Interactive Co-presence Environment with Mixed Reality Using Remote and Local Avatar

Hao Luo
Information and Computer Science
Graduate School of Science and Engineering, Doshisha University
1-3 Tatara Miyakodani, Kyotanabe-shi, Kyoto, 610-0321 Japan
8luohao8@gmail.com

Hideki Shimada
Department of Information Systems Design, Doshisha University
1-3 Tatara Miyakodani, Kyotanabe-shi, Kyoto, 610-0321 Japan
hshimada@mail.doshisha.ac.jp

Kenya Sato
Department of Information Systems Design, Doshisha University
1-3 Tatara Miyakodani, Kyotanabe-shi, Kyoto, 610-0321 Japan
ksato@mail.doshisha.ac.jp

Recent years, with the rapid development of ICT (Information and Communication Technology) technology, there are more and more applications which can provide users with different styles of indirect communication over the internet to socially connect people more closely. As typical applications, for examples, SNS (Social Network Service) of Facebook, Twitter, and E-mail, VoIP (Voice over Internet Protocol), blog and so on can be mentioned. However, the traditional communication style which users can get face-to-face communication at same space in real time is still the most effective communication method to contribute users' socially relationship. Therefore, recent years there are more and more applications which can induce users from indirect communication over internet into direct communication in real world. As a typical example, Facebook Places can be mentioned. However, these applications are not able to provide users with feelings of direct communication in real world through the network virtual space yet.

In our research, we focused on two of real world space-time elements sharing problems. First problem is that remote user can hardly share local user's real-time motion, second problem is that remote user can hardly get space interactivity with local space. Based on the two problems above, we designed and built a mixed reality interactive environment system called HYBRIDi. Through proposed system we solved the above two problems, and successfully provided more real world space-time elements into users' virtual world communications.

Keywords-component; Mixed reality;3D virtual;Avatar

I. INTRODUCTION

In traditional direct communication style in real world, users can share the space-time element in common in real-time when communicating and interacting with each other. Current popular internet communication applications and systems have already provided the functionality of communicating mutually in real-time over internet with users. However, there are still no perfect solutions to provide functionality of sharing the space-time element in common in real-time over internet.

Therefore, in our research we attempted to use mixed reality concept, real-time motion capture technology, 3D(3-dimentional) virtual environment which simulates the real environment as a medium, and combine them with internet space to build a mixed reality interactive environment which can provide the functionality of sharing the space-time element in common in real-time over internet with users. Through this approach, users are able to contribute their socially relationship more deeply closely through internet space, like the style of direct communications occurred in real world.

II. RESEARCH BACKGROUND

A. Present Popular Communication Methods with Internets

In recent years, with the rapid development of ICT(information and Communication Technology) technologies, the socially communication styles between users is being evolved day and day, users can be

involved into different communication styles over internet space in indirect communication forms, there are lots of applications emerged recent years, and some of typical applications can be mentioned here.

SNS(Social Networking Service) applications such as Facebook [1], Renren [2], Mixi [3], Google+ [4], Twitter [5], Weibo [6], VoIP(Voice over Internet Protocol) service applications such as Skype [7], IM(Instant Messenger) service applications such as MSN Messenger [8], Online photo sharing service applications such as Flickr [9], E-mail service applications such as Gmail [10], MMO(Massively Multiplayer Online) social community service applications such as Second Life [11] and PlayStation Home [12], Blog services applications and many other similar applications.

These internet communication applications do give users more choices and chances to socially connect with other users deeper and more closer, and also brought more vivid communication element into real society. Through these internet communication applications, users can get lots of fun during the indirect communication processes over internet space.

B. Communication Tendency over Internet

Through present popular communication applications with internet, users can communicate with each other over networking virtual world though the users are not actually at the same space in real world. However, the traditional direct communication style in real world which users share the same space-time element in real-time while talking and interacting with each other is still the most effective communication style for users to contribute their socially relationship.

Therefore, to meet the needs of users, nowadays, there are more and more internet communication applications emerged which are different with those appeared in past years, the features and goals of these new internet communication applications are not merely provide the indirect communication style over internet space with users, the most important motivation of these internet communication applications is trying to induce users from indirect communication style which occurs only in network space to traditional direct communication style that can lead users do communications in real world and share the same space-time element in real-time as Ken Ohta said in his paper [13]. There have already emerged lots of such applications, 2 typical examples can be mentioned are Facebook Places [14] and Foursquare [15], by checking the location information of users in real world, users could get to know if the place and area around the users located have any other users' friends, family members or colleges. Thus, it becomes possible to go to the places in real world to do traditional direct communications.

From these emerged new internet communication applications, we can discover that the development of internet communication applications is silently changing from which are totally used in network virtual space as indirect communication forms to trying to induce users into direct communication styles as in real world in some extend.

Nowadays, there are lots of related on researching systems about how to induce users from indirect communications over network space into direct communications occurred at places in real world more smoothly and actively. Such as Light footprint system which is an online personal connection presentation system for communication assistance proposed. Light Footprint system attempts to make use of the activity history of users in the house and combined the concrete time that users rested in the house by using different types of footprint icons projected by projector to inform the users' past and current location information and even predict future location information of other users. Through Light footprint system, it became possible to induce users from indirect communications in virtual world into direct communications at places in real world through the hints of footprint icons.

However, we can see that though these emerged internet communication applications and on researching systems can effectively induce users from indirect communications in virtual world into direct communications at places in real world more smoothly and actively, there is still a barrier wall exists between indirect communications in network virtual world and direct communications in real world.

Users still cannot get the same feelings and experiences as direct communications and socially interaction occurred at places in real world while over network virtual world. Though VoIP and Tele-presence meeting systems can provide the experiences that they are actually talking mutually in real time, these systems cannot provide the experiences that they are “EXISTING” in the same space, because users who are not in the space at that real time cannot walk around in the space, do communications and interactions based on the real space-time element of the space and master the real-time location information of other users.

In other words, current internet communication applications and on researching systems are not able to consider real-time space-time elements and provide communications and interactions with users based on space-time elements of real world in real-time. Though some internet communication applications and on researching systems can provide real-time communications in forms of dialogue with users over network space, such as IM(Instant Messenger) applications, VoIP, and telepresence meeting systems, they cannot provide any real-time space-time interaction elements with users, which can make the communications as direct communication occurred in real world. In direct communication style in real world, users can walk around in the space while communicating with each other based on the real-time space-time elements.

III. RELATED SERVICE TYPES AND SYSTEMS

A Network Communication Servive Types

1) E-mail, IM Applications

a. E-mail

E-mail such as Gmail is an effective method to replace letters by using ICT technologies, the invention of E-mail successfully reduced the time for message sending, which is the most important communication cost while communicate between far distances.

b. IM Applications

IM (Instant Messenger) applications such as MSN Messenger can provide users with possibility of frequent message exchanging in a style of half real-time. If user checks that each other is online, they can send instant messages to each other, the communication style is similar with dialogue occurred in real world. Though the degree of real-time is lower than dialogue happened in daily life, the timeliness of IM applications is superior to E-mail.

