Mobile Remote Presence Enhanced with Contactless Object Manipulation: An Exploratory Study

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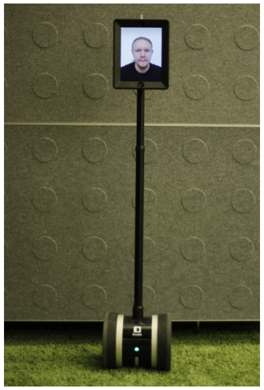
Abstract
A telepresence robot is a mobile telecommunication device, remotely controlled by its "pilot", which supports an embodied presence of the pilot in a different location (the "local setting"). A common problem with telepresence robots is their limited capability of interacting with the physical environment. A potential solution, explored in the present study, is supporting "double remote control" interaction, that is, making it possible for the pilot, in addition to remotely controlling the robot, to also remotely control objects in the local setting. In the study we enacted meaningful scenarios of employing telepresence robots with and without double remote control capabilities. The evidence collected in the study allows us to tentatively assess the effects of double remote control interaction on user experience and social context. Issues for future research are discussed.

Author Keywords
Telepresence robots; mobile remote presence; double remote interaction; user enactments.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.



(a)

(b)

Figure 1. Telepresence robots: a) Double by Double Robotics b) BEAM + MAX by Suitable Technologies

Introduction

Telepresence robots, or Mobile Remote Presence (MRP) systems, are mobile telecommunication devices, which are remotely controlled by their users (also known as "pilots") [10, 18]. A typical telepresence robot comprises a video/ audio communication unit connected to a wheeled base (Figure 1). An MRP system makes it possible for the pilot, located in a *remote setting*, to more actively and spontaneously engage in social interactions with people in a *local setting*. Telepresence robots are available as a diversity of off the shelf products (e.g., [5, 16]). In recent years the robots are increasingly common in various everyday contexts, such as office environments, education, and healthcare [8, 11, 13, 19]).

A key limitation of existing MRP systems is a lack of capabilities for manipulating objects in the local setting. While the main purpose of using telepresence robots is to interact with local people, not local objects, the communication has to be properly contextualized in the physical environment. For instance, an MRP system should be able to reach a meeting location by negotiating various obstacles, make it possible for the pilot to use presentation equipment, such as projectors, and ensure appropriate spatial arrangements when communicating with local people. Action capabilities of most telepresence robots do not allow them to adequately deal with such challenges and it is not uncommon for pilots to ask local people for help (which is negatively experienced by many pilots [10, 17]).

One way to enhance action capabilities of telepresence robots is to equip them with advanced manipulation arms. The solution, however, may be not feasible because of high costs and safety issues. An alternative solution, which is explored in the study reported here, is based on the idea of "double remote control", that is, combining the remote control of a telepresence robot with a remote control of objects (e.g., IoT-enabled ones [12]) in the local setting. For instance, if the pilot who controls an MRP system can also control the lights in the local setting, there is no need for the MRP system to have a physical contact with the light switch.

Currently we are conducting an empirical study of the effects of supporting double remote control interaction on pilot's performance and experience, as well as social interactions between the pilot and local people. This paper reports on the first results of this ongoing study.

Method

Overall methodology

The research methodology adopted in the study is informed by the notions of experience prototyping [3], sketching user experience [4], and user enactments [14]. We employed rapid prototyping techniques and enactment of meaningful scenarios of using telepresence robots to get an early insight into how double remote control interaction is experienced by different kinds of users.

Participants

Four persons, 30-58 y.o., academics, one female and three males, with above average technology skills and little to no experience of using telepresence robots, took part in the study.

