Developing a telepresence robot for interpersonal communication with the elderly in a home environment

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Abstract—“Telepresence” is an interesting field that includes virtual reality implementations with human-system interfaces, communication technologies, and robotics. This paper describes the development of a telepresence robot called TRIC (Telepresence Robot for Interpersonal Communication) for the purpose of interpersonal communication with the elderly in a home environment. The main aim behind TRIC’s development is to allow elderly populations to remain in their home environments, while loved ones and caregivers are able to maintain a higher level of communication and monitoring than via traditional methods.

Keywords — Telepresence, Interpersonal communication, autonomous behaviors, robot, tele-homecare.

I. TELEPRESENCE APPLICATION IN INTERPERSONAL COMMUNICATION

“Telepresence” is an interesting field that includes virtual reality implementations with human-system interfaces, communication technologies, and robotics. The earliest research in telepresence dates back to the 1960’s. Goertz in 1965 and Chatten in 1972 showed that when a video display is fixed relative to the operator’s head and the head’s own pan-and-tilt drive the camera’s pan-and-tilt functions, the operator feels as if she were physically present at the location of the camera, however remote it is [1].

Sheridan [1, 2] defines telepresence as: “...visual, kinesthetic, tactile or other sensory feedback from the teleoperator to the human operator that is sufficient and properly displayed such that the human feels that he is present at the remote site, and that the teleoperator is an extension of his own body. Akin et al. [3] described telepresence such that, “At the worksite, the manipulators have the dexterity to allow the operator to perform normal human functions. At the control station, the operator receives sufficient quantity and quality of sensory feedback to provide a feeling of actual presence at the worksite.” These two definitions emphasize control and sensory feedback between the human operator and the “teleoperator” or the “manipulator at the worksite”.

Schloerb [4] defines telepresence from the point of view of an “observer”, “a person is objectively present in a real environment that is physically separated from the person in space.” He uses three types of specifications to make the definitions more precise: (1) a set of tasks, (2) a transformation imposed on the human operator’s control output and sensory input, and (3) a transformation of the region of presence. The degree of objective telepresence is equal to the probability of successfully completing a specified task. Schloerb also proposed that perfect telepresence occurs when the operator cannot discriminate virtual from reality.

To summarize, telepresence provides a connection between a user (or the “operator” as defined by Sheridan and Akin) and a distant participant or an environment (real world or computer generated world), to perform social interactions (user-participant interactions) or specific tasks (user-environment interactions). In this research, we are interested in the application of a telepresence robot for communicating and interacting between the “user” and the “participant” in a remote site. In such applications, the remote participant is not only an “observer” as in Schloerb’s definition, but also a “dialogist” in the interpersonal communication.

Following this framework, there are two views in telepresence application for interpersonal communication: the user’s view and the participant’s view, as depicted in Figure 1. From the user’s view, telepresence enables the user to project herself/himself to another place by controlling the telepresence robot or system. In the meantime, the user perceives immersion from the sensory feedback from the remote environment created by telepresence.

As discussed earlier, the “participant” may have two roles in telepresence application in interpersonal communication: as an observer and a dialogist. From the participant’s view, telepresence provides necessary elements to the user and the telepresence robot, so that the participant recognizes the telepresence robot as a representation of the user. Telepresence also enables dialogue between the participant and the user by transmitting audio, video, gestures, physical movements, and other environmental information between the participant and the user, which are helpful for effective communication.

For interpersonal communication, telepresence differs from traditional video conferencing by establishing a true sense of shared space among geographically remote persons. By duplicating the three-dimensional human experience via actual face-to-face encounters, telepresence is a stunningly different way to telecommunicate.
Telepresence robot lets a person be in two places at once. It needs to be controlled by human operators. In telepresence research, there have been few examples in the field of medical care, emphasizing the use and application of telepresence robots as a tool for interpersonal communication. “Physician-Robot (or Dr. Robot)” is a telepresence robot developed by Intouch-health Company in cooperation with Johns Hopkins University for physicians to easily and more frequently visit with hospitalized patients [5]. Physicians operate the robot with a swiveling video camera and computer screen mounted on a mechanical base by guiding it through patients’ rooms via a remote-control joystick. Physician-Robot is not expected to replace visits from real physicians, but is to act as an extension of physician-patient contact. In the evaluation at the Johns Hopkins University Hospital, patients are more satisfied because physicians spend more time with them.