2) VoIP, Video VoIP

a. VoIP

VoIP (Voice over Internet Protocol) applications such as Skype can provide users with real time online communications. Though the function of VoIP is the same with traditional telephone, VoIP can let users now whether each other is online or offline before dialing, traditional telephone cannot provide users with such communication style. In other words, before dialing to other user, the user can get a type of real time information which is that whether user in far distances is online or offline, from this point of view, VoIP has evolved while compared with the communication style of traditional telephone.

b. Video VoIP

Video VoIP applications such as Facetime [16] can provide users with real time online video communications. Real time online video communication is a progress while compare to VoIP, the progress of network communication speed, and the development of digital image recognition and processing technologies realized Video VoIP. By using Video VoIP applications users can see a part of real-time scene of each other's place while communicating. This is an indispensable element of communication occurred at same space in real world.

3) Social Network Services, Location Aware Social Network Services

a. Social Network Services

Recent years, the emerged social network services such as Facebook converged the functions of E-mail, IM applications, VoIP and Video VoIP, and provide new features with social elements, such as instant comment, instant photos uploading and virtual communities. The emergence of social network service gradually let communications occurred in network virtual space became a more important role to contribute socially relationship.

b. Location Aware Social Network Services

After traditional social services emerged, recently with the development of location information detection technologies such as GPS (Global Positioning System), location aware social network services such as Facebook Places and Foursquare emerged. The most evolved part of location aware social network services is that, user can command the 3D (3-dimension) location information of himself or herself and other users', and communicate with other users by using the location information. It makes communication more vividly in network virtual space. More import thing is, it can induce users from indirect communication which occurs only in network virtual space to traditional communications occurs in in real world by simply checking if there are some friends or family members around the same area. In fact, real-time location information is an indispensable element of communication occurred in real world.

B. Social Participatory Simulations

1) MMO Community

Recent years, Besides MMORPG (Massively Multiplayer Online Role-Playing Game), MMO Community is becoming more and more popular with online users. MMO Community applications enable multi-users participate in social activities in a totally online 3D virtual environment such as Second Life and PlayStation Home. In related research filed, Digital city Kyoto [17] can be mentioned.

2) Multi-agent Simulation

By making multi-agent simulation, users can join social activities in 3D virtual space which simulates the real world, by this means, user can join social activities as the same form as realized in real world. User's identification in real world is conducted as agent avatar in virtual world, and all the actives of agent avatar acted in 3D virtual world is controlled by input device such as keyboard. As a related research, FreeWalk [18] can be mentioned, and the augmented Experiment had be conducted [19].

3) Massive Transport Simulation

Despite of directly simulate human activities, Social Participatory Simulations can also simulate dynamic scene of social activities in real world. As a typical related work, massive transport simulation [20] can be mentioned.

C. Ultra-Realistic Communications

Recent years, the concept of Ultra-Realistic Communications has been proposed[21].This part takes five senses communications as a typical example for giving a brief introduction to the latest and prior research of how to provide users in different places with the feelings that they are sharing the same space in real time. The following takes five senses communications as a typical example.

1) Five Senses Communications

When users at same places, they can share five senses including senses of vision, hearing, taste, smell and touch. Researches on five senses communications means despite of senses of vision and hearing, users in different places can also share the senses of taste, smell and touch while communicate with each over network virtual space in real-time. As prior research, high-realistic communications research project [22] being conducted by kaihanna collaborate graduate school now can be mentioned.

D. Telecommunication Robot

Telecommunication Robot in an import research field in telecommunication over network virtual space, with the development of robot and artificial intelligence (A.I) technologies, it has already became possible to create a human-like robot as user's avatar in remote place, user can act basic five senses and emotion communication through human-like robot by real-time controlling and face motion capturing in local place. Human-like robot can present smile, thinking, talking and some other basic communication styles and gestures synchronized with user in real-time. A typical research instance can be mentioned is a human-like robot called Geminoid HI-1 [23] made by Hiroshi Ishiguro in Osaka University.

IV. PROPOSED SYSTEM

A. Technology Background

1) Mixed Reality Concept

Milgram Paul firstly defined the Reality-Virtuality (RV) Continuum diagram [24] in 1994 as shows in Figure 1, he showed that there was a not critical point between reality and virtuality, the area between reality and virtuality was considered not as distributed form, but as continuum form. So Mixed reality area can be seen as the whole areas which are between the start point of reality and virtuality. The proposed system used the thinking of mixed reality concept to enable users in different places enter a 3D virtual environment which smoothly linked the real world and virtual world by using real-time motion capturing information from real world and 3D virtual space which proportionally simulates real space as a medium.

a. Real-time Motion Capture

The proposed system uses real-time motion capture technologies to capture user's real-time motion information, and synchronize the action made by user in local real space with the action of that user' avatar in 3D virtual space. By this means, the system can bring users into a more smoothly and seamlessly mixed reality interactive environment between real world and virtual world with unconsciousness of that they are controlling the avatar by input device, because there is no need for excrescent input devices. Local users' real-time action is integrated into avatar.

b. Proportional 3D Space for Real Space

The proposed system also made items around real space in 3D model form and built a 3D virtual space which simulates the local real space in proportional form. The 3D virtual space is been designed as a medium to smoothly and seamlessly connect action of user in local place and user in remote place. The remote user can command the whole condition in local space in the 3D virtual space by controlling his or her avatar. The 3D virtual space is been designed as a medium to give a more smooth and seamless two-way communication between real space and 3D virtual space.

