REMOTE ASSISTANCE IN CAREGIVING USING TELEROBOT

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INTRODUCTION

Telerobot is a mobile robotic platform providing mobility to sensors, actuators and communication devices for home telehealth services. Teleoperated from a distant location, a mobile robot with some autonomous capabilities can become a beneficial tool in telehealth applications [2,3,5]. Assistive technologies for telemonitoring in homes constitute a very promising avenue to decrease load on the health care system, reduce hospitalization period and improve quality of life. This simple idea is not as easy to put in place, as it addresses issues in robotic locomotion, navigation and remote user interaction through interfaces, evaluation of clinical needs, its integration into health care information systems and patient acceptability. With a team of robotics, clinical and geriatric experts, we initiated in 2003 the design of a new robotic platform for this type of application, and more specifically for elderly people that have disabilities living at home. This paper summarizes our iterative design methodology addressing these issues for the development and validation of a robotic telepresence system for home care assistance.

PRELIMINARY STUDIES

Three types of preliminary studies were conducted in our project: telerobotic systems in home environments; focus groups with healthcare professionals and elderly people; interviews with system users to model the health information architecture. The objective of these studies was to gather more information to come up with good initial specifications for the telerobotic system.

Telerobotic Systems in Homes

Homes are complex environments presenting a great variety of conditions (e.g., doorsteps, carpets, hard floor, stairs, objects of all sort, constrained space). With the current technology, it is unrealistic to believe that such machines can operate right away autonomously in homes; limits in structural, perceptual and processing capabilities are still too important for their efficient and secure uses. A teleoperated system is therefore more realistic, exploiting technological capabilities already available and relying on human interventions to compensate for the robot's limitations. But even by being teleoperated, ensuring the safety of the individual in the home where the robot is used and the safety of the robot itself are primary concern. The quality of the robotic teleoperation user interface and the operator experience in teleoperating the robot are two factors that seem to have a direct impact on efficient and safe use of such systems.

Therefore, we conducted a pilot study to evaluate two conceptually different user interfaces for teleoperated mobile robotic systems, with trained and untrained operators [4]. This study aimed at identifying locomotion and structural requirements for the new robotic platform, as for user interface requirements for improved efficiency and security of novice operators of mobile robots. Field trials were conducted using two commercial robotic platforms: one specifically designed for telepresence application (the CoWorker, which uses visual waypoint navigation directly using images coming from the robot's navigation camera); the other being a generic research platform (the Magellan, to validate laser-mapped position point navigation from a top-view, 2D map). A first set of trials (2 homes and 5 operators – 1 expert, 2 roboticists and 2 clinical researchers) was conducted in 2004. Even though we had a small number of operators, we found the experience rich in information. For instance, In addition to characterizing physical constraints (measurements of different elements such as doorsteps, corridors, doorframes; carpets that are not fixed to the floor; instability of the platform when going over a doorstep and the effect on the video stream), we also faced the difficulty of conducting an evaluation of complete teleopreation systems in natural settings (i.e., homes, instead of in controlled conditions such as the lab). Coming up with a good evaluation methodology and following a rigorous experimental protocol revealed to be a non-trivial task. We explored the use of a method comparing trained and untrained operator performances with respect to the performance of an expert, thus eliminating potential bias from the robotic platform and the environment. We noted that untrained operators performed better using position point navigation, while trained operators had better performance with waypoint navigation. Therefore, conducting preliminary trials revealed to be very useful in getting a holistic view of the issues to address in our project, and to prepare the methodology in the different studies as the project progresses.

Focus Groups

Many different uses can be imagined for a home care assistive robot, such as manipulating and transporting objects, navigation assistance, cleaning, monitoring, etc. While these ideas can lead to interesting technological development, they may not address real needs. On the other hand, users do not necessarily know what new technology can do, so it may be difficult to outline needs, constraints and specifications for home care assistive robots.

Motivated by the practical nature but still abstract of the application, in addition to the novelty of its technical challenges, we put efforts on identifying and addressing the actual needs in telehome care interventions. The objectives of this study [1] were to explore with healthcare professionals involved in geriatric care and potential client (the elderly) the concept of in-home mobile robotics in order to 1) conduct a preliminary needs assessment, 2) identify potential target applications, 3) identify check list items needed for the development of an prototype that could be used in pilot testing of these applications.