Site

The events we studied were simultaneously taking place in two physical locations: (a) the "remote setting", an office room serving as the pilot's work

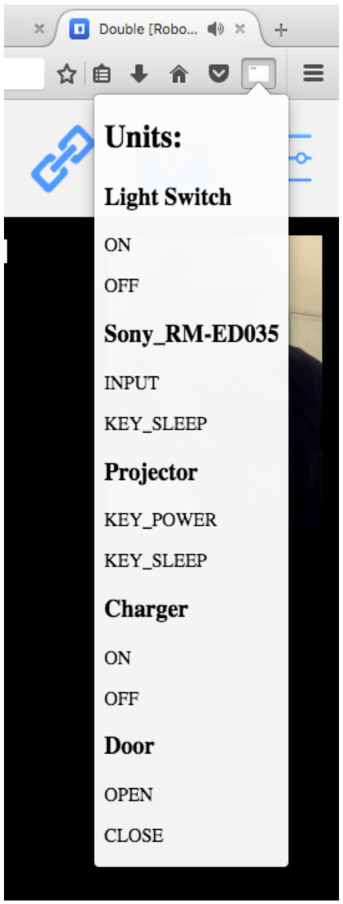


Figure 2. The on-screen panel for remote control of objects in the local setting.

environment, and (b) the "local setting", the immediate physical environment of the telepresence robot used in the study. At different points of time the local setting could be a classroom, meeting room, docking station room, or hallway. All rooms and hallways were located on the same floor of a university building.

Technological setup

The technology used in the local setting included a telepresence robot Double by Double Robotics (Figure 1a), TV sets and desk lamps that could be remotely controlled via the internet through Raspberry Pi – based actuators, a projector, and a laptop computer connected to the projector and the TV sets.

In the remote setting a desktop computer (an iMac with a 27" monitor) was used to control the telepresence robot through a standard web-based interface. A web page plugin displaying a panel with a set of clickable items was used to remotely control objects in the "double remote control" condition (Figure 2). When the pilot clicked an item on the panel the indicated action was either directly completed through a Raspberry Pi-based actuator or performed in a Wizard of Oz fashion, by sending an automatic action request to the mobile phone of a dedicated "robot assistant". The pilot could show slides or videos using a projector or TV in the local setting by sharing a presentation or URL with a local computer via a Lync connection.

Study design and procedure

The study was organized into eight sessions, which were 30-40 minutes long. In each session a possible usage scenario was collaboratively acted out by the participants. The scenarios were enacted in either "standard" condition (to manipulate local objects the pilot had to ask local people for help) or "double remote control" condition (the pilot could remotely manipulate local objects through an on-screen panel).

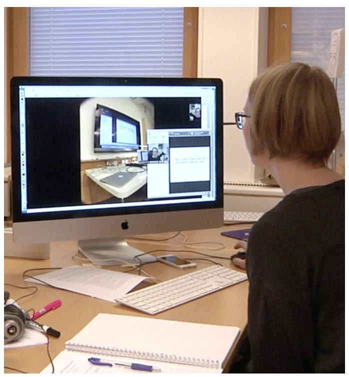
The study employed two usage scenarios, structured as events that were meaningful and familiar to the participants: the "lecture" scenario and the "research project meeting" scenario (see Figure 3). In each of the scenarios the pilot was required to navigate the MRP system from the docking station to a classroom or meeting room (which involved going through several closed doors), greet local people, adjust the lighting, give a presentation using a projector or a TV, discuss the content with local people, say good bye, and return to the docking station. The scenarios were equally assigned to the standard condition and double remote control condition.

The participants were divided into sub-groups, which were located, respectively in the remote setting and the local setting and played the roles associated with the settings (that is, the pilot and local people). The roles were balanced across the sessions: in particular, each participant acted as the pilot in one "standard" session and one "double remote control" session.

Data collection

The evidence collected in the study included pilot's think aloud data, participants' time-stamped notes, and a log file of the use of the remote control on-screen panel. In addition, each session was videotaped (in both remote setting and local setting) and followed by a focus group-type meeting, in which the participants shared their experiences and observations.

(a)



(b)

Figure 3. Enactment of the "lecture" scenario: (a) local setting, (b) remote setting.