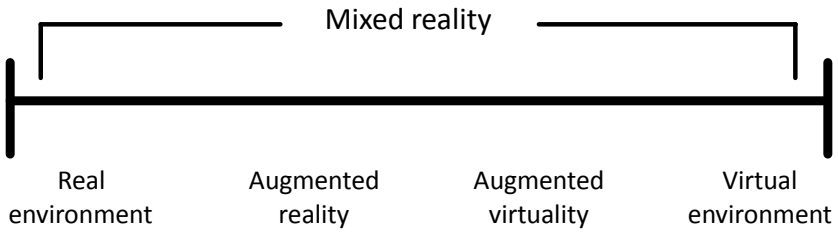


Figure 1. Milgram Paul's Reality-Viruality (RV) Continuum

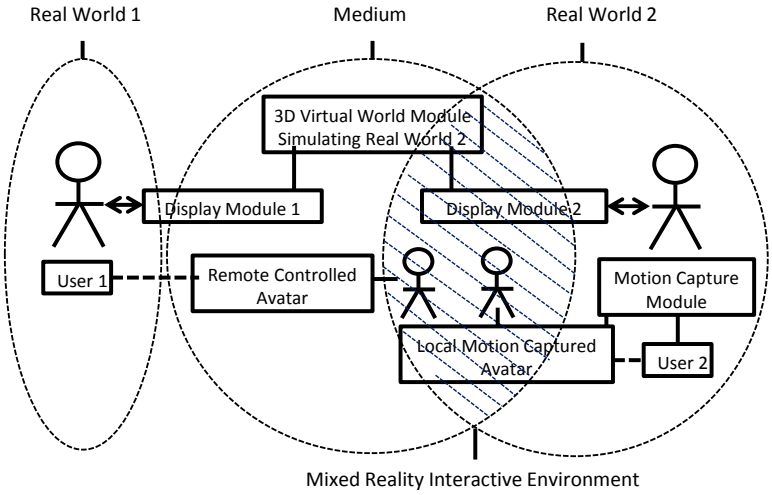


Figure 2. Module Design for Proposed System

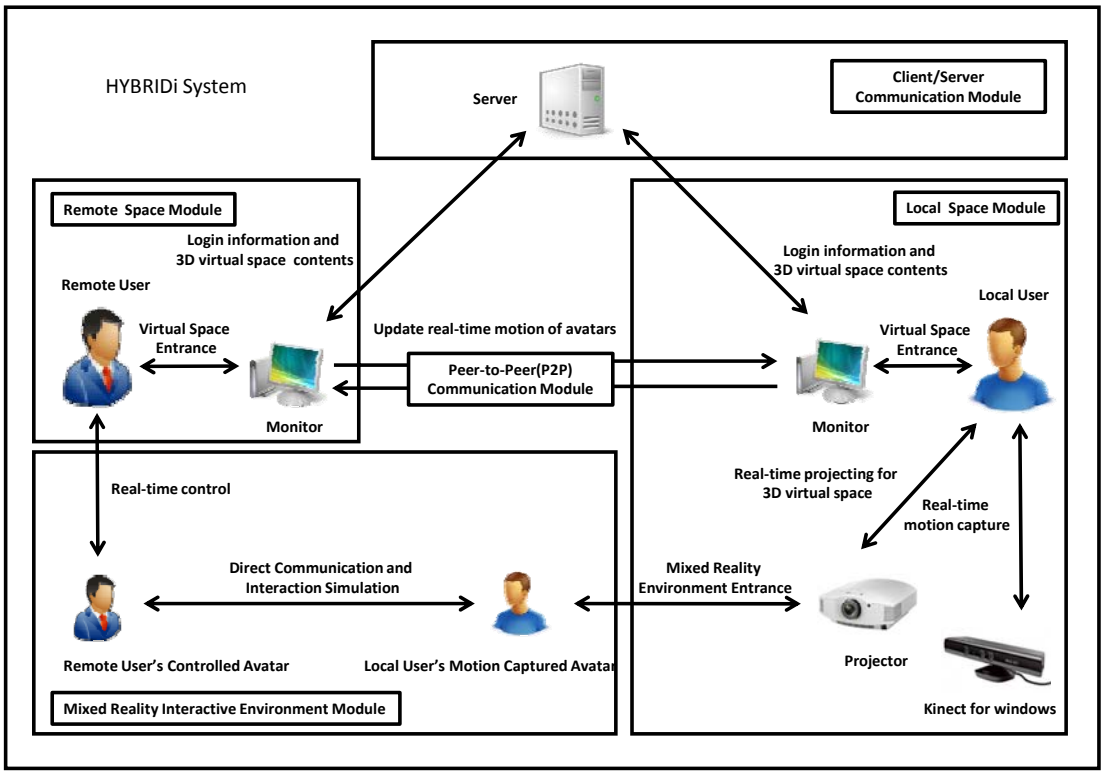


Figure 2. Architecture for Proposed System

B. System Design

1) Proposed System: HYBRIDi

To contribute a mixed reality interactive environment which provides users with the feelings that they can share the same space in real time though they are communicating and interacting with each over the network virtual space, our method is bringing a MiRA (Mixed Reality Agents)[25] avatar as other self of the user who is not in the local space, and the MiRA avatar can act as the user communicate and interact with the user in local space. Through this approach, the two users can acquire the feelings that they are sharing the same space in real time.

2) Architecture for Proposed System

The system structure and architecture are shown as Figure2 and Figure3. The user in remote space in real world will act his or her self as MiRA avatar by controlling it in a 3D virtual world simulating the real local space in proportional form, meanwhile the user in local space will use a projector as a screen to find the MiRA avatar of remote user to communicate and interact with the MiRA avatar.

Table 1. Development Environment for Proposed System

Development Environment for Proposed System	
Operation System	Windows 7 Professional Service Pack 1 32 bit
Central Processing Unit(CPU)	Intel(R) Core(TM) i5-3550 CPU@3.30GHz
Random Access Memory(RAM)	8.00 Gigabyte(3.39 Gigabyte available)
Development Language	C# Language
Integrated Development Environment(IDE)	Microsoft Visual Studio 2010 Professional
System Development Framework	Microsoft XNA 4.0 Framework
Software Development Kit(SDK)	Kinect for Windows Developer Toolkit version
3D Modeling Development Tool	Autodesk 3DS Max 2009
Picture Texture Edit Tool	Adobe Photoshop Creative Suite(CS) 5
Real-time Motion Capturing Tool	Microsoft Kinect for Windows

At the same time, the motion capture device of Microsoft Kinect for Windows [26] will capture the real-time motion data and location information data of the local user and reflect them on the 3D virtual world in the form of 3D avatar of the local user. Therefore, the remote user can also communicate and interact with the local user in real-time in the 3D virtual world through the 3D avatar of the local user.

By this system environment above, remote user and local user will share the same space in real-time while communicating and interacting with each other over the network space through the medium of MiRA avatar and a 3D virtual world simulating the real space in proportional forms. Figure3 shows the architecture for proposed system.

3) Develop Environment for Proposed System

Table1 shows the system development environment. To construct the 3D virtual space, we chose the Microsoft Visual Studio 2010 as the programming environment, and used the C＃language based on the Microsoft XNA 4.0 Framework as the main environment to build the 3D virtual environment, the reason to choose C＃ language and Microsoft XNA Framework is that the framework have a friendly interface for developers who are not specialist in 3D computer graphics, and can provide lots of features, powerful tools and SDK(Software Development Kits) relating to 3D contents construction to help developer build 3D virtual environment easier and faster to save the developing time. Also the XNA Framework can smoothly integrate the Kinect for windows SDK in the development environment.

After successfully investigating, collecting and analyzing the data of laboratory room in real world, we extracted 10 items which exist in the room and constructed them into 3D models in the 3D virtual world in proportional forms, and configured them in the corresponding location in 3D virtual world. We chose Autodesk 3DS Max 2009 as the 3D model tool to construct all the 3D models, because Autodesk 3DS Max series is a most popular 3D model making tool and the most important point to choose Autodesk 3DS Max is that the format .FBX of 3D model create by 3DS Max can provide the best compatibility to the Microsoft XNA 4.0 Framework, when import these 3D models into the environment, there will not occur some errors or problems which will mistakenly import the size, figure or sharp of original 3D models.

The texture modify tool we chose is Adobe Photoshop Creative Suite 5, because it has high compatibility to the format .FBX of 3D models created by Autodesk 3DS Max and it is easy for user to edit and change the texture design when shift between the import of 3DS Max operating interface and Photoshop operating interface.

4) Login Process for Proposed System

The mixed reality interactive environment for co-presence of remote controlled avatar and local motion captured avatar in real-time is an online system. The design of it consists of the part of server and client.

When a user want to login on the system, the user can chose to login on as Remote controlled avatar or Local Motion Captured Avatar. When users login on as Remote controlled avatar, the process of login is very simple, which only check the user's ID information and the user will control his or her avatar when enter the system.

