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DESIGN FOR AN OPTIMAL SOCIAL PRESENCE EXPERIENCE WHEN USING TELEPRESENCE ROBOTS

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1. Introduction

Research in the domain of teleoperation has yielded robots that allow users to interact with and control objects within a remote real-world environment. Applications include remote controlled manipulators that enable humans to work in remote, hazardous or challenging environments such as underwater, in bomb disposal, in hazardous clean-ups, or to expand access to medical specialists. The design goal for these kinds of systems is to allow users to be physically present in a remote location when it is impossible for them to do so. Some examples of these kinds of applications are; working at depth under the sea [Yoerger and Slotine 1987], in microscopic workstations [Codourey et al. 1997], and performing space-station maintenance [Li et al. 1996].

It can be seen from these examples that for many years military and law-enforcement agencies have used these specialised robots in limited places only. However, robotics has entered telepresence space, not as manipulators in sealed nuclear facilities as envisioned by Minsky [1980], but as personal communication tools. Since the 1990s, telepresence robotics systems have started to manifest themselves in a large number of places in the form of interactions through live video. With recent advances in telecommunication technologies, systems and software, telepresence robots have become technologically viable. Smaller and faster computers, low-cost and high resolution webcams, lightweight video screens, relatively inexpensive range sensors and nearly ubiquitous wireless communication (i.e. Wi-Fi, 3G and 4G cellular services) have transformed robotic telepresence from being solely a research concept into commercially available products [Tsui et al. 2012].

Telepresence is commonly defined as a set of technologies that allow people to feel as if they are present in a location other than their true location. Since then, various studies have investigated diverse disciplines such as psychology, communication, computer science and philosophy in relation to telepresence. Lombard and Jones [2007] have identified over 1,400 articles, written mostly over the previous twelve years that have addressed the telepresence concept. The majority of these studies were undertaken to try to solve technical challenges such as audio and video, navigation, safety and overall design.

There has been a significant amount of work towards making TP robots that are believable characters, exhibiting social competence [Brooks 1999, 2002] and [Cassell et al. 2000]. These studies discuss guidelines for increasing social acceptability and also raise concerns about social issues such as the sense of social presence. In this paper, we review the state of social presence theories and propose some criteria and scope conditions to improve social presence. We hope this analysis and the criteria proposed can contribute to the development of a social presence that is sufficiently large in scope, but also controlled.

2. Commercial telepresence

Commercial telepresence robots can be described as embodied video conferencing on wheels [Tsui 2011], as typically, cameras that follow the operator's instructions to provide presence on the remote site. These new telepresence robots provide a physical presence and independent mobility in addition to communication, unlike other video conferencing technologies.

2.1 Telepresence structure

It is important to adopt a common framework for definitions and terminology of telepresence structures, as it will allow us to communicate and collaborate more effectively, compare theoretical propositions and ultimately build knowledge in this area. Though we found different terminology and structures of telepresence systems, the majority of these terminologies have the same base architecture. This typical architecture can be found in the majority of robots, and in general it is composed of two sites and a communications link between them. In figure 1, we propose a general TP robotics architecture which might be used regardless of the nature of the telepresence or its performance. Figure 1 identifies the two main sites of telepresence which include four major functional components; a home site which consists of a human operator and an operator interface, and a remote site which consist of a remote human, and a telepresence or teleoperator. Both sites have computer interfaces to process the data from both sites via the communication links which have a bandwidth capable of transmitting all of the data at a fast speed.

The human operator represents the driver (pilot) of the telepresence robot in the home site. The interface for the driver uses a set of displays, controls and sensors to provide a high fidelity interaction between the hardware and the human, or the environment at the remote site. Also, it is used in order to provide continuous feedback from the telepresence robot in the remote environment to the driver.

The telepresence robot is a machine that functions as a surrogate for the human driver (which consists of sensors and a display). The remote site includes displays which provide information inputs from sensors to control the system. The remote site is described as the real environment, or the people interacting with the robot that are physically separated from the remote operator in space [Sheridan 1992a, 1992b], [Schloerb 1995], [Mair 1997, 2007].

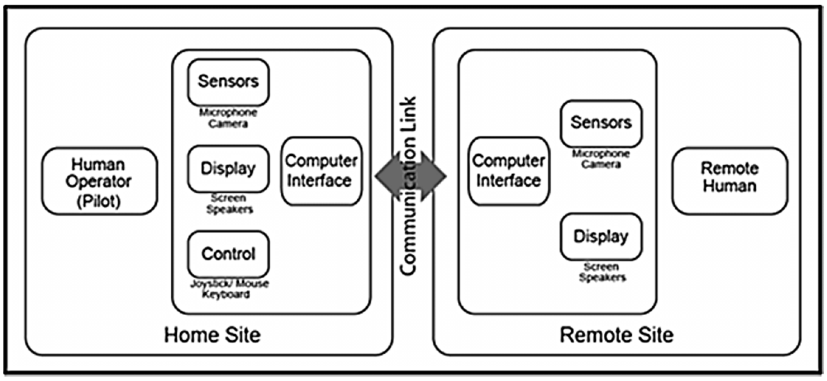

Figure 1. Telepresence communication structure

2.2 Our motivation

In the late 1990s, an early telepresence robot system called PRoP (Personal Roving Presence) was introduced. PRoP was an Internet-controlled, untethered, terrestrial robotic telepresence, developed as a research platform. It was basically a mobile robot with video, audio and pointing devices. Users of this system were able to wander around a remote space, converse with people, examine objects, read and gesture. PRoP highlighted a vital point in telepresence research as it differs fundamentally from the traditional definition of telepresence; according to Paulos and Canny:

> "Our research is driven by the study and understanding of the social and psychological aspects of extended human–human interactions rather than the rush to implement current technological advances and attempt to re-create exact face-to-face remote human experiences" [Paulos and Canny 1998].

Their study highlights the importance of human social and psychological aspects as a way to provide a better understanding of the dynamics of human communication. This understanding is crucial to providing the most compelling overall experience for both the remote and local users, which is related to the social presence.

After the development of PRoP, while considerable work has been invested in developing strongly human-like robots in order to augment the human-robot interaction experience [Dragone 2006], the core complexity and significant costs of such an approach render it difficult to justify for practical real-world applications. There are many different sorts of interactions included in such a system. In one side, the pilot interacts with the remote human, this is –human-human interaction– (HHI), while being embodied in a robot which they cannot see themselves, and at the same time they control the robot via a computer –human-computer interaction– (HCI). On the other side, the remote human of the system interacts with another human –the pilot– (HHI) put also at the same time, they are interacting with a robot – human-robot interaction (HRI). Michaud et al. [2007] focused on HCI by evaluating navigational and interface aspects, whereas Lee and Takayama [2011] and Tsui et al. [2011] explored the perspective of co-workers by focusing on HHI and HRI.

The above-mentioned projects showed that touch and teleoperated gestures can enhance interactions between humans and robots, even in cases where robots are located away from their operators. Furthermore, these projects raised concerns about social issues, such as the sense of engagement as perceived by the remote site which is seen as part of the sense of social presence.

We can see that considerable research related to the sense of presence generally and social presence of users, has been done; user acceptance [Mair and Whitten 2000], [Broadbent et al. 2009], robot appearance and interface aspects [Li et al. 2010], [Goetz et al. 2003], [Arras and Cerqui 2005] and Michaud et al. 2007]. However, the focus of most of these studies was on the function or utility of the robot, ignoring the relationships between the user characteristics and the feelings towards the robot. Based on this concept, we decided to start our research by analysing human-human interaction, highlighting some of the key factors affecting the success of telepresence (human–robot interaction). These findings can provide practical guidelines for researchers, professionals and practitioners in the field of telepresence robot design.

3. Social presence

Until the mid-1990s, most social presence research dealt primarily with low bandwidth media, textual media, or teleconferencing systems, for example; [Goffman 1959], [Short et al. 1976], [Steinfield 1986], [Rice and Love 1987], [Walther 1992], [Walther and Burgoon 1992], [Rice 1993], [Walther et al. 1994], [Tidwell and Walther 2000]. However, around this time, some definitions started to include behavioural engagement and behavioural interaction as a component of social presence theories (Figure 2). Short et al. [1976] was an influential work on social psychology related to telecommunication, which was itself influenced by a number of previously published works of authors such as Birdwhistell [1970], Mehrabian [1972], Argyle [1975], and Argyle and Cook [1976], whose main focus was on non-verbal communication and its pivotal role in interpersonal interactions.

Despite the conflicts inherent in these various theories, they guided both the emphasis of early social presence and recent research on communication behaviour by addressing the issues of which essential attributes are needed to establish connection with others, and how communication behaviours function to define and maintain communications. The next section will outline one of these theories (behavioural engagement theory), and some of the definitions associated with it, and we will explain how we can progress our research based on this theory.

