The Role of Embodiment in Assistive Interactive Robotics for the Elderly

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Abstract

We argue that physically embodied robotics presents a niche of key importance in elder care of the future. We present our work toward assistive interactive robotics that will enable intelligent robots, using little if any physical contact with users, to provide individualized and adaptive monitoring, coaching, training, encouragement, and aid to people with a variety of needs.

Introduction

Robotics is readily recognized as a technology of potentially key importance in helping the growing elderly population with their need to retain independence and to extend ageing in place. In those capacities, robots are seen service entities for rudimentary physical tasks. In this paper, we argue that robots have a rather different, and scientifically more interesting as well as socially more important role to play in elder care. We argue that intelligent, socially assistive robots have the potential to provide affordable and individualized 24-hour social interaction and availability for the elderly (Feil-Seifer & Matarić, 2005). We posit that the robot's physical presence and the shared context with the human user present the critical "hook" for establishing a human-robot relationship that can fill a complex and much-needed mixed role of pet, nurse, and friend to an elderly user, without requiring much, if any, physical contact between the robot and the user. We believe that the same important role cannot be filled with disembodied solutions (e.g., software agents, PDAs, intelligent watches, etc.) for reasons that are deeply embedded in what makes us human social animals.

Embodiment

Placing robots in human environments inevitably raises important issues of safety, ethics, and economics. It is therefore important to understand the niche for physically embodied robotics as a complement to alternative technologies, such as personal digital assistants (PDAs) and software agents. Our research is based on the premise that the robot's physical embodiment plays a key role in its assistive effectiveness. It is well established that people attribute intentions, goals, emotions, and personalities to even the simplest of machines with life-like movement or form (Reevs & Nass, 1998). This inherently human property is irrepressible; it is culture-independent (but manifests itself in culture-specific ways), impervious to background and education, and resistant to habituation with repeated interactions (Lee & Nass, 2003). Because of this combination of properties, it constitutes a key means of establishing human-robot interaction, of getting people to respond to the robot and become engaged in an interaction with it. Research into social robotics has already empirically validated these facts (Breazeal, 2002; DiSalvo et al., 2002; Kiesler & Goetz 2002; Fong et al., 2003; Lee et al., 2004).

However, social robotics has not yet tackled the complex challenges of assistive robotics where the overall goal is to achieve measurable progress toward the prescribed health, education, or training goals. Assistive interactive robotics, our field of research focus, presents a new paradox: the goal of retaining user engagement can be in conflict with the health/training/education goals. It is known that human nurses that are deemed most likable by patients are not always the ones most effective in facilitating patient recovery. While social interaction does not require physical embodiment (see Ziemke 2001 for five different notions of embodiment in robotics and AI) and can be accomplished in both embodied and disembodied ways, we believe that the robot's physical embodiment, its physical presence and shared context with the user, will play a key role in time-extended, sustained, goal-driven interactions in assistive domains. The elderly thus constitute one of the most interesting target beneficiary populations for assistive interactive robotics.

The research we are pursuing that is most relevant to the goals of the workshop is based on the testable hypothesis about the importance of the role of physical embodiment in elder care. To test this hypothesis, we are developing prototypes of embodied technology and testing its effectiveness relative to alternative, disembodied technologies on subjects from the relevant elderly populations. We are also pursuing experiments that study human conscious and unconscious social responses to robots in social settings, as described later in this paper.

Recent Work and Results

Our recent work has developed and empirically evaluated examples of several assistive interactive robot systems, briefly summarized here.

We have developed Clara, a mobile robot assistant for nurses in the cardiac hospital ward. Clara is capable of navigating a hospital room, locating the hospital bed and patient, and interacting with the patient through speech. Clara's "specialty" is spirometry, the exercise of breathing into a specially-designed tube that measures lung volume. Post cardiac surgery patients are asked to perform spirometry exercises ten times per hour for several days, in order to facilitate regaining lung function and warding off infection. Given its frequency, spirometry requires a significant amount of nurse time and attention in the context of a rather repetitive and unsophisticated task, therefore creating a perfect nice for non-contact assistive interactive robotics. As described in Kang et al. (2005), Clara was designed to describe the spirometry exercise to a patient, monitor a patient's performance, provide feedback/encouragement, and report results to healthcare staff. Given these capabilities, Clara can serve multiple patients in the cardiac ward, while maintaining individual models of each patient's performance and interaction preferences. Clara has been tested by the nursing staff at the USC Hospital cardiac ward. Our continuing work with Clara involves the use of different personalities and interaction modalities with different patients, in order to further personalize the interaction and the care the robot provides.

While our work on Clara has explored human-robot interaction in the context of repeated, short-duration engagements, our work on robot-assisted stroke therapy focuses on long-duration interaction and relationship building between the robot and patient. One of the most effective post-stroke rehabilitation methods, constraint induced therapy, involves an active exercise schedule of about 6 hours per day in the first two months of recovery. Since such extended-duration of care is not available through health care (the provided average is 39 minutes per week), this creates yet another important problem domain for assistive interactive robotics. Our work to date has developed a non-contact socially assistive robot that monitors the exercises and general use of the patient's affected limb, and provides continuous feedback and encouragement. Our system was tested with six stroke patients, and the results, reported in Eriksson et al. (2005), were strongly encouraging. The stroke patients' compliance to the exercise regime was increased through the interaction with the robot, and all reported to have enjoyed the interaction. Our continuing work in this rich domain is described in the next section.