A telepresence system PEBBLES, or “Providing Education By Bringing Learning Environments to Students” is developed to unite medically fragile children who are hospitalized for prolonged periods with their regular school site. PEBBLES was developed in Canada by a private company called Telbotics in cooperation with Ryerson University and the University of Toronto. A PEBBLES system consists of two child-sized robots capable of transmitting video, audio and documents to each other. One unit is placed with the hospitalized child and the other unit is located in the child’s regular classroom. The units are connected via a high-speed communications link. The classroom unit has a swiveling monitor that duplicates human head movement and a hand that serves as an attention getting device. PEBBLES creates a virtual presence for the remote child in the classroom. The presence is so real that in the many evaluation cases, teachers and fellow students come to react to the school unit as if it were the hospitalized child [6].

Aging is associated with an increased risk for isolation. However, social interaction can delay the deterioration and associated health problems of elderly people. This paper describes the development of a telepresence robot called TRIC (Telepresence Robot for Interpersonal Communication) for interpersonal communication with the elderly in a home environment. The main aim behind TRIC’s development is to allow elderly populations to remain in their home environments, while loved ones and caregivers are able to maintain a higher level of communication and monitoring via traditional methods.

There are three major research issues in this study:

1. To study how users’ verbal and nonverbal communication elements can be expressed through TRIC.
2. To study how users’ verbal and nonverbal communication elements can be expressed through TRIC.
3. To investigate how TRIC can interact with remote participants effectively.

TRIC is positioned as a low-cost, lightweight robot, which can be easily implemented in the home environment. Actually the TRIC robot is intended to be used as often and as easily as a home appliance. A challenge for this research is that TRIC’s applications need to be both useful and engaging. It is expected that TRIC not only provides a convenient interactive communication device for caregivers to communicate with and express care to elderly people, but also a tool for tele-homecare visits and home tele-health monitoring tasks such as measuring vital signs (blood pressure, glucose, etc.), and monitoring activities of daily living.

II. DESIGN ELEMENTS IN TELEPRESENCE SYSTEMS

In order to establish necessary design elements in TRIC, this section surveys the application-oriented telepresence literature which describes the development of a telepresence system. The design elements emphasized in these studies are extracted and summarized in Table 1.

Table 1. Design elements and related technological keywords for telepresence.

<table>
<thead>
<tr>
<th>Design elements</th>
<th>Related technological keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transmission</td>
<td>RF and Internet transmission, time-delay improved algorithm</td>
</tr>
<tr>
<td>Teleoperation</td>
<td>simultaneous operation, robotic design</td>
</tr>
<tr>
<td>Supersensory</td>
<td>dexterous mechanism</td>
</tr>
<tr>
<td>Anthropomorphic</td>
<td>humanoid mechanism and expression</td>
</tr>
<tr>
<td>Stereoscopic elements</td>
<td>binocular and panoramic vision, image processing</td>
</tr>
<tr>
<td>Stereophonic elements</td>
<td>head-related transfer function, stereo audio</td>
</tr>
<tr>
<td>Eye contact</td>
<td>camera and screen with specific placement</td>
</tr>
</tbody>
</table>

(1) Data transmission

Data transmission, the transmission of control commands and sensory feedback, is a basic design element for the connection between the user and the remote telepresence robot or system. Wireless radio frequency and Internet are used in most telepresence applications, and dedicated lines are used in specific applications (such as operation in space and deep sea).

From the user’s view, timing of data transmission is important. Time delays would degrade the telepresence

Fig. 1. The framework of projection-immersion and observer-dialogist
performance in both projection and immersion of the user. From the participant’s view, the time delays also affect the participant’s impression as an observer and interactive capability as a dialogist. Therefore, past telepresence research in data transmission focused on the development of a control scheme to deal with time delays for promoting performance [7, 8].

(2) Teleoperation
Many studies in telepresence emphasize on enabling the user to modify the remote environment [9, 10, 11], that is, projecting the user to the teleoperator. A teleoperator is a machine that extends the user’s sensing and/or manipulating capability to a location remote from that user. Teleoperation refers to direct and continuous human control of the teleoperator.

(3) Supersensory
Supersensory refers to an advanced capability to modify the remote environment provided by a dexterous robot or a precise telepresence system. From the user’s view, the user’s manipulative efficiency for special tasks is enhanced when projecting onto a telepresence robot with supersensory.

