Making friends: Building social robots through interdisciplinary collaboration

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1 Introduction

Social roboticists aim to create "natural" and "compelling" robots that can engage in social interaction with people in their everyday environments. To accomplish this aim, they seek to endow robots with various combinations of traits: the capacity to express and perceive emotion, the skill to engage in high-level dialogue, the aptitude to learn and recognize models held by other agents, the development and maintenance of social relationships, the learning and use of social competencies and natural social cues (gaze, gestures, etc.), and the capability to exhibit distinctive personality and character [8]. The performance of such behaviors by robots poses a variety of compelling technical challenges for the fields of computer science and engineering. Furthermore, the emergence of these behaviors within the context of social interaction, along with the direct and personal (and often unpredictable) impact socially interactive robots have on humans, bring up issues of appropriate design principles and modes of analysis that require expertise from social science and design disciplines.

The design of socially interactive robots is an impetus for work at and across disciplinary boundaries in the context of problem-centered inquiry. Social robots attract the interest of and require input from engineers (fascinated by the technical challenges posed by hardware and software requirements), social scientists (who study the relationships and distinctions between humans and non-humans and the interplay between technological, scientific, and social factors), and designers (who aesthetically and compellingly give form to heterogeneous living networks of technologies, people, and artifacts), among other fields. As such, social robots are exemplary "boundary objects" [25], which can be imagined, perceived and interpreted differently by various disciplinary communities, yet still provide a common focus for inquiry and action. The practice of social robotics entails constant renegotiation of conceptual boundaries: between the technical and the social sciences; between functional and emotional artifacts; between human and machine; and between scientific disinterestedness and social responsibility. Social robotics is a "hybrid science" [2] in the making—a knowledge space in which engineers, designers, artists, natural and social scientists, and humanities scholars can engage in mutually beneficial collaboration, construct methods for traversing disciplinary boundaries, and create consilience between the humanistic, social, natural and applied sciences.

Attempts at collaboration among practitioners in such a wide variety of fields are understandably accompanied by various challenges and the constant need to re-establish mutual understanding and rapport. In this paper, we discuss our own experiences in collaboration in socially assistive robotics and suggest ways of negotiating disciplinary differences in worldviews, language, methodologies, research tools, and theories in the pursuit of mutually beneficial cooperation. To counter the inevitable 'clash of disciplinary cultures,' we discuss how to use interdisciplinary collaboration as a "cultural fix" [15] to expose widely accepted disciplinary assumptions and to develop alternative meanings and practices contextualized within the hybrid knowledge space of social robotics.

2 Balancing the scales: A model of interdisciplinarity

Rather than insisting on the maintenance of oppositional identities and disciplinary boundaries, collaborative modes of inquiry emphasize the complementarity of skills among researchers with diverging social and technical expertise and common goals. Campbell's "fish scale model of omniscience" [1] is a model for interdisciplinary collaboration such as the design of socially assistive robots, and illustrates the kind of disciplinary structure we can aspire to (in figure 1 we juxtapose a more realistic current state of social robotics over the fish scales). Rather than aggregating as clusters of specialties, disciplines in this model

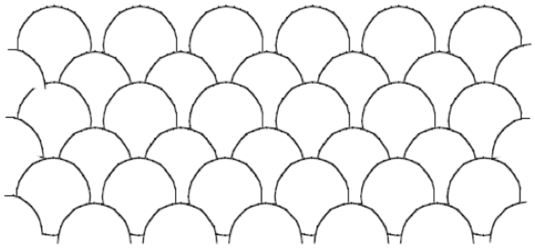

Figure 1: The fish-scale model of omniscience [1].

overlap enough to enable collaboration, but not so much as to produce a situation in which scholars are constantly replicating each others efforts rather than working together to move beyond existing knowledge structures. Campbell's model underscores the idea that interdisciplinary knowledge production cannot be individual; rather, it must strive for "collective comprehensiveness through overlapping patterns of unique narrowness" [1]. In order to participate in such efforts, scholars do not need to be specialists in all the related disciplines, but are required to have a certain level of expertise in other fields. "Interaction expertise" [4] will enable them to interact around the multidisciplinary development of a technological boundary object while comprehending it from the viewpoint of their respective disciplines. "Contributory expertise" [4], on the other hand, makes possible transdisciplinary collaboration between participants who have a shared understanding of the research goal and enough knowledge and skill to contribute to scientific inquiry in the relevant socio-technical system [4, 11].

3 Clash of disciplinary cultures: Challenges in interdisciplinary collaboration

Transdisciplinary, problem-based research projects expose disciplinary assumptions about what counts as scientific knowledge and the valid methods by which it is obtained. This is readily visible in the case of social robotics, in which differing emphases in the epistemic cultures of the technical and social disciplines (general, rational, logical, objective, and quantitative in the former, versus contextual, relational, narrative, subjective, and qualitative in the latter) become a source of tension in the search for partial consensus, tolerance, and collaboration.[9, 13].

Relating incommensurable frameworks The computational and technological metaphors of the human mind, having become prevalent in the past century through communication between neuroscience, cognitive science, and computer science, are the basis of most work in robotics and artificial intelligence. These metaphors depict the mind as a rational, logical, neutral, and detached input-output device inside the skull [3]. Within social robotics, this perspective comes into conflict with social interpretations of intelligence, which focus not only on discrete computations and problem-solving but on the embodied, mobile, socially embedded relationship between human actors and their dynamic environment. Social interactivity needs to be understood as the ability of agents to participate in a dynamic sequence of actions between individuals or groups and to modify their actions according to those of their interaction partner(s), rather than as an inherent capability of the agent—there is no socially interactive robot by itself. The meaning of the interaction, and the agency of the robot, emerge from its situatedness in the interaction (as with Okada's Muu). Within this framework, the computational model "in which '*the* [single given] environment' is conceived in terms of a set of autonomously determinate features, can be seen as crucially confining, or, indeed, disabling" [13]. From time to time, disciplinary tensions bubble up in statements such as Donald Norman's brusque encouragement for the "engineers to go back to engineering" [20] or the common griping of roboticists who say that they prefer not to work with social scientists or designers because they don't understand them and their problems. It is easy to see that frustration with those who take a different perspective cuts both ways.

Bridging the quantitative/qualitative divide The hybrid social and technical agenda of social robotics projects also highlights the difference between the quantitative and the qualitative with respect to problem definition, data collection, methodology selection, and the types of social knowledge that inform robot design. Social robotics, with roