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Defining Socially Assistive Robotics

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Abstract— **This paper defines the research area of socially assistive robotics, focused on assisting people through social interaction. While much attention has been paid to robots that provide assistance to people through physical contact (which we call contact assistive robotics), and to robots that entertain through social interaction (social interactive robotics), so far there is no clear definition of socially assistive robotics. We summarize active social assistive research projects and classify them by target populations, application domains, and interaction methods. While distinguishing these from socially interactive robotics endeavors, we discuss challenges and opportunities that are specific to the growing field of socially assistive robotics.**

I. Introduction

The field of socially assistive robotics is growing but has not yet been properly defined and circumscribed. There has been significant attention given to and great progress made in contact assistive robotics. Yet it is crucial to note that hands-on assistive robotics is only part of the total composition of assistive robotics. Currently there is no clear definition of robots that provide assistance through interaction and without physical contact, namely *socially assistive robotics*. We begin by distinguishing these categories.

A. Assistive Robotics

In the past, assistive robotics (AR) has largely referred to robots that assisted people with physical disabilities through physical interaction. This definition is no longer appropriate as it is lacking in scope: it does not cover assistive robots that assist through non-contact interaction, such as those that interact with convalescent patients in a hospital or senior citizens in a nursing home.

Assistive robotics itself has not been formally defined or surveyed. An adequate definition of an assistive robot is one that gives aid or support to a human user. Research into assistive robotics includes rehabilitation robots [6][9][18][20][26], wheelchair robots and other mobility aides [1][16][34][38], companion robots [3][31][35], manipulator arms for the physically disabled [17][15][24], and educational robots [21]. These robots are intended for use in a range of environments including schools, hospitals, and homes.

B. Socially Interactive Robotics

The term socially interactive robotics (SIR) was first used by Fong [14] to describe robots whose main task was some form of interaction. The term was introduced to distinguish social interaction from teleoperation in human-robot interaction (HRI). Fong conducted a survey of socially interactive robots and evaluated them along social interaction principles, categorizing them by the aspects of social interaction (speech, gestures, etc.) they used. Concerns regarding human perception of robotics, particularly the difference in social sophistication between humans and social robots, were addressed, and field studies, evaluation, and long-term interaction were all noted as areas worthy of future research.

C. Socially Assistive Robotics

We define socially assistive robotics (SAR) as the intersection of AR and SIR. SAR shares with assistive robotics the goal to provide assistance to human users, but it specifies that the assistance is through social interaction. Because of the emphasis on social interaction, SAR has a similar focus as SIR. In SIR, the robot's goal is to develop close and effective interactions with the human for the sake of interaction itself. In contrast, in SAR, the robot's goal is to create close and effective interaction with a human user for the purpose of giving assistance and achieving measurable progress in convalescence, rehabilitation, learning, etc.

The motivation for defining SAR is not to create a schism within SIR but rather to expand assistive robotics to include robots that operate via social interaction and to better understand the key unique challenges of this growing field.

In the following sections, we will discuss the motivation for and the definition of socially assistive robotics. We will define a taxonomy of interaction components that augments the definition of socially interactive robotics toward assistive domains and uses. Finally, throughout the discussion, we will provide a comprehensive summary of related work.

II. Motivation

There is ample motivation to research SAR. There exists a multitude of important assistive tasks where social interaction rather than contact with the user is the central focus. One example task domain we have studied is recovery post-stroke [12]. A variety of assistive robot manipulators [6][20] have been developed for post-stroke rehabilitation, which physically move the patient's limbs as a form of physical therapy. However, Constraint Induced (CI) therapy [37], where a human therapist reminds and coaches a stroke patient to repeatedly use the affected limb(s), is recognized to be one of the most effective rehabilitation methods. ThaI approach involves no physical contact between the patient and therapist, and thus presents an excellent candidate for a social assistive robot solution, as our other work has demonstrated [13]. By using their own limbs, patients learn more generalizable skills and tend to exercise longer, useful behavior patterns [37]. The capability to encourage and train such exercise activity can be employed beyond the stroke domain to other physical therapy fields.