The participants were also asked to produce 10 adjectives describing their experience in both standard and double remote control condition. The adjectives were used to create a combined set of 26 seven-point semantic differential scales, which scales were subsequently employed to elicit participants' assessment of the experience of the pilot and local people in the conditions of the study.

Results and discussion

The evidence from the study, including the semantic differential scales (see Table 1) allows us to identify several key themes related to employing the double remote control solution for enhancing mobile remote presence.

Pilot's cognitive load

Implementing the double remote control solution means that pilot's cognitive load is increasing: in addition to navigating the telepresence robot, which is a challenging task in itself, the pilot needs to carry out the task of remotely manipulating local objects. In our study pilots could successfully manage both tasks, but not without difficulty. Our evidence indicates that there are several issues that need to be addressed to help the pilot manage double remote interaction:

Feedback. Because of limited field of view and equipment delays pilots may not see the immediate outcomes of their actions. It may result, for instance, in repeating the same remote control action again and again. Therefore, pilot's user interface should provide prompt and clear feedback on the changing status of on-screen controls and remotely controlled objects.

Mapping on-screen controls to real-life objects. In our study it was relatively easy for the pilot to choose right controls because the range of objects was rather limited. Nevertheless, it did require an effort to decide what control to choose on the on-screen panel. In the future, with an increasingly wide range of controllable objects, the need to deal with this issue is likely to become more pressing.

We envision several design strategies to support a more efficient mapping of on-screen controls to real-life objects: (a) pilot's on-screen panel can be redesigned to rely on images rather than text, (b) the objects themselves could provide visual clues or augmented reality annotations suggesting appropriate pilot's actions, and (c) "smart defaults", e.g., automatic mapping of a control to the object depending on the orientation of the telepresence robot and the proximity of the robot to "controllable" objects in the environment [1].

Switching between navigation and object manipulation. When a double remote control interaction was supported, pilot's cognitive load also increased because of efforts needed to switch between robot navigation and remote object manipulation. For instance, the robot navigation window had to be re-activated after using the object control panel to allow navigation. The pilots often forgot to do that, and experienced frustration when arrow keys, which control robot's movements, "suddenly" stopped working. Simple solutions, such as automatic re-activation of the navigation window, can support more effortless switching between navigation and object manipulation tasks.

Scale, 1-7	*SC*	*DR*
1 obtrusive - 7 discreet	1,8	5,3
1 lonely - 7 social	5,5	3,0
1 ignoring - 7 attentive	4,3	5,8
1 uncomfortable- 7 comfortable	3,3	5,0
1 slow - 7 fast	3,5	4,8

(a) Pilot

Scale, 1-7	*SC*	*DR*
1 confusing - 7 clear	5,8	3,0
1 impolite - 7 polite	5,8	3,3
1 lonely - 7 social	5,8	3,5
1 impersonal - 7 personal	5,5	3,5
1 absent - 7 present	5,5	3,8

(b) Local people

Table 1. Mean scale scores of participants' assessment of the experience of (a) the pilot, and (b) local people in the standard condition (SC) vs. the double remote condition (DR), selected scales.

INDEPENDENCE VS. SOCIABILITY

Despite the cognitive load issues, mentioned above, pilots' assessment of their experience in the double remote control condition was generally positive. The pilots especially appreciated the feeling of independence that came from the ability to deal with one's problem without the need to ask other people for help.

In the standard condition (no contactless object manipulation) the pilots knew that a dedicated robot assistant was always supposed to be around. However, since the pilots typically did not see the assistant (who often stayed out of sight), they experienced uncertainty regarding whether someone was going to respond to their call for help. The possibility to execute an object manipulation command by simply clicking an on-screen control made the pilots feel more comfortable.