Supersensory elements can also provide the user with a novel immersion feeling in a remote environment. For example, the user can control the zoom function of the camera on a telepresence robot to observe the small details of the remote environment, which the user does not normally see with the naked eye.

(4) Anthropomorphic elements
In telepresence applications, non-anthropomorphic telepresence robots are usually designed to perform specific tasks which do not involve interacting with human. Anthropomorphic elements are of great importance for robots involving human-robot interaction. Many researches added anthropomorphic elements to their telepresence robots in order to improve the interaction between users and participants.

For interacting with the participants, the user’s face displayed on a LCD screen is incorporated in many telepresence robots, such as Dr. Robot and PEBBLES.

There are many other solutions for anthropomorphic elements [12, 13, 14, 15]. For example, Burgard et al. installed mechanical facial expressions and a touch screen interface on their tour-guide robots to attract on-site visitors’ reactions.

In summary, anthropomorphic elements enhance the impression of the telepresence robot as a true representation of the remote user. The friendly interface and characteristics of the anthropomorphic telepresence robot also increase the interactive capability of the participant as a dialogist. Mechanical facial expressions can also be used to increase the humanoid characteristics of the telepresence robot to further encourage people to interact and communicate with the user.

(5) Stereoscopic and stereophonic elements
In telepresence research, stereoscopic and stereophonic design elements are often emphasized to create a telepresence illusion of the remote environment or people aiming to increase the feeling of immersion for the user. For example, the user can identify the distance between an object and the telepresence robot by bino-

cular vision [16]; the head-related transfer function (HRTF) for stereophonic effect enables the user to identify the location and direction of a sound [17].

Telepresence videoconferencing is an important application using stereoscopic and stereophonic elements [18, 19, 20]. Telepresence videoconferencing enables the users and the participants to communicate more efficiently. In other words, the interactive capability of the participant as a dialogist is enhanced.

(6) Eye contact
Eye contact is an important element for human-to-human communications. It is a well-known cue for gaining attention and attracting interest. In human-robot interaction, a robot with eye contact would be more familiar and comfortable for humans to interact with. Yamato et al. [21] focused on the effect that recommendations made by the agent or robot had on user decisions, and designed a “color name selection task” to determine the key factors in designing interactively communicating robots. They used two robots as the robot/agent for comparison. From the experiments, eye-contact and attention-sharing are considered to be important features of communications that display and recognize the attention of participants.

(7) Autonomous behaviors
In principle, a telepresence robot is operated by a remote user, and does not possess autonomous behaviors. However, the telepresence robot should be able to deal with possible hazardous situations autonomously when the remote user is not aware of the hazardous situation, cannot control the telepresence robot properly, or the data transmission is lost. From the user’s view, autonomous behavior increases the user’s capability of projection to operate the telepresence robot safely and reliably in a dynamic environment. From the participant’s view, autonomous behavior also increases the interactive capability of the participant as a dialogist. For example, a telepresence robot with the autonomous behavior of identifying the direction of the participant who is speaking can assist the remote user to respond more quickly and properly.

III. BASIC DATA TRANSMISSION STRUCTURE AND DESIGN ELEMENTS OF TRIC

The telepresence robot TRIC (shown in Figure 2) developed in this research aims to be a low-cost, lightweight robot, which can be easily implemented in the home environment. Therefore the primary decision was to use ADSL and Wireless Local Area Network (WLAN), which are commonly found in the home environment, as the channel of data transmission. Two-way audio and one-way video communication can be transmitted through a network Internet Protocol (IP) camera, which is also a common tool for home monitoring.
The controlling cores of most telepresence robots are PC-based. Dr. Robot, and PEBBLES used video conferencing technology for data transmission. It needs specific software and interface running in users’ computers. The channel between a user’s computer and the telepresence robot is a peer-to-peer communication. The advantage is that the remote user’s face can be displayed on the LCD mounted on the telepresence robot’s head. However, it is difficult for multi users to log in telepresence robot at the same time.

An interactive museum tour-guide robot was developed by two research projects TOURBOT and WebFAIR funded by the European Union [12, 14, 15]. The core of the interactive museum tour-guide robot is a PC-based web server. It allows thousands of users over the world to log in the robot through the web to visit a museum. They developed a modular and distributed software architecture which integrates localization, mapping, collision avoidance, planning, and various modules concerned with user interaction and web-based telepresence. With these autonomous features, the user can operate the robot to move quickly and safely in a museum crowded with visitors.