When user wants to login on as Local motion captured avatar, firstly, the system will initialize the user's space and body information and user's motion by getting the signals from Kinect for windows to check the user's accessibility to the system, if the user is in local space, the user will login on as Local motion captured avatar and send his or her real-time initialized information data to the HYBRIDi system, if the user is in remote space,

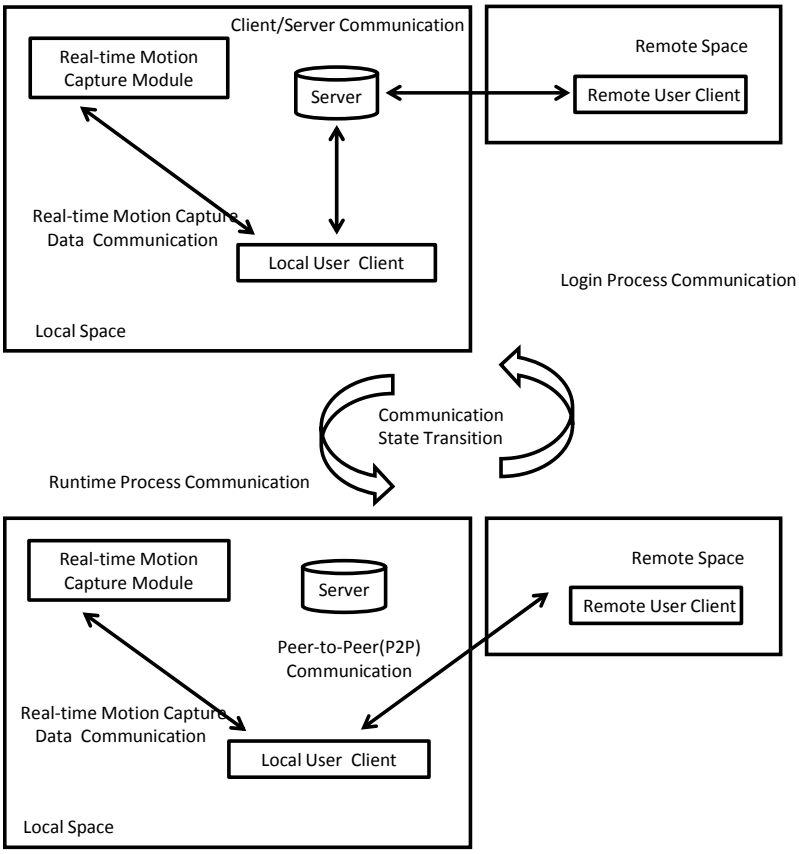


Figure 4. Communication State Transition for Proposed System

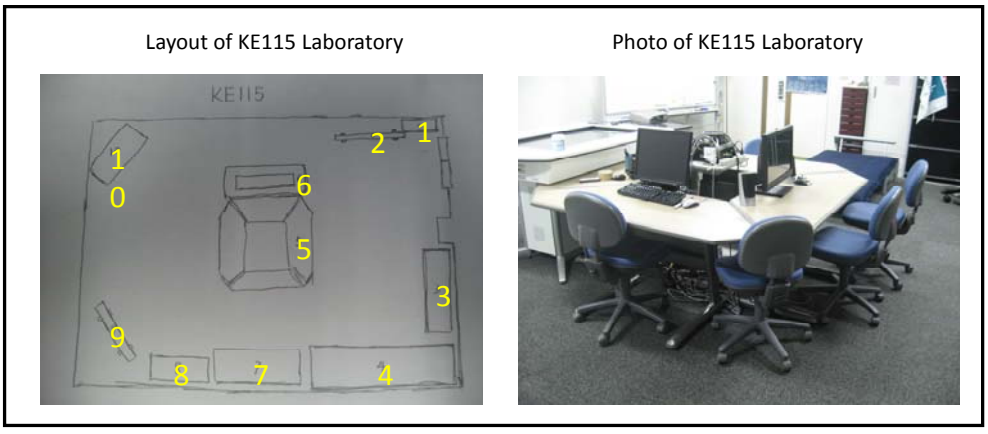


Figure 5. Real Space Data Collection for Proposed System

secondly, the system will check if the user is willing to login on as Remote controlled avatar, when the user selects "NO", the login process fails and the user will quit the login process.

5) Communication Model for Proposed System

As shown in the upper part of Figure4, the login process of the system uses Client/Server communication model. During the login process, user will login in the system, download the 3D virtual space data and get the initialized information of another user.

After successfully login in the system, as shown in bottom part of Figure4, communication model between two users will shift to P2P model. After login process, two users will only update their real-time location information data of avatars of each other on the system.

C. Realization for Proposed System

1) Real Space Data Collection for Proposed System

We chose our network information system laboratory room KE115 as the experiment environment to develop the proposed system. As Figure5 shows, the left side shows the bird's eye air scape data collection and analysis

Figure 6. Human-to-avatar Real-time Avateering for Proposed System

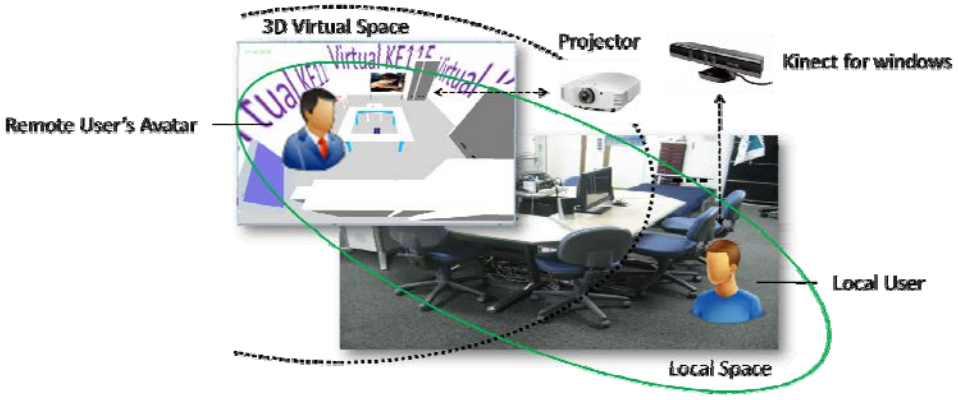


Figure 7. Runtime Image of Proposed System for Remote Use

of the laboratory, there are 10 items located on the network information system laboratory room KE115. The right side shows the real space photograph data connection and analysis of the network information system laboratory room KE115.

2) Real-time Human-to-avatar Avateering for Proposed System

We use the SDK of Kinect for windows developer toolkit version 1.5.2 for the human-to-avatar avateering module, and get referred of the sample C＃ language source code [27] called Avateering from the developer toolkit browser. The human-to-avatar avateering by Kinect for window can provide accuracy in skeleton level, so when user wave his or her hand, rise his or her legs or turn around his or her head, the real-time motion change will also simultaneously be reflected in the local motion captured avatar in the virtual world.

Through this ways, the user can get the maximum experience, interaction and feelings that he or she is get reach his or her body into the avatar in virtual world, when the user interact with remote controlled avatar in the mixed reality interactive environment, they can get the two way communication from real world and virtual world by synchronizing his or her body with the local motion captured avatar.

Figure6 shows running scene of proposed system in real-time human-to-avatar avateering while the user in real world is waving his hand to the remote controlled avatar controlled by another user in different place, we can see that the motion of local motion captured avatar is synchronized with the local user, so the local motion captured avatar is also waving his hand at the same time.