3.1 Social presence and behavioural engagement

One of the early theories that drove the recent research about social presence can be traced back to the end of the 1960s; Mehrabian's [1969] concept of immediacy, which he defined as "those communication behaviours that enhance closeness to and nonverbal interaction with another". The emphasis on interactive behaviour is followed by a more recent definition, as in Palmer's [1995] definition of social presence and Heeter's [1992] definition which emphasises reaction and

interactivity which propose that an increase in the social presence is related to an increase in the engagement.
Based on these theories and definitions, we believe that in order to improve the communication with a TP robot, or in general in mediated communication, we need to create an engagement experience. This typically would involve a mixed-initiative, and well-coordinated process that includes non-verbal cues and signals, such as gaze and mutual attention, head and hand gestures, and verbal greetings. These non-verbal cues in turn would lead to more effective and immediate interactions. Thus, a robot needs to simultaneously exhibit competent behaviour, convey attention and intentionality, and handle social interaction. Exhibition of naturalistic behaviour and appropriate emotions by the robot is the main core for an effective system as suggested by different studies [Bates 1994] and [Rousseau and Hayes-Roth 1997].

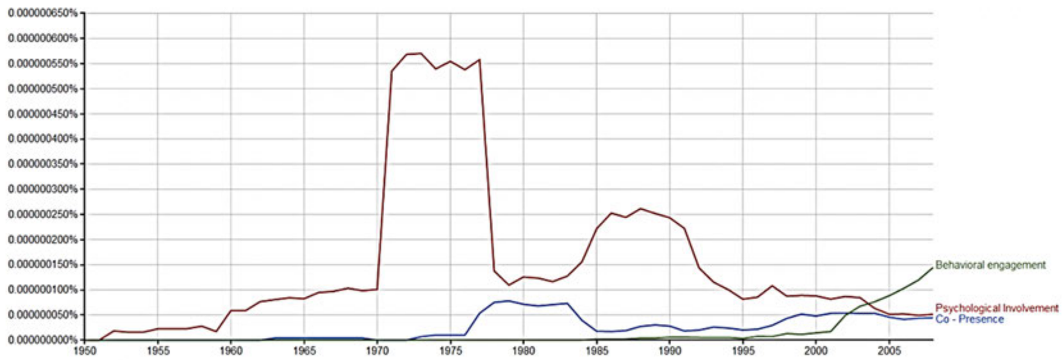

Figure 2. Timeline of definitions of social presence (utilizing Google Ngram)

As the early TP robot PRoP suggested, it is essential to understand human social aspects and human psychology [Paulos and Canny 1998]. This understanding is fundamental to increasing the overall functionality of a TP robot. For example, understanding the arm and hand mechanisms within human interaction will lead to an improvement in prototyping simple gestural mechanisms within a TP robot. Thus, we decided to start our research by understanding the engagement processes within human to human interaction as an essential basis for understanding human to robot interaction; we view this approach as a valid means to test our theories about engagement as well as to produce useful technology results.
The next section will explain engagement and the associated behaviours more detail, we will also, cover some of the recent projects on TP and engagement.

3.2 Behaviours indicative of engagement in human interaction

Engagement is similar to any other collaborative activity which maintains a connection by various means, and then ends the engagement or opts out of it. Engagement is supported by three kinds of behaviours, which are; linguistic behaviour, collaborative behaviour and attention behaviour that conveys connection between the participants. Linguistic behaviour includes both spoken words, and sign language [Sidner et al. 2002]. Collaborative behaviour covers all spoken or physical acts which move the participants towards their collaborative goals. Attention behaviour is to initiate, maintain or disengage in interactions, such as looking at or away from the conversational participant, physically pointing, and addressing the conversational participant or other persons or objects in the environment.
Mainly we are concerned with attention behaviour in face-to-face conversation, as it provides significant evidence of connection between the participants. In addition, addressing this type of behaviour is the first step towards building a realistic human-like companion with rich visual expressiveness. These attention behaviours (facial expressions, head movements and body movements) convey what the participants are or should be paying attention to.
Considerable work has been done on investigating facial expressions within the telepresence robot [Hara et al. 2001], [Kobayashi et al. 2003], [Breazeal 2003], [Bethel and Murphy 2006], but the

authors found that limited work has been done in regard to the other two behaviours. Therefore, we decided to carry on investigating attention behaviours such as head movement and body movement.

3.2.1 Head movement

People involved in face-to-face conversation tend to move their heads in predictable ways. Various patterns have been discussed by many researchers from a variety of disciplines; however, one of the obvious patterns is to classify movements as to whether they are horizontal, vertical or inclined and whether they are large or small. Most of these classifications are based on changes in head position associated with a generic function determined by many variables. Heylen [2006] summarized these functions in several different points:

- Being interested in the conversation, or impatient, or as signal for saying yes or no.
- As a way to enhance communicative attention.
- Head nodding by the listener indicating being interested in or valuing the speaker more.