Instead of using a PC, a “Mobile Data Server (MDS)” was developed as the core of TRIC. The MDS is consisted of a PIC server mounted on a peripheral application board which can be easily customized to adapt to different sensors and applications.

The PIC server integrates a PIC microcontroller, EEPROM and a networking IC. It provides networking capability and can be used as a web server. Compared to a PC, the MDS is low-cost, has smaller dimensions, consumes less energy (thus can be powered by batteries), is not affected by viruses, and is safer and more reliable.

Figure 3 shows the basic data transmission structure of TRIC. The user projects herself/himself to TRIC in the remote environment by sending control commands to TRIC through the Internet gateway. The user is able to immerse in the remote environment from the sensory feedback transmitted through the Internet gateway. TRIC uses a WLAN the connector by connecting to the WLAN in the home environment. MDS takes charge of receiving commands from the user and sending commands to specific modules which coordinate with each other to perform specific tasks. Finally the user can have physical interaction and verbal communication with the participant by controlling TRIC as his/her physical extension in the remote environment.

Under this basic structure, Table 2 lists the design elements currently planned for the design of TRIC. The implementation of “teleoperation” in TRIC is quite fundamental. Teleoperation allows the user to move TRIC through the environment while controlling the pan and tilt of the IP camera from a remote client PC. It lets user be in two places at once by teleoperating TRIC. Supersensory ability is reflected in the zooming capability of the IP cam and the sensing capability of the various sensors installed for environment detection.

<table>
<thead>
<tr>
<th>Design elements</th>
<th>Related technological keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transmission</td>
<td>use MDS for the core of system</td>
</tr>
<tr>
<td>Teleoperation</td>
<td>design of mobility platform</td>
</tr>
<tr>
<td>Supersensory</td>
<td>provide zoom of IP cam, implement various sensors for environment detection</td>
</tr>
<tr>
<td>Anthropomorphic elements</td>
<td>design of humanoid appearance and interactive behaviors</td>
</tr>
<tr>
<td>Stereoscopic elements</td>
<td>Not included</td>
</tr>
<tr>
<td>Stereophonic elements</td>
<td>Not included</td>
</tr>
<tr>
<td>Eye contact</td>
<td>control TRIC to gaze at participant</td>
</tr>
</tbody>
</table>

TRIC is not intended to be only a communication service.
media, such as the “movable teleconference system”. Through TRIC, one important goal is to give the participant the impression the remote user that he/she is communicating is actually in the local environment. Anthropomorphic elements enhance the impression of TRIC as a true representation of the remote user. Design of humanoid appearance and interactive behaviors for TRIC can facilitate interaction with participants.

The camera on TRIC is packaged into a “head” with humanoid expression, which also facilitate the design of “eye contact” because the camera is indeed the “eye” of TRIC. Sophisticated stereoscopic and stereophonic elements have been omitted to keep TRIC a low-cost, affordable homecare robot. Table 3 is the specifications of TRIC.

Autonomous behavior is the design element that received the most attention during the planning of TRIC. In principle, a telepresence robot is operated by a remote user who possesses complete control authority. However, a major emphasis of this research is to implement key autonomous behaviors in TRIC, such as “automatic obstacle avoidance” in order to increase the user’s operating capability and reduce the user’s workload during operation. By doing so, the aim was to also increase the interactive capability of elderly people as reciprocal communicators.

**Table 3. The specifications of TRIC.**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>L×W×H</td>
<td>38×38×70cm</td>
</tr>
<tr>
<td>Battery type</td>
<td>LiFePO4</td>
</tr>
<tr>
<td>Capacity</td>
<td>12.8V 10Ah</td>
</tr>
<tr>
<td>Weight</td>
<td>6.5kg</td>
</tr>
<tr>
<td>Speed</td>
<td>10~25cm/sec</td>
</tr>
<tr>
<td>Operation time</td>
<td>120~150 minutes</td>
</tr>
<tr>
<td>Recharge time</td>
<td>90 minutes (6A)</td>
</tr>
</tbody>
</table>

**IV. THE EVALUATION OF TRIC**

This section describes the design of an experiment to evaluate the participants’ subjective impression towards TRIC.

Figure 4 shows the experimental setup. Two subjects and TRIC were in an experiment room and an operator was in an operation room. TRIC was teleoperated from the operation room by the operator using the control interface; behaviors control and audio-video transmission were done through a wireless LAN.