A trained moderator independent to the research team conducted focus groups interviews with two target groups consisting of 8 healthcare professionals (HP) and 6 community-living elderly (CLE). The concept of an in-home telepresence robot was illustrated using a photograph of a mobile robot, and participants were then asked to suggest potential health care applications. Interview data derived from the transcript of each group discussion were analyzed using qualitative induction based on content analysis.

The shift from a traditional hospital-centred model of care in geriatrics to a home-based model creates opportunities for using telepresence with mobile robotic systems in the context of telehome care. It was perceived by healthcare providers and community-living older adults with disabilities as a means of accomplishing specific tasks such as: (1) facilitating the provision of care for older adults living at home; (2) enhancing their safety; and (3) giving caregivers some respite and support. A robotic telepresence service would not replace healthcare professionals or family members, but could supplement them in providing care. Robotic telepresence was also seen as a way of reducing the travel time of healthcare professionals, especially for interventions that are of short duration (e.g. monitoring of injuries, verification and follow-up with the family). Furthermore, the results suggest that the perceived capabilities offered by teleoperated mobile robotic systems in the home could be used to assist multidisciplinary comprehensive patient care through improved communication between patients and healthcare professionals.

Health Information Architecture

The specific activities undertaken in any clinical setting revolve around three major themes: care, research and education. Through the implementation of an information system, these three themes must be employed and calibrated with, at the very least, the same precision found in the real clinical environment. The achievement of this calibration is an extremely challenging task as their are many different informational aspects to consider. For instance, embedded within each of the three themes are any number of major objectives depending on the particular clinical settings, which in turn must be precisely matched to each of their respective users. Therefore, the development of an informational architecture helps to ensure, facilitate and stabilize this integration.

To that end, experience has shown that without an integrated methodological approach there is a high risk of a poorly functional health information system. The system design process has, at the very least, two phases: the business process (the elicitation of user requirements) and the system analysis process. A general entreprise-based methodology is required, one in which its use results in the total integrative design, implementation and deployment of any type of health information system under any condition.

Our review of these methodologies indicates that it is difficult to assess the completeness of these methods because they are so inherently different with respect to one another. The main reason is that each particular methodology is context-specific so that their applicability does not reach beyond the particular situation that necessitated the development and implementation of a particular health information system. A more general methodology is preferred, one in which its use results in the total integrative design, implementation and deployment of any type of health information system under any condition.

To address this issue, we adapted the Zachman framework [7], a framework utilized abundantly in non-health information domains, for health information purposes. Essentially, this framework originated from the need to develop an architectural approach to the design of any complex engineering product, including an information system. It conceptualizes all the information required as a two-dimensional table subdivided into six columns (specific informational perspective according to the following questions: WHAT – the material description; HOW – the functional description; WHERE – the location description; WHO – who is doing what; WHEN -- when the events take place; WHY –why the choices are made) and five rows (representing the points of view of different actors in the system development process such as: Scope; Owner's view; Architect's view; Designer's view; Builder's view). Having such an analytical framework helps better visualize the arrangement of the necessary informational components required to achieve the system's purpose. It also encompasses the other methodologies into a simplified and consistent across clinical contexts.

For our project, as an initial study, we focused on the Owner's view, the Architect's view and the Designer's view. For the Owner's view, we conducted individual interviews with a representative set of users (i.e., five engineers, one kinanthropologist, two physiotherapists, one nurse, one doctor and one social worker). Three elements emerge from these interviews: information oriented toward the robot (teleoperation, autonomy, health-related sensors and actuators); information oriented toward the patient (medical evaluation, biological evaluation, functional evaluation); information oriented toward the robot with the patient (audio-video communication). The information gathered during these interviews was then modelized using UML (Unified Modeling Language) diagrams. This led to the design of an architecture illustrating how information gathered from the teleoperated robot and from communication with the patient would be exchanged toward a distant information system that would also be interconnected to the electronic health database. In addition to the teleoperating interface for the robot, two additional interfaces would be required, one for audio-video communication between the patient and the remote operator, and one for accessing the electronic health database (to be access only by medical personel, and not natural caregivers). We are currently in the process of analyzing the information architecture using a typical use-case scenario involving how a doctor, a nurse, a physiotherapist, a occupational therapist, analyzing if the flow of information is complete (eventhough is may be different from the various types of users) for the proposed architecture, in preparation of the next phase which is to build such information architecture.