Another important motivation for SAR is the significantly decreased safety risk in non-contact human-robot interaction. Because of this feature, systems are more easily tested and deployed.

III. Taxonomic Description

The taxonomy defined by Fong [14] describes the interaction component of a socially interactive robot by the following properties:

- A Embodiment
- B Emotion
- C Dialog
- D Personality
- E Human-oriented perception
- F User modeling
- G Socially situated learning
- H Intentionality

For a socially assistive robot, additional properties need to be added to the taxonomy definition, as follows:

I. User Populations

Socially assistive robots can address various populations of users, ranging in age, impairment, and need. These categories are not mutually exclusive so a robot can help users belonging to one or more of the populations listed below.

1) Elderly: To address a growing health care crisis affecting the elderly in the US and elsewhere, researchers have focused on assistance in the home and hospital environments. Some of the developed robots have the goal of keeping users up to date with nursing home schedules [3][29]; others, based on results showing that pet companions can help reduce stress and depression [11], attempt to recreate these results with a companion robot [35]. Still others assist seniors with disabilities [7].

2) Individuals with Physical Impairments: Robots can act as mobile prosthetic devices for people with physical impairments. Traditionally, this area of assistive devices has focused on wheelchairs and robot manipulators, but research into service robots has broadened to consider devices designed for people with reduced mobility [19]. This category encompasses a variety of tasks that a socially interactive robot could perform in order to provide assistance with a physical impairment.

3) Individuals in Convalescent Care: Studies indicate that there are in excess of 730,000 strokes per year in the United States [37]. With a six-week recovery period needed for CI therapy, over thirty million patient days in a hospital would be required due to stroke alone. Various other conditions (such as cardiac surgery recovery, addressed in our other work [23]) also require extended hospital or therapist care. This large and growing patient population is creating a major niche for SAR.

4) Individuals With Cognitive Disorders: A significant body of research has shown that socially assistive robots can therapeutically interact with children with autism [8][27][28]. This research can be generalized to other cognitive and behavioral disorders.

5) Students: Aside from their growing role in primary education as tools for teaching science and engineering topics, robots have been used in schools in order to encourage socialization among students [21]. Socially assistive robots could serve as tutors, coaches, and companions, especially during interactions among students from different social groups and populations (e.g., special education).

J. Task Examples

In addition to crossing population boundaries, SAR crosses task boundaries as well. The task of the robot is driven by the needs of the user.

1) Tutoring: While there is no replacement for human teachers, robots may prove useful in several areas of learning. Hands-on learning with robots has already been shown to be effective. Robots can also provide individualized or small-group tutoring and/or class-wide rote tasks such as drills for spelling and math problem practice. They could augment teachers and allow them to devote more in one-on-one interactions with students.

2) Physical Therapy: As mentioned above, our work has implemented and validated assistive robots for aiding stroke patients with CI therapy [13] and post-operative cardiac patients with spirometry exercises [23]. Like stroke, cerebral palsy is another domain where repetitive exercise plays a key role in therapy. However, getting children to comply with the prescribed exercise regime is a daunting task for caregivers. That burden can be eased through game-playing and choreographing exercises into a dance that accompanies story-telling [31]. SAR can provide a variety of rich game-playing scenarios to assist both the child and his/her caregiver in meeting rehabilitative goals.

3) Daily Life Assistance: Robots can be used to assist in daily activities from the cognitive to the physical. The *Pearl* project uses a robot to help the elderly with schedule planning and maintenance [29][32]. SAR has the potential to provide engaging cognitive aides in combination with tools to monitor compliance and performance.

4) Emotional Expression: Robots can be used to encourage emotional expression in situations where such expression may be challenging. For example, robots have been used to encourage children with autism and children facing cardiac illness to open up emotionally by having the child and the robot create a story to act out together, expressing the child's feelings and concerns about the future [2][5][4][31]. Robots have also been used to examine the nature of socialization between autistic children [36], serving as a facilitation for interaction and expression.