In general, head movement indicates how much the person is engaged in the conversation.

3.2.2 Body movement

Body movement is basically the dynamic movement of parts of a person's body during communication - posture and gesture. These kinds of movement indicate how much the person is engaged in the conversation in general. Gestures have many different communication functions as they are used for coordinating conversational content as well as referencing and assisting turn taking. Posture is used often in conjunction with other visible signals to determine the degree of attention or involvement, for example the inclination and the orientation of the conversational participants body, in particular their trunk and upper body.

Clearly, one of the fundamental factors in human interaction is attention behaviour. In face-to-face interaction at near or even far distance, these behaviours are the means of communicating beliefs, intentions and desires. A person who physically demonstrates that they are fully engaged in a conversation has clearly grasped the protocols and behaviours expected by society, and has the capability of turning nonverbal behaviours into conversational aids. Both conversation and attention behaviour are naturally present in most human-human encounters. As McNeill [1992] stated, they are tightly intertwined in human cognition. For example; 2 people are about to start a conversation and person 1 looks at person 2. Knowing that people look at each other to indicate interest and attention, person 2 interprets person 1's look as a sign that person 1 is interested and wants to hear what person 2 has to say. Person 1 has the same inherent knowledge, and knows how person 2 will interpret their look, so person 1 can actually use the look intentionally to signal to person 2 that they have person 1's attention, and the exchange of information can proceed.

In our case, we believe that telepresence robot behaviours need to be socially correct in order to be useful in society. Though it is impossible to present a human face in all its details, Bartneck [2001] found that machines with affective expressions could be as convincing to humans as human expressions, regardless of how unhuman-like the machine is, provided the expressions themselves were distinguishable as being different from each other, and were appropriate to the circumstances.

This leaves the question - what are the most important human-like engagement behaviours for the robot to exhibit? This answer to this question will inform the telepresence robot design.

4. Related work

Engagement is not well understood in human-robot interaction, as much of the focus has been on language comprehension and production rather than gestures, or on the fundamental problems of how to get started and stay connected and the role of gesture in connecting. While some efforts have been reported in literature, only a limited number of studies have addressed the problem.

Milne's [2012] work provides an overview of non-verbal behaviour for telepresence robot application, especially eye gaze, highlighting how face-tracking and the ability to communicate the gaze could be incorporated to increase social presence, especially in a work-related environment. Adalgeirsson and Breazeal [2010] developed an interactive design process on the MeBot platform which is capable of social expressions that are commonly used in HHI. The MeBot project is a cell phone platform which conveys the caller's internal emotional state (such as excitement or sadness), in a subtle way via posture or expressive movement. Both projects developed lab trials to evaluate the public's acceptance of such systems.

While these projects provided important insights as well as methodologies for improving engagement, they did not intend to explore the nature of engagement within a tolerance context, nor did they attempt to provide general categories into which such behaviours could be placed. Thus, our research proposes to interpret these features, studying their effect and providing a framework for increasing engagement and social presence in general, in order to develop a telepresence robot that can explain things to people in more realistic way.

5. Current design and capabilities in telepresence robotics

Proper engagement behaviour by the robot and the correct interpretation of human behaviour dramatically affect the success of interactions, and inappropriate behaviours can cause humans and robots to misinterpret each other's intentions. To design a proper TP robot that follows social conventions and norms, it must, as a minimum, have the following:

- Head movement behaviour which includes head tilt and head nod.
- Body Movement which includes pointing gestures, adjustable height and body orientation.

Many telepresence robots have been developed for commercial purposes. These systems are usually marketed for remote meetings, home security or entertainment. Kristoffersson et al. [2013] made a list of different Telepresence robotic systems, comparing their hardware and software specifications. Though they produced a good review about current design capability of TP robots, they failed to cover the social design aspects. The author chooses to group commercially available TP robots by adjustable height, manipulation/expressions and head movement; this is not only because of their obvious visual differences but also because of their role in engagement.

Based on these factors we have reviewed most of the current TP robots, presenting the differences between each individual system (Table 1).