3) Mixed Reality Interactive Environment for Co-presence of Remote Controlled Avatar and Local Motion Captured Avatar in Real-time

As Figure7 shows, user in remote place is controlling his or her avatar in the 3D virtual environment by keyboard while interacting and communicating with the local motion captured avatar whose motion is based on real-time human-to-avatar motion capture taken by Kinect for windows.

Meanwhile, as shown is Figure8, user in local place is acting in the local real space while he or she can see his or her local motion captured avatar's motion synchronized in the 3D virtual space from the projector set in the space. The local user can also see the real-time motion of remote user's controlled avatar and do communications and interactions with the avatar. Through this ways, though remote user is not in the same place with local at that time, they can share the same space-time element in real-time through the mixed reality interactive environment.

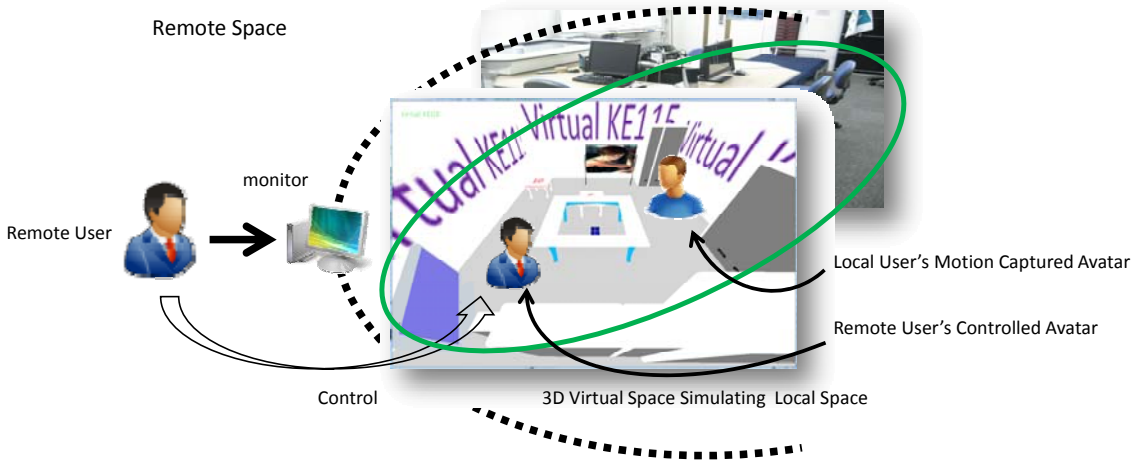


Figure 8. Runtime Image of Proposed System for Local User

V. EVALUATIONS

A. *Five Senses Communication and Space-time Element*

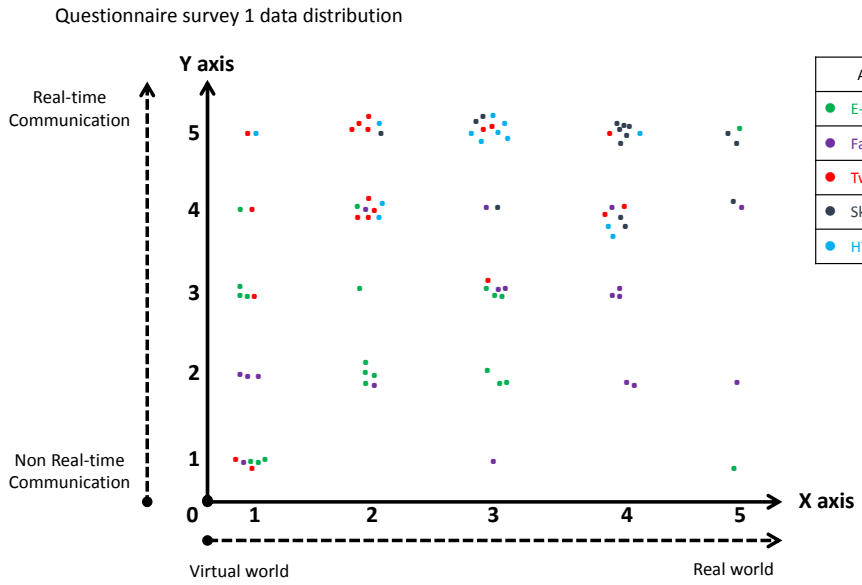
As Table2 shows, we made proposed system being compared with E-mail, IM Applications, VoIP, Video VoIP, MMO Community, SNS and location aware SNS. Symbol circle means the service type will meet the condition in any situations, symbol triangle means the service type will meet the condition depends on situations, symbol cross means the service type will not meet the condition in any situations. For example, in Video VoIP, the service type will provide the sense of vision while user is communicating with other users over internet, so the in Video VoIP's column of Vision the symbol will be a circle, and in E-mail, when in a time user send his or her mail to another user, and at that time an another user is online, E-mail service will meet the real-time condition, but if another user is offline at that time, E-mail will not meet the real-time condition, so in E-mail's column of Real-time, the symbol is triangle. And when the symbol is a cross, it means the service cannot meet the condition in any situations. From Table2 we can see that in all of the compared service types, only the proposed system can meet the conditions of Vision and Hearing in real world five senses communications and conditions of Real-time and Space Interactivity in real world space-time element in any situations. So it proves that proposed system is closer to direct communication in real word than other present service types.

B. *Real-time Communication and Direct Communication*

As introduced before, direct communication in real world should involve sharing five senses communication element and sharing of space-time element in real-time. This gives a comparison with present four typical internet communication applications by evaluating condition of real-time, and users' feeling of direct communications. Proposed system is compared with four typical applications (E-mail, Facebook, Twitter, Skype (video)/Facetime) by analyzing the questionnaire survey data collected from undergraduate and graduate students major in informatics engineering.

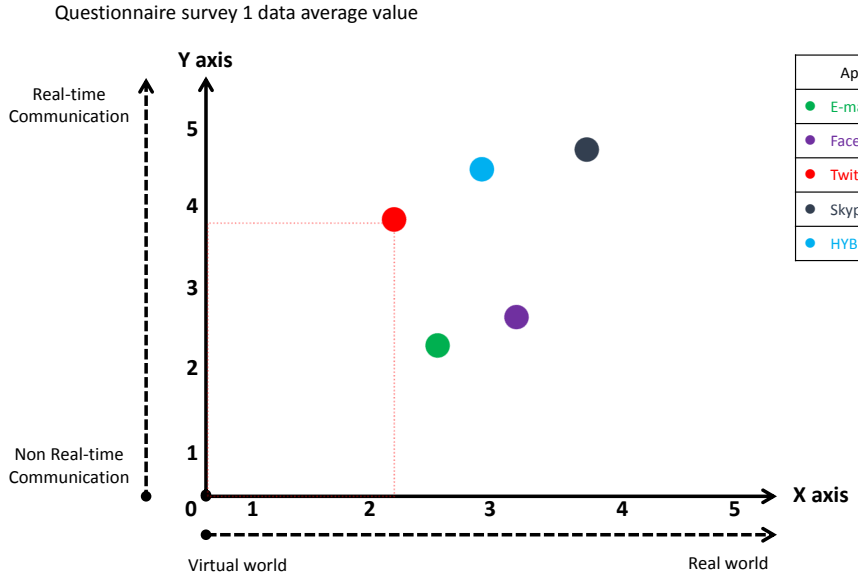
Table 2. Evaluation of Five Senses Communications and Space-time Element