K. Sophistication of Interaction

SAR interactions vary in type and sophistication. While Fong described this feature as "emotion" in his survey, in the assistive domain in particular, it is important to treat interactions separately from the robot's personality. Emotion classification only describes how the robot interacts with a human; it does not describe the reciprocal interaction by the human user. The following are the most common interactive modalities currently employed in SAR.

1) Speech: Conversation is the natural, though not all-encompassing, means of social interaction between people and would thus be convenient for social communication with robots. While there is ongoing research into speech recognition in noisy real-world environments, this is still an open problem.

A conversational robot may use synthetic speech generation or pre-recorded human voice. The degree to which the human-robot interaction must be pre-scripted determines which is more viable; our preliminary work show patient (in the post-stroke domain) preference for pre-recorded human voice [12].

2) Gestures: Body language is a large component of human communication and can be useful if the robot and human are expected to interact with the environment. Gestures, when augmenting a vocal grammar, are an important part of interactions with the real world [30]. The ability to point and recognize the object of pointing, for example, are instrumental for commanding focus of attention and shared context within an interaction. Furthermore, for physical therapy, recognizing body position is vital and can enhance the interaction between the robot and the user [22].

3) Direct Input: Sometimes, it is most appropriate for the user to give direct input to the robot. For example, when deciding among several locations on a map or when searching a schedule, verbal or gesture commands can become tedious. In these situations, an input device such as a mouse or a touchscreen may be highly effective [29][19] even if not otherwise preferred for natural social interaction. In assistive domains, the nature of some users' conditions may preclude other means of interaction at some or all times.

L. Role of the Assistive Robot

Social assistive robots have worked as caregivers alongside doctors, nurses, and physical therapists. They have been used as therapy aids for children dealing with grief and loss as well as social mediators for children with autism. Robots have been used as companions in nursing homes and elementary schools. Correctly defining the role of the robot in these interactions is important for crafting its appearance and interaction modalities. The role may be defined by the task the robot is assisting with [10] and the user population it is working with [33], and by the impression it gives through its appearance and behavior. For example, a hospital robot may act like a nurse or a medical instrument depending on the task and the nature of the interaction. While a robot may serve multiple purposes, human user bonding preferences may mandate more specialized and individualized behavior.

IV. Evaluation

Socially assistive robotics must address a spectrum of novel challenges in terms of performance.

A. User Task Performance

A SAR system must engage the user effectively, achieve the goals of the domain-specific activity (recovery, training, etc.), and be responsive to the needs and requirements of not only the user but also the caretaker and health care/educational staff. For example, a robot may prompt a patient to do a given task properly, yet the patient may still not perform the task [25]. A robot may be appealing to a user but ineffective at achieving measurable outcomes in rehabilitation or vice versa. The requirement of achieving multiple potentially conflicting goals and concurrently "serving many masters" with varying needs and requirements presents novel and complex challenges for socially assistive robotics.

B. Level of Autonomy

Ideally, a SAR system requires no expert operator or extensive training for use. It should be self explanatory and capable of being started, stopped, and configured by people already providing care with a minimum burden placed upon them. It must also conform with the changing routines and demands of the user and caretakers, another challenge inherent to SAR.

C. Embodiment v. Non-embodiment

SAR brings the question of the role of embodiment to the forefront. If the robot does not need to engage in a physical contact task, what is the reason for using a robot at all? Would a computer or personal digital assistant (PDA) suffice? Social robotics relies on the inherently human tendency to attribute goals and intentions to even the simplest physical mobile entities. While embodiment has a key role to play in engagement, how that role translates into measurable outcomes in robot-assisted therapy, convalescence, and learning is yet to be addressed and is one of our major areas of pursuit.

V. Discussion

We have proposed a definition and taxonomy of socially assistive robotics (SAR), a research field with a large set of associated application domains. Our goal has been to begin to identify where this class of assistive solutions, which leverage non-contact interaction, can be effective relative to available alternatives. By explicitly defining and exploring the properties of SAR, we hope to discover new ways for robotics to be of assistance to people in all walks of life.

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