SYSTEM DESIGN

Based on the knowledge acquired in these preliminary studies, we decided to design a mobile videophone robotic platform, thereby known as Telerobot. The first prototype is shown in Figure 1. Locomotion is realized using two motorized wheels and four omnidirectional wheels attached to rocker-boggie suspension to minimize disturbances of the video streams coming either from the bottom camera for teleoperation (placed underneath the laser range finder), or the two cameras fixed on the top shelf, and increase mobility on irregular ground.

Fig. 1 – Telerobot

Video user interfaces are common in telerobotic systems and intelligent interfaces are becoming increasingly important as users face increasing system complexity and information overload. An optimal teleoperation user interface must provide pertinent information about the system' states and conditions (objects, persons, free space, data, etc.) in conjunction with an efficient command system to the operator, with reasonable cognitive load for sustain and adequate uses. More specifically, we found that in home environments, the presence of small obstacles, corridors and doorways substantially increase the level of difficulty for both trained and untrained operators. Different teleoperated navigation strategies are possible with performance affected by the task to accomplish. In order to keep a minimum level of security for the operation of the teleoperated system, automation of the navigation strategy must keep the operator in sufficient vigilance without causing information overload. The system must provide different navigation strategies ranging from manual to semi and complete autonomy (e.g., when the robot must return to the charging station). Position-point navigation using a 2D map and sensor reading representations requires a certain level of cognition and complex mental models [6], while way-point navigation is limited to the field of view of the camera. We are investigating a new user interface combining the advantages of waypoint navigation and position point navigation to improve operator performances. As illustrated in Figure 2, one of our new user interfaces has the central window showing a 3D model of the environment, on which the camera view is placed. A 2D map and a robot sensor's representations are placed on the left side windows, and controls are on the bottom.

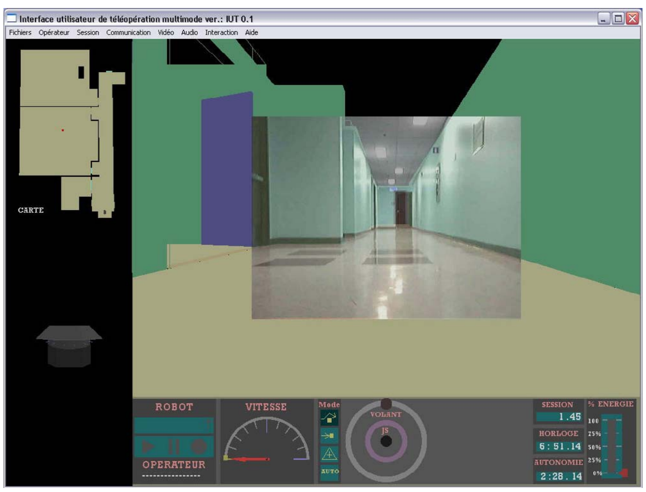

Fig. 2 – Graphical User Interface

Validation of Telerobot and the user interfaces in controlled laboratory conditions are currently being executed. Trials with a representative set of operators (*n*=36) were conducted to analyze the influences of the graphical interfaces on teleoperation tasks. Additional tests will be done to characterize Telerobot's locomotion and navigation (e.g., localization is required to match the 3D model with the video stream) capabilities. Once completed, we will be able to proceed with testing Telerobot in homes with no elderly people involved, conducting trials with a representative set of operators, focussing this time more on the control metaphors of the user interface and on illustrating concretely potential uses of the robot. The results will be used in focus groups for subsequent design iterations with clinicians and elderly people.

CONCLUSION

This paper presents the first iteration in our project of designing a telepresence robotic system for home care assistance. We believe that adopting an iterative elucidation process inside a requirement engineering activity is the right solution for the work described in the paper. This project is influenced by the complex integration of rapidly evolving technological components (both hardware and software), in a novel application in which difficulties are difficult to anticipate, involving a large number of participants (clinicians, natural caregivers, seniors, engineers, etc.), each with their own set of needs and constraints. Therefore, there are just too many factors (ranging from robotics, human and environmental) to take into consideration to start elaborating design specifications without conducting preliminary trials and assess their combined effects, or to initiate extensive testing in home environments to quantify the usability of the system in such settings.

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