Service List	Real World Face-to-face communications						
	Real World Five Senses Communications					Real World Space-time Element	
	Vision	Hearing	Touch	Smell	Taste	Real-time	Space Interactivity
Proposed System	○	○				○	○
Location Aware SNS	△	×				△	△
SNS	△	×				△	×
MMO Community	×	○				△	△
Video VoIP	○	○				○	×
VoIP	×	○				○	×
IM Applications	×	×				△	×
E-mail	×	×				△	×



Application Name	Number of Valid Value
E-mail	21
Facebook	18
Twitter	19
Skype(video)/Facetime	15
HYBRIDi	13

Figure 9. Questionnaire Survey 1 Data Distribution



Application Name	Average Value
E-mail	(2.505,2.205)
Facebook	(3.112,2.568)
Twitter	(2.221,3.845)
Skype(video)/Facetime	(3.917,4.800)
HYBRIDi	(2.833,4.690)

Figure 10. Questionnaire Survey 1 Data Average Value

The comparison has two aspects. First aspect compares the evolvement of communication which from completely occurring over virtual network world in no real-time form into communication occurring in real world in real-time form as shown as horizontal axis and ordinate axis in Figure9. Second aspect compares users' feeling of completely indirect communications occurred in virtual network world into completely direct communication occurred in real world as shown as horizontal axis and ordinate axis in Figure11. We collected valid questionnaire survey data and analyzed them by watch the distribution of collected data in the two axis and the average value of collected data in the two axis.

In the following, firstly gives an introduction of data analysis in users' feeling of communication as real-time/non real-time communication real world /virtual world communication form of compared applications. Secondly gives an introduction of data analysis in users' feeling of communication as direct/indirect communication and real world/virtual world communication. Because direct communication in real world must in real-time form, the questionnaire survey and data analysis was designed by stage.

1) Real-Time- Non Real-time Communication and Real World-Virtual World Communication

This time we collected questionnaire survey data from 21 undergraduate and graduate students major in informatics engineering in Doshisha University. Because some students have no using experience of some of investigated applications or have no comprehensive understanding of some of investigated applications, not all students finished all the questionnaire survey to every applications. We gained 21 valid data of E-mail, 18 valid

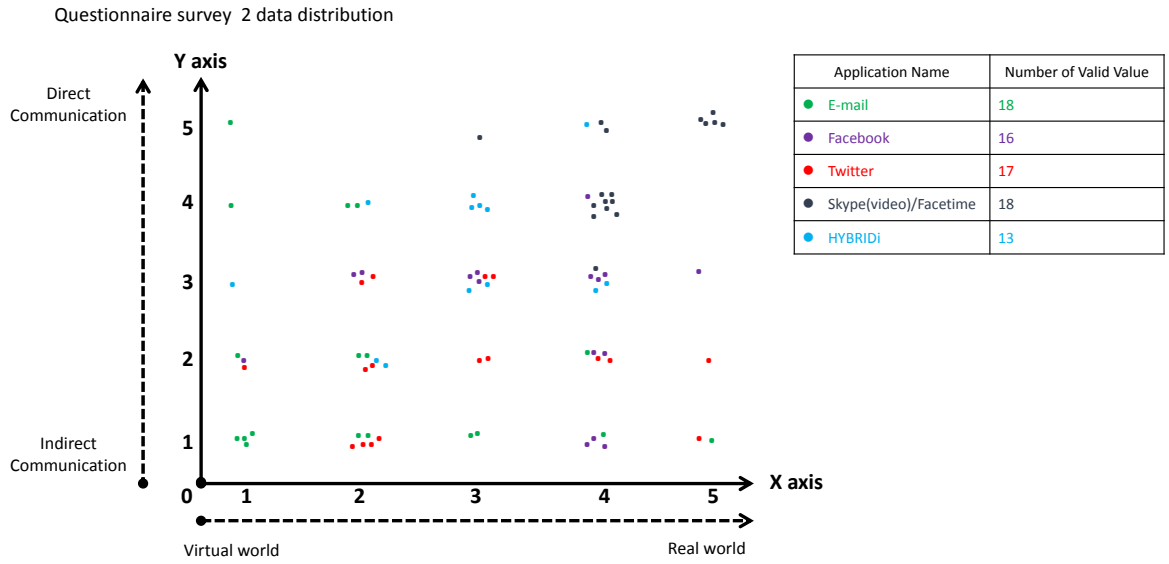


Figure 11. Questionnaire Survey 2 Data Distribution

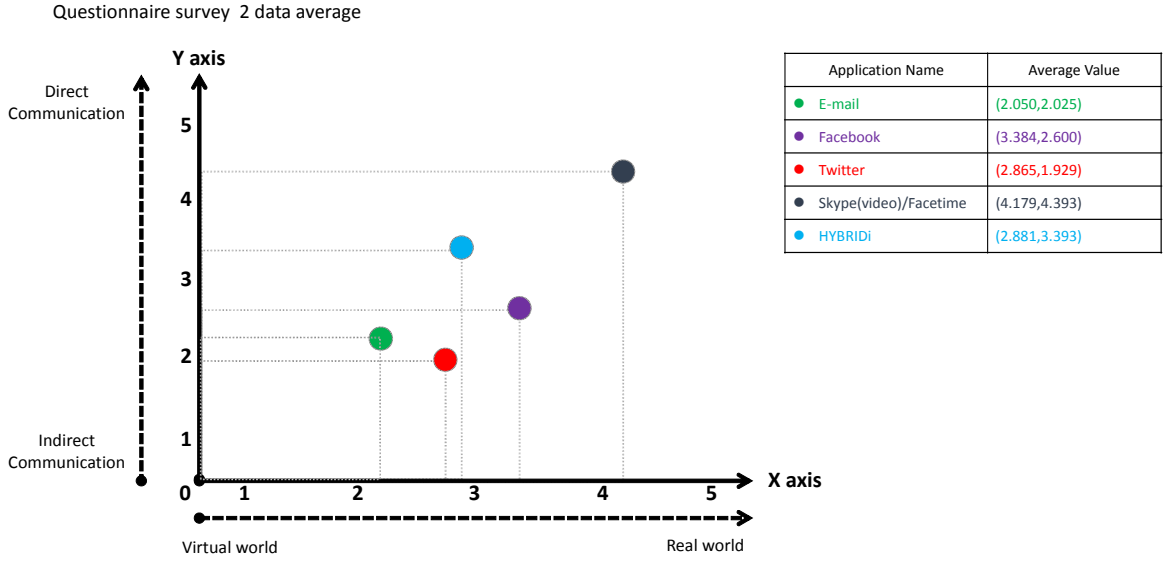


Figure 12. Questionnaire Survey 2 Data Average Value

data of Facebook, 19 valid data of Twitter, 15 valid data of Skype (video) /Facetime and 13 valid data of proposed system HYBRIDi.

The questionnaire survey data distribution is shown as Figure9. We can find the data distribution of E-mail from the points in coordinate axis that lots of the data are near the Non Real-time Communication in y-axis and virtual world in x-axis, the data distribution of Facebook is very randomly, the data distribution of Twitter has lots of points near the Real-time Communication in y-axis and virtual world in x-axis, the data distribution of Skype (video)/Facetime) is near the Real-time Communication in y-axis and in the middle of x-axis between the virtual world and real world, the data distribution of proposed system HYBRIDi is near the Real-time Communication in y-axis and also between the virtual world and real world in x-axis.