Ongoing Research

Our results to date with the implemented and realistically validated assistive interactive robots are encouraging, and open the doors to a large field of fascinating and much-needed research. The following are some of our ongoing projects with immediate relevance to elder care.

Core hypothesis testing We continue to design and implement experiments that test our core hypothesis of the role and impact of embodiment on assistive human-machine interaction. In different contexts (school, hospital, rehabilitation center, elder care home) and with appropriate user populations, we are assessing and comparing user responses to different types and embodiments of assistive technology. Our research is evaluating not only conscious behavioral responses (such as verbal and physical behavior, reports in post-experiment interviews, etc.) but also unconscious social responses such as proximity, posture, and eye gaze and fixation. A better understanding of the role of embodiment is fundamental in the elder care context, where the user populations may be more technologically averse that average (typically younger) users, and where the safety and expense tradeoffs of physical robots are especially acute.

Structing embodied interaction The physical embodiment, presence, mobility, and expressiveness of the robot collectively provide the foundation for productive human-robot engagement. However, so far there is no structured formalism for how a robot should behave relative to the user, and how it should leverage its embodiment effectively. Our ongoing work is studying different users (personalities, ages, etc.) and their preferences of robot embodiment and behavior styles; it is well established that personal styles affect human communication, but how this may transfer to robotics is not yet known. This research direction is also important for elder care; the elderly are known to be firmly set in their ways and preferences, and it is crucial that any assistive agent or robot be able to recognize and appropriately respond to those tendencies if a productive relationship is to be established and maintained.

Goal sharing and transfer As noted above, assistive robots much achieve the combined goal of user engagement and assistive outcomes, whose components may be in conflict. We are developing a model for enabling robots to leverage physical embodiment in order to effectively convey, train, and facilitate the human user's internalization of the goals of the interaction (exercise, treatment, training, rehabilitation). This area of research involves issues of of the level of robot autonomy and authority in the assistive context. In the context of elder care, user vulnerability and susceptibility to influence are just some of the ethical issues that must be immediately addressed.

Modeling embodied empathy Empathy is a key tool in health and elder care by human caretakers. Effectively modeling empathy in ways that leverage the robot's embodiment and its capabilities without losing site of technological limitations is one of the areas of research we are pursuing. Here, too, user susceptibility and manipulability must be carefully taken into account in particular in elderly and cognitively disabled beneficiary populations.

Summary

Our research into assistive interactive robotics is not solely focused on elderly users, but the key research questions, listed and briefly discussed above, all directly relate to elder care. Consequently, the growing elderly population presents one of our most important user and evaluation groups. We strongly believe that the physical embodiment of the robot presents a unique means of achieving assistive goals in elder care and other contexts. Our ongoing research is aimed at testing our underlying assumptions about embodiment, developing effective embodied assistive systems, and broadening our understanding of human social behavior as it relates to assistive technology.

References

Cynthia Breazeal (2002), Designing Sociable Robots, Cambridge, MA, MIT Press.

C. DiSalvo, F. Gemperle, Jody Forlizzi and Sarah Kiesler (2002), "All Robots Are Not Created Equal: Design and the Perception of Humanoid Robot Heads". *Proceedings, Conference on Designing Interac-tive Systems: Processes, Practices, Methods, and Techniques*. London, England.

Jon Eriksson, Maja J. Matarić, and Carolee Winstein (2005), "Hands-Off Assistive Robotics for Post-Stroke Arm Rehabilitation", *Proceedings, IEEE International Conference on Rehabilitation Robotics (ICORR-05)*, Chicago, IL, Jun 28-Jun 1.

David Feil-Seifer and Maja J. Matarić (2005), "Socially Assistive Robotics", *Proceedings, IEEE International Conference on Rehabilitation Robotics (ICORR-05)*, Chicago, IL, Jun 28-Jun 1.

Terry Fong, Illah Nourbakhsh and Kerstin Dautenhahn (2003), "A survey of socially interactive robots", Robotics and Autonomous Systems 42 (3-4):143-166.

Kyong Il Kang, Sanford Freedman, Maja J. Matarić, Mark J. Cunningham, and Becky Lopez (2005), "A Hands-Off Physical Therapy Assistance Robot for Cardiac Patients", *Proceedings, IEEE International Conference on Rehabilitation Robotics (ICORR-05)*, Chicago, IL, Jun 28-Jun 1.

Sarah Kiesler and J. Goetz (2002), "Mental Models and Cooperation with Robotic Assisatnts", *Proceedings, Conference on Human Factors in Computing Systems (CHI)*, Minneapolis, Minnesota.

Kwan Min Lee and Cliff Nass (2003), "Designing Social Presence of Social Actors in Human Computer Interaction", *Proceedings, SIGCHI Conference on Human Factors in Computing Systems*. Ft. Lauderdale, Fl.

Lee, K. M., Park, N. K., & Song, H., (2004, May). "Can a Robot be Perceived as a Developing Creature?: Effects of Artificial Developments on Social Presence and Social Responses toward Robots in Human-Robot Interaction". Paper presented at the International Communication Association Conference, New Orleans, LA.

B. Reeves and Cliff Nass (1998), "The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places". Cambridge University Press, New York, NY.

T. Ziemke (2001, July). "Disentangling Notions of Embodiment". *Proceedings, Workshop on De-velopmental Embodied Cognition*. Edinburgh, UK.