Table 1. Review of current TP robots based on engagement gestures

MRP system	Intended application area	Adjustable Height	Manipulation	Body Orientation	Head Movement
PRoP	Research	No	Laser pointer, 2DOF, hand/arm	No	Fixed screen
Giraff	Elderly	No	No	No	Adjusted manually by the driver
QB	Office	Yes	Laser pointer	No	Fixed screen
Texai	Office	No	No	No	Fixed screen
VGo	Office	No	Handheld remote for local control	No	Fixed screen
PEBBLES	School	No	Hand	No	Fixed screen
MantaroBot Classic	Office	Yes	Laser pointer	No	Fixed screen
RP-7	Healthcare	No	No	No	Adjusted manually by the driver
iRobot Ava	Healthcare	Yes	Yes	No	Adjusted manually by the driver
Jazz Connect	Office	No	No	No	Adjusted manually by

					the driver
RP-VITA	Healthcare	No	Yes	No	Adjusted manually by the driver
Luna	Personal	No	Special hands that can be placed in any position for various activities	No	Fixed Screen

It is clear from the table that most current designs are mainly focusing on the physical capabilities of the robots, ignoring the vital importance of the full breadth of engagement behaviour content humans experience in our daily life. We plan to fill this gap by focusing on engagement behaviours, as we believe that the generation of these kinds of movements can affect how the human judges the interaction experience. We will use these findings as a base for our next study, by applying the human–human interaction we discussed earlier to human–robot interaction.

Next step: Plan for investigation

As we have previously stated, telepresence in the context of this application means replacement of human presence with a robot, which is operated by a human driver from a location at a distance. Increasing presence is crucial in designing an effective robot system, thus it becomes the goal of most research projects in the area of telepresence robots. Our research will therefore focus on improving the interface design in respect to the sense of social presence which can be improved further by adding more non-verbal cues in either the local site or the people interacting with the robot. Though we did find a great deal of work relating to non-verbal cues and social robots, we found few researches in regard to sense of engagement. One of the researches we found in the same area was conducted by Adalgeirsson and Breazeal [2010] to measure and evaluate the validity of a system that is capable of conveying social expression. They found that their platform showed promise for improved communication systems based on social expression. Therefore, our research will focus on the same area and carry on the same study with some changes and differences to the overall experimental design. We hypothesis that making telepresence system socially expressive by affording them the ability to convey part of their operators' non-verbal behaviours such as gesture, posture, can make remote interactions more present, more engaging.

Based on this, for our first study we decided to focus our research on the head rather than any other body part as it is a rich source of information for speech-related movement. We believe by adding some features to the TP robots head will allows them to perform human-like conversational gestures such as turning to face someone in order to see them, address them, or just give attention to them. Head movements effectively give real-time reactions, and form part of the feedback loop that we all rely on to tell us how effective our communication is being, and whether our listener is not only engaged, but understands and agrees or disagrees with what we are saying. As these actions are visible to people interacting locally with TP robot, it will help individuals to know when they are being addressed or looked at by the driver.

In general, we aim in this study to investigate the value of incorporating head movements into the use of telepresence robots as communication platforms; by means of investigating a system that manually reproduces head movement which includes nodding and head orientation as closely as possible.

6. Conclusion

Human-robot interaction research involves empowering a robot with the social functionality required to engage human participants. This requires a system to be built with a degree of capability for verbal and visual behaviour [Dragone et al. 2005], such as head movement, body movement, and eye contact, as these have a direct effect of increasing the engagement. A large body of research shows that humans will treat computers as equal social partners if they behave in a human-like manner [Reeves and Nass 1998], thus facilitating natural interaction. There is still a long way to go before we produce a robot that can interact in a fully human-like manner, but advances in control and sensor technologies now make it possible for researchers to carry out experiments with different configurations of hardware and software.

Significant progress has been made in understanding the use of explicit, deliberate cues for the pilot site such as communication of primary emotions through facial expressions, arm and body gestures, and vocal tone, and the communication of attention through gaze and pointing gestures [Colburn et al. 2000]. These studies have highlighted the role of non-verbal information in mediated communication. Non-verbal information awareness is one of the main triggers of awareness of the presence of a person, which frequently takes place without our being conscious of it. Thus, a robot needs to simultaneously exhibit competent behaviour, convey attention and intentionality, and handle social interaction. Though telepresence robotics for communication purposes is an idea that has been around for a while, to the authors' knowledge, little work has been put into developing socially expressive systems.

Our research we will investigate the same perspectives with the aim of adding value to the systems, such as the capability for head nodding and adjustable body orientation, as we believe that a socially expressive embodiment is needed. Thus, we will investigate a system that reproduces face-to-face interaction as closely as possible, as we argue that nonverbal behaviours are an important area for investigation in telepresence robot interactions. Our choice of head movement for our initial experiments as a subject originated in the perceived lack of research in this area, even though it is acknowledged as having an important role in engagement. By this we will be able to design technologies that exploit visible information to provide more effective remote communication.

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