Figure10 shows the questionnaire survey data average value in coordinate axis. As shown in Figure 10, the average value of E-mail is (2.505, 2.205), the average value of Facebook is (3.112, 2.568), the average value of Twitter is (2.221, 3.845), the average value of Skype (video)/Facetime is (3,917, 4.800), the average value of HYBRIDi is (2.833, 4.690). We can get the conclusion from the collected data that HYBRIDi is second place in real-time communication and third place in near the communication in real world in all of the 5 compared applications. The reason of Skype (video)/Facetime in first place is conferred that the application can provide real-time vision of users more than other 4 applications.

2) Direct Communication-Indirect Communication and Real World-Virtual World Communication

We collected questionnaire survey data from 18 undergraduate and graduate students major in informatics engineering in Doshisha University. Because some students have no using experience of some of investigated applications or have no comprehensive understanding of some of investigated applications, not all students finished all the questionnaire survey to every applications. We gained 18 valid data of E-mail, 16 valid data of Facebook, 17 valid data of Twitter, 18 valid data of Skype (video)/Facetime and 13 valid data of proposed system HYBRIDi.

The questionnaire survey data distribution is shown as Figure11. We can find the data distribution of E-mail in coordinate axis is random, the data distribution of Facebook is also random as shown in Figure 9, the data distribution of Twitter has lots of points near the Indirect Communication in y-axis and in x-axis the distribution is random, the data distribution of Skype (video)/Facetime) is near the Direct Communication in y-axis and Real world in x-axis, the data distribution of proposed system HYBRIDi is random.

Figure12 shows the questionnaire survey data average value in coordinate axis. As shown in Figure12, the average value of E-mail is (2.050, 2.025), the average value of Facebook is (3.384, 2.600), the average value of Twitter is (2.865, 1.929), the average value of Skype (video)/Facetime is (4.179, 4.393), the average value of HYBRIDi is (2.881, 3.393). We can get the conclusion from the collected data that HYBRIDi is second place in direct communication in all of the 5 compared applications and third place near the real world communication. This time the second place in near real world communication is Facebook, the result is different to the former result, we conferred that proposed system provides users with sense of real-time, but because all the space is made by 3D virtual model and the model is simply so it cannot give user enough sense of reality.

C. Related Works

To comparison with two related works, they are Invisible Person[28] and FreeWalk, and a short discussion with one related work Telecommunication Robot Geminoid HI-1 mentioned in sectionⅢ.

1) Comparison with Two Related Works: Invisible Person and FreeWalk

a. *Invisible Person*

Invisible Person system is a system which can provide the sense of existence to remote user by filtering and capturing the feature of local users, and bring the photo into 3D virtual world, through which remote users can see the photo of local user.

b. *FreeWalk*

FreeWalk system is a system which brings video VoIP into a 3D virtual space, in which users can move their talking window freely, through the system, it can provides sense of space in 3D virtual world with user which present video VoIP cannot.

We compared proposed system with Invisible Person and FreeWalk by index setting on direct communication element shown as Table3, and used 3-dimension axis to show the result of comparison as shown in Figure 13.

From Figure 13 we can see that in HYBRIDi and FreeWalk paid more weight than Invisible Person on direct communication in x-axis, and HYBRIDi, FreeWalk and Invisible Person paid the same weight on real-time communication, HYBRIDi and Invisible Person paid more weight than FreeWalk on space element in communication.

Table 3. Comparison to Related Works using Index

Axis List	Index List		Index Value
Direct Communication Axis (X)	Real Identity of User		1
	Real-time Motion of User		1
	Five Senses Communication	Vision	1
		Hearing	1
		Touch	1
		Smell	1
		Taste	1
Time Axis (Y)	Time Information		1
	Real-time		1
Space Axis (Z)	Location Information		1
	3D Space		1
	Real Space		1
	3D Space Interactivity for User		1
	Real Space Interactivity for User		1

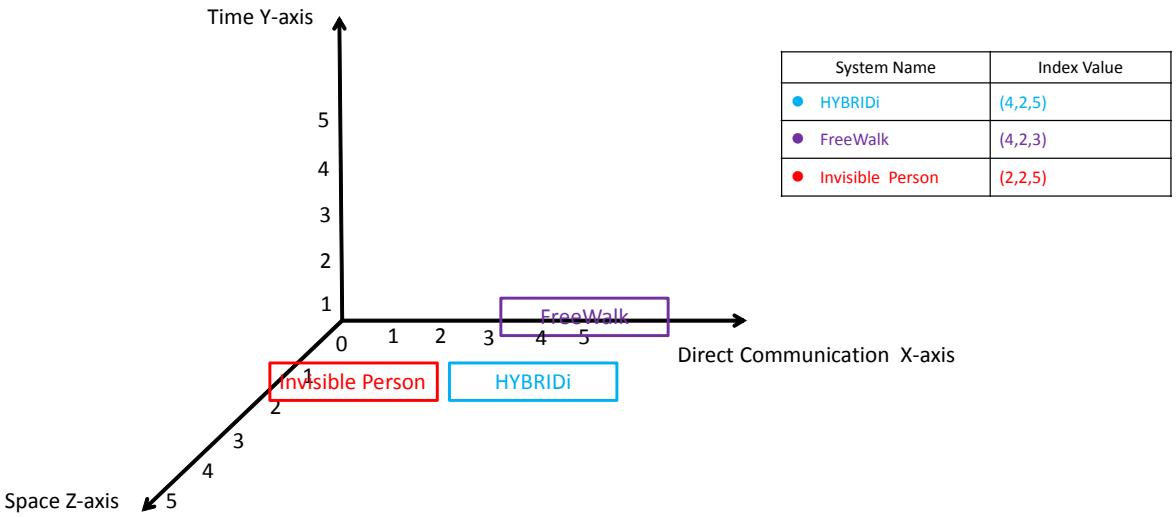


Figure 33. Index Distribution in 3D-axis for Compared System

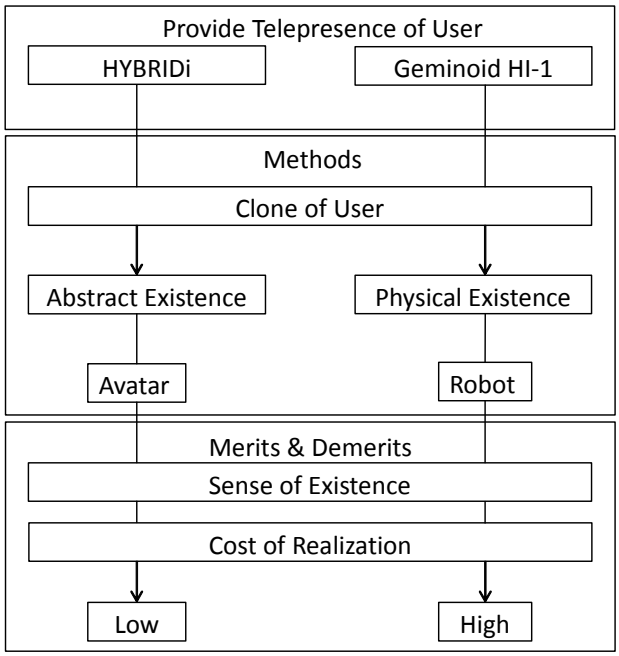


Figure 14. Relationship between Proposed System and Geminoid HI-1

2) Relationship with Related Work: Telecommunication Robot Geminoid HI-1

Geminoid HI-1 is a human-like robot developed by Hiroshi Ishiguro in Osaka University. Because Geminoid HI-1 is a human-like robot which designed to fully simulate the appearance of human, so it can be seen as a clone of user in remote place, and can present basic communication and emotion styles such as smile, thinking and talking. This robot can provide high sense of existence of its user with other users in remote place.

