SOCIALLY ASSISTIVE ROBOTICS

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Robotics is finally at the brink of entering our daily lives. Having transitioned from success in factory automation (auto assembly) and high-precision laboratory work (aiding DNA sequencing and medication delivery), it is now poised to move into much messier, less structured, and more uncertain human-inhabited environments. While simple robot vacuum cleaners are already doing their work in over a million homes, robotics researchers are eagerly developing much more complex and intelligent robots that will work with and for people in hospitals, elder care centers, and eventually homes.

What happens when intelligent robots and people share an environment and even share goals? This question is at the heart of human-robot interaction (HRI), an inherently interdisciplinary research endeavor that brings together engineering and social science, cognitive science, neuroscience, ethics, and the disciplines directly related to the application domains the robot technology would operate in, such as health care and education. Human-robot interaction, as an instance of human-machine interaction, is as much a study of people as it is of robots; it requires us to gain insight into a new and dynamically changing relationship between humans and intelligent machines.

Within the larger context of HRI, our research work is focused on *socially assistive robotics (SAR)*, whose challenge is to aid people through social interaction, rather than through physical contact. SAR brings together HRI and assistive robotics, which has demonstrated successes in hands-on rehabilitation through the use of high-precision but low-autonomy and low-interactivity systems. Thus, SAR presents an entirely new set of research challenges, as we strive to understand how robots can interact with people in order to effectively and measurably help in the difficult processes of convalescence, rehabilitation, socialization, training, and education.

It may seem counter-intuitive that physical robots are used for social assistance. After all, why not use software agents or devices such as personal digital assistants (PDAs) endowed with intelligent interfaces? The answer rests on the fundamentally human tendency to socially engage with, and attribute life-like properties to machines, especially embodied ones like robots, that exhibit sufficient (often quite simple) attributes of biological-like movement or appearance. The human projection of intentions, goals, and emotions to such embodied devices has been shown to be is inescapable, culture-independent (although featuring culture-specific responses), uninhibited by sophistication of knowledge and familiarity with the details of the technology, and resistant to change with time or with repeated encounters. This means that people cannot help but respond to engaging physical machines. Our research builds on this human characteristic to develop a novel robot-assisted research paradigm with two distinct but inter-related goals: 1) to study human social and performance-related behavior in order to better understand those phenomena and their underlying mechanisms and 2) to elicit sustained productive goal-driven behavior in as part of the diagnostic, therapeutic, or educational process. We are thus motivated by the vision of using assistive technology as a dual tool: for scientific discovery and for societally-relevant application of assistive robots.

From the basic science perspective, socially assistive robotics presents a new and unique tool for scientific inquiry. Machines have long been used in research, but usually in the form of passive, if sophisticated, tools. Through socially-aware robots, we can introduce a fundamentally new type of machine into the research realm: one capable of detecting, monitoring, and responding to user behavior in a physically shared context. As tools of scientific inquiry, robots can have both their form and behavior manipulated in a fully controllable manner; we can carefully design the information that is shared with the participants about the robot, in order to attempt to control their beliefs and biases. Using that experimental paradigm, we can measure participants' responses, both voluntary and involuntary, ranging from observable behavior (eye gaze, body posture, movement patterns, linguistic interactions) to physiological responses (heart rate, body temperature, galvanic skin response). We can also combine such robot experiments with functional brain imaging, aiming toward structural insights about relevant social and learning mechanisms. Thus, we can ask scientific questions that could not previously be asked or experimentally answered. By perfectly tuning how life-like, human-like, believable, socially engaging, and intelligent robots are, we can probe into human social behavior and use the gained insights to design social interaction toward measurably improved therapeutic, educational, and training outcomes.

The physical *embodiment* of the robot is a critical means of eliciting the richness of the user's response, both in the context of scientific discovery and in real-world applications. The properties of that embodiment, such as how the robot looks (is human-like and animal-like appearance important and desirable; should the robot match the user in approximate size and, if humanoid, in apparent age?), how it behaves (how expressive should the robot be relative to its user; what means of expression are most effective; how far does physical embodiment and embodied cues go in conveying information and what is the appropriate balance between non-linguistic and linguistic interaction; should the robot have a detectable personality and if what should it be?), and how it relates to its niche (how does the hospital environment different from the school or home; how to handle different types of users within an environment, such as doctors, nurses, therapists, patients, and the family at the hospital, for example?) all present open and rich avenues for research into both human nature and assistive human-robot interaction.

Figure: A stroke patient interacting with a socially assistive robot that is monitoring, coaching, and motivating prescribed exercise therapy.

Situated at the interplay of science and technology, SAR research is aimed at impacting major societal challenges, focusing specifically on the growing ageing population, rising costs of medical care and education, and shortages of social programs for education and training of children and adults with disabilities. To aid people in need, robots will need to perform truly challenging tasks in both structured/controlled environments (hospitals, elder care facilities, and schools) and unstructured settings (homes, cities, roadways, rubble piles). One of the outstanding challenges for SAR is found at the juxtaposition of needing to be *both useful and engaging*. The most popular human nurses are known to not be the most effective; it is very hard indeed to compel a person to do something painful, difficult, or dull that needs to be done in a sustained manner, such as exercising 6 hours per day post-stroke, or breathing into the spirometer ten times per hour after cardiac surgery, or performing weeks and months of vocabulary and pronunciation drills. The socially assistive robot must remain appealing as well as effective over a long time-period, whether it be months in stroke rehabilitation, years in special education, or, potentially, life-long. This presents an entirely novel and compelling challenge for both robotics and artificial intelligence. Effective human teachers, coaches, nurses, and therapists are all too rare yet too important to do without; those very shortages serve as motivators for SAR research, whose goal is not to replace humans but to fill in large gaps where attentive and individualized human care is diminishing or entirely unavailable.

Figure: Our child-sized humanoid robot (which works from a desk top or on a mobile platform) interacting with a child, part of the research toward robots that can help in the education and socialization of children with special needs.

Embarking on assistive robotics involves being problem-driven and facing complex scientific and technological challenges in noisy and sensitive real-world domains that involve interactions with vulnerable users. Our research that has so far placed simple robots with stroke patients, cardiac patients, and children in special education classrooms has already demonstrated positive and promising results (described in the relevant readings listed below), as well as pointed toward a plethora of fascinating research questions. The rich potential of SAR for gaining novel insights into human cognition and social behavior, and for improving human quality of life for populations where it most needs improving, represents one of the most exciting and uniquely compelling topics in the field of modern robotics.