A subject had two roles in this experiment: as an observer and a dialogist. The first subject (dialogist) was asked to stand by at point A. The operator controlled TRIC to move from the conversation site to point A. The subject was greeted and invited to sit down in the conversation site. The operator then had a 5-min. conversation with the subject. After the conversation, the first subject was asked to fill out a questionnaire for subjective evaluation of experience of interacting with TRIC.

In the mean time, the second subject (observer) standing by at point B was asked to observe the interaction between TRIC and the first subject. Then the second subject was asked to fill out a questionnaire on the subjective impression of TRIC’s anthropomorphic elements. After finishing the questionnaire, the second subject was asked to move to point A and become a dialogist. The next subject was asked to enter the experimental room to be an observer for next turn. During the experiment, all subjects understood that TRIC was controlled remotely by an operator in a remote site.

57 subjects (51 males and 6 females) participated in this experiment. They were all university students majored in mechanical engineering in Yuan Ze University, Taiwan.

Table 4 lists part of the questions on the questionnaire on the subjective evaluation of experience of interacting with TRIC and the evaluation results. On the questionnaire, the subjects were also asked about their experience of using instant massager (such as MSN) to interact with another person.

**Table 4. Specifications for paper layout.**

<table>
<thead>
<tr>
<th>Experience of interacting with the remote operator through TRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-2. Did you notice the facial expression of TRIC during conversation? (Yes/No)</td>
</tr>
<tr>
<td>B-3. Did you notice the body movement of TRIC during conversation? (Yes/No)</td>
</tr>
<tr>
<td>B-4. Did TRIC look at you when you speak (eye contact)? (Yes/No)</td>
</tr>
<tr>
<td>B-7. Who did you communicate with? (TRIC/operator in remote site)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experience of using instant messenger to interact with another person</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-2. Did you notice the facial expression of the other person during conversation? (Yes/No)</td>
</tr>
<tr>
<td>C-3. Did you notice the body movement of the other person during conversation? (Yes/No)</td>
</tr>
<tr>
<td>C-4. Did the other person look at you when you speak (eye contact)? (Yes/No)</td>
</tr>
<tr>
<td>C-6. Where was the other person? (Your home/A remote place)</td>
</tr>
</tbody>
</table>

From the evaluation results in Table 3, TRIC is effective as a verbal communication tool. When using an
instant messenger such as MSN to interact with another person, 93% of the subject noticed the facial expression and 77% noticed the body movement of the other person. During conversation through TRIC, most subjects also noticed the important communicative cues for gaining attention and attracting interest, 89% for facial expression and 81% for body movement. During the experiment, some subjects were interested in TRIC's facial expression and asked questions about it actively.

When using an instant messenger, the other person’s face can be displayed on the LCD. However, only 58% of the subject responded that they felt the eye contact. In their experience of interacting with the remote operator through TRIC, 86% of the subjects responded that they felt the eye contact. Actually both the operator and subjects realized that they were looking at each other during conversation.

Finally, 42% of subjects felt that they were talking to a person right here, while only 11% of the subjects reported the same impression when using an instant messenger. This result shows that TRIC’s success fully gave the operator a physical representation for communication and interaction with subjects. Though the result was not high, it supported that TRIC is more than just a communication media.

V. CONCLUSION

This paper presents the development of a telepresence robot TRIC. The main aim behind TRIC’s development is to allow elderly populations to remain in their home environments, while loved ones and caregivers are able to maintain a higher level of communication by establishing a true sense of shared space among geographically remote persons.

TRIC can be categorized into a service robot which has extensive interaction with humans. TRIC allows users to project a sense of self via telepresence. By controlling TRIC’s IP camera, navigational actions, real-time voice communication, and limited non-verbal cues the user is able to communicate and monitor the elderly participant in a manner above video-audio communication. Human factors considerations have also been implemented to allow for optimal communication and use by both sets of users (local and remote), and to lessen any risk of potential injury.

Besides interpersonal communication, there is also a potential of using TRIC for home telehealth monitoring and tele-homecare visits. The MDS can gather data from many households, a single household is the fundamental unit for sensing, data transmission, storage and analysis in the MDS.

In conclusion, one obvious advantage of using TRIC in home tele-health monitoring is its mobility and capability of interpersonal communication. Caregivers can actively approach the elderly participants through TRIC to express care if abnormal signals are detected.

REFERENCES