Figure14 shows the relationship between proposed system HYBRIDi and telecommunication robot Geminoid HI-1. As the figure shows, to provide telepresence of user, proposed system HYBRIDi and telecommunication robot Geminoid HI-1 share the same idea of creating a clone of user. In HYBRIDi, the clone of user is in virtual abstract existence form which is a virtual avatar only exists in the virtual space, and reflected through display module. In Geminoid HI-1, the clone of user is in real physical existence form through a human-like robot which can really exist in real physical space. The two methods to realize clone of user both have merits and demerits, there is not a method can perfect adjust all condition in different application field, we can see from the figure that HYBRIDi using virtual abstract existence for clone of user provide lower sense of existence than Geminoid HI-1, but also lower cost of realization for clone of user than Geminoid HI-1.

Contrarily, telecommunication robot Geminoid HI-1 can provide higher sense of existence than proposed system HYBRIDi, but it will take much higher cost of realization for clone of user than HYBRIDi. Based on the discussion and analysis above, we can confer some environment and situation which are fit for virtual abstract existence as avatar of clone of user, and some environment situation which are fit for real physical existence as robot for clone of user.

For example, in ordinary applications, such as simple telepresence interactive entertainment and telecommunication collaborate application which need remote user to master real-time condition of local space and collaborate with other local users, using virtual abstract existence as avatar form for clone of user maybe an appropriate method. Contrarily, in particular applications, such as scientific analysis for human-like clone of user, and A.I test for robot acting as human, also some special event need clone for user in physical existence form to get better effects, such as special event in big shopping mall and festivals in some theme parks whose aim is to create more economic profits, using human-like robot can get better effects than merely using virtual abstract existence form for clone of user.

VI. Conclusions

Under the background of present internet communication applications cannot provide enough direct communication sense by sharing space-time element in real world in real-time with users, we proposed a mixed reality interactive environment system called HYBRIDi. Proposed system focused on two of space-time element sharing problems that remote user can hardly share local user's real-time motion and can hardly get space interactivity with local space. To solve the two problems, we proposed a mixed reality interactive environment by using ideas of real-time motion capture technology and 3D virtual world proportionally simulating real world, and bring users' avatar into the environment to share the space-time element.

We also investigated features of related applications and works, and compared proposed system with them. Furthermore, we also analyzed the relationship between avatar and robot. Through all the comparison, finally we get the conclusion that proposed system solved the above two problems, and can provide more space-time element of real world into users' virtual world communications.

Reference

[1] Facebook, “About Facebook,” https://www.facebook.com/.
[2] Renren, “About Renren,” http://www.renren.com/.
[3] Mixi, “About Mixi,” http://mixi.jp/.
[4] Google+, “About Google+,” https://plus.google.com/.
[5] Twitter: “About Twitter,” https://twitter.com/.
[6] Weibo: “About Weibo,” http://weibo.com/.
[7] Skype: “About Skype” http://www.skype.com/intl/en/home.
[8] MSN Messenger: “About MSN Messenger” http://windows.microsoft.com/en-US/messenger/home.
[9] Flickr: “About Flickr,” http://www.flickr.com/.
[10] Gmail: “About Gmail,” https://mail.google.com/mail/help/intl/en/about.html.
[11] Second Life: “About Second Life,” http://secondlife.com/?lang=en-US.
[12] PlayStation Home: “About PlayStation Home,” http://us.playstation.com/psn/playstation-home/.
[13] Ken Ohta, ICT to Vitalize Japan : 8. Facilitating Face-to-face Communication and Networking among Persons, Proceedings of Information Processing Magazine Vol.53 No.4, pp.384-386, 2012.
[14] Facebook Places: “About Facebook Places,” https://www.facebook.com/about/location.
[15] Foursquare: “About Foursquare” https://foursquare.com/.
[16] Facetime: “About Facetime” http://www.apple.com/ios/facetime/.
[17] Toru Ishida. Digital City Kyoto: Social Information Infrastructure for Everyday Life. Communications of the ACM (CACM), Vol.45, No.7, pp.76-81, 2002.
[18] Hideyuki Nakanishi,Chikara Yoshida, Toshikazu Nishimura, Toru Ishida, FreeWalk: supporting casual meetings in a network, Proceedings of the 1996 ACM conference on Computer supported cooperative work,pp. 308-314 1996.
[19] Toru Ishida, Yuu Nakajima, Yohei Murakami and Hideyuki Nakanishi. Augmented Experiment: Participatory Design with Multiagent Simulation. International Joint Conference on Artificial Intelligence (IJCAI-07), 2007.
[20] Massive Transport Simulation: “About Massive Transport Simulation,” http://www-01.ibm.com/software/info/television/
[21] html/W522292G55788H97.html.
[22] Kazumasa Enami. Research on ultra-realistic communications.Proceedings of the SPIE, Three-Dimensional Imaging, Visualization, and Display 2009, Vol.7329, pp.732902-732902-8,2009.
[23] High-realistic Communications Research Project: “About high-realistic communications research project,” http://www.keihanna-univ.jp/.
[24] Christian Becker-Asano, Kohei Ogawa, Shuichi Nishio and Hiroshi Ishiguro, “Exploring the uncanny valley with Geminoid HI-1 in a real-world application”, Proceedings of IADIS International Conference Interfaces and Human Computer Interaction 2010. pp.121-128,2010.
[25] Milgram, Paul, H. Takemura, A. Utsumi, F. Kishino (1994). “Augmented Reality: A class of displays on the reality-virtuality continuum”, Proceedings of Telemanipulator and Telepresence Technologies. pp. 2351-34. Retrieved 2007.
[26] Thomas Holz, Abraham G. Campbell, Gregory M.P. O'Hare, John W. Stafford, Alan Martin, Mauro Dragone. “MiRA-Mixed Reality Agents”, Proceedings of International Journal of Human-Computer Studies.Volume 69, Issue 4, pp.251-268, 2011.
[27] Kinect for windows: “About Kinect for windows”, http://www.microsoft.com/en-us/kinectforwindows/.
[28] Avateering C Sample: “About Avateering C Sample Source Code”, http://msdn.microsoft.com/en-us/library/jj131041/.
[29] Ogawa Takefumi,Shirai Hiroaki, Yanagisawa Yutaka, Tsukamoto Masahiko, Integration of Virtual Space and Real Space for Designing the 'Invisible Person' Environment,Proceedings of the institue of electronics, Information and communication Engineers,Technical report of IEICE MVE96-53,pp. 55-62, 1996.