At the same time, contactless object manipulation capabilities were experienced as making the pilots/telepresence robots less social (see Table 1). The ability to control things independently of other people made the pilots pay less attention to local people, especially when navigating the robot. It can be partly explained by the limited field of view of the telepresence robot used in the study. Because of that limitation it took considerable effort for the pilots to maintain awareness of their environment, an effort they tried to avoid when possible.

AUTHORITY AND SOCIAL TRANSLUCENCE

Our evidence indicates that pilot's ability to remotely manipulate objects may also have other types of negative effects on social interactions in the local setting. First, it may cause uncertainty regarding local people's authority to use local objects. In many social contexts the rights to control shared objects are specified by an elaborated system of rules, often implicit, which may be based, e.g., on the physical proximity of a person to an object [1]. In the double remote control condition such rules are somewhat unclear: the pilot can manipulate certain objects irrespective of where the objects are located relative to other people in the setting.

Another implication of double remote interaction was that local people could only see the results of pilot's manipulation of local objects, but not how and why the actions were performed. Arguably, the notion of social translucence, originally developed for digital environments [6], can be applied to the physical environment of our study, as well: in both cases it points to the need to deliberately provide additional perceptual clues to make people and their actions more visible.

COMMUNICATION EXPRESSIVITY

A widely recognized limitation of most telepresence robots is a lack of gesturing/pointing capabilities. Our study suggests that the limitation is especially significant for double remote interaction. For instance, when choosing an object to manipulate pilots cannot simply point to the selected object; they have to explain their intention in words. It is often associated with additional costs in terms of time and effort. Therefore, making double remote control interaction more efficient requires providing telepresence robots with more advanced gesturing capabilities ([2, 9, 15]).

Conclusion and prospects for future work

The study reported in this paper presents a first step in exploring double remote control interaction as a solution to enhancing action capabilities of telepresence robots. The combined evidence obtained in the study allows us to make a number of tentative claims. The most central ones are related to the effects of double remote interaction on user experience, which effects, according to our study, are not straightforward. On the one hand, for the pilot, an added remote object control capability was generally associated with an increased feeling of autonomy and self-reliance, even though it also somewhat increased pilot's cognitive load and caused certain usability problems. On the other hand, local people perceived double remote control interaction as less personal and somewhat challenging their own control over objects in their environment.

Another set of conclusions has to do with the research strategy used in the study, that is, simultaneously focusing on two physical locations and combining videotaping, observation, log files, self-reports, and semantic differential scales. Our experience indicates that the strategy made it possible for us to address the potential problem of "blind spots" associated with using individual methods and focusing on only one location.

For instance, when navigating the robot one of the pilots used to repeatedly move it sideways before making a turn. The behavior was interpreted by an observer as scanning the environment, but the pilot explained that in fact the reason was that slow visual feedback caused the device to be moved too far to one side or the other before choosing the right angle (the pilot himself became unaware of the issue after eventually dealing with it). Another example is the detection of a pilot's failure to use gestures in the "lecture" scenario. On one occasion the pilot was actively gesticulating to convey his point, but the gestures were performed outside the camera view and therefore were not visible to the audience. Even though neither the pilot nor the audience was aware of the issue, the problem was successfully detected by an observer at the remote location.

In addition, as shown in Table 1, the experience evaluation instrument we developed was sensitive enough to detect differences in user experience between the conditions (standard vs. double remote control) and participants' roles (pilots vs. local people).

The results of the study set the stage for next steps of our exploration of mobile remote presence enhanced by contactless object manipulation. We intend to apply the research methodology, tried out in the present study, in our future work. We plan to further develop the pilot's user interface, to ensure more transparent and seamless coordination of navigation and object manipulation, and extend the range of remotely controlled objects. Given that our evidence indicates that employing the double remote control solution may have some adverse effects on social interactions, special attention will be paid to the social context of mobile remote presence and co-experience of telepresence technology [7]. In particular, we plan to enhance communication expressivity of telepresence robots by providing them with more advanced pointing capabilities [2, 9].

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