prototype will work well in the collaboration which is less than 10 people. When the number is more than 10 people, communication speed will be affected to some extent. But the proposed spaces still optimize collaboration efficiency comparing with current environment. The 11~15 people collaboration which be conducted in the proposed spaces can optimize efficiency about 5.7%.

Chapter 6

Conclusion and Future Work

In this paper, we propose the smart cooperative working spaces which allow let users who are in the proposed space can join group interaction without any resistance.

First, we construct the smart cooperative working spaces by the Peer to Peer network which requires no server. It can allow the users to have the collaboration without the restrictions of time and place. In addition, we set that the users can only utilize the others' screen information by viewing in order to ensure the information security. And we adopt the smart image transmission method to achieve the high requirement because of the interaction provision in our research.

After we construct the proposed spaces, we develop a presentation application which is based on the proposed spaces. And in order to have the collaboration better, we design two modes for the presentation application according to the local collaboration requirements. They are speaker mode and audience mode. We also design different modules for the two modes in order to utilize the advantages of the smart cooperative working spaces fully. Then, we conduct experiments to analyze the commonality of collaboration. We regard them as the evaluation standards to evaluate the smart cooperative working spaces. In addition, we analyze the collaboration efficiency optimization comparing with current environment by the developed presentation application based on the smart cooperative working spaces.

As a future work, we will improve the image transmission quality and speed continually including image refresh rate and system share. Also, we will improve interface and function according to the collection of user feedback in order to improve the efficiency of collaboration and allow users join group work with no restrictions in the smart cooperative working spaces.

Acknowledgements

I would like express my gratitude to all those who helped me during the writing of this thesis.

First of all, I gratefully acknowledge the help of Professor Jiro Tanaka, my thesis supervisor. I do appreciate his patience, encouragement and professional instructions. He has walked me through all the stages of the writing of this thesis. Without his consistent and illuminating instruction, this thesis could not have reached its present form.

Also, I would like to thank the other professors in the IPLAB, Dr. Shin Takahashi, Dr. Misue Kazuo and Dr. Buntaro Shizuki for their constructive suggestions during the seminar. I am also grateful to all the members of the NERF, IPLAB, Interactive Programming Laboratory, University of Tsukuba, for their suggestions and help every time.

Special thanks should go to my friends who have put considerable time and effort into their comments on the draft.

And I should finally like to express my gratitude to my beloved parents who have always been helping me out of difficulties and supporting without a word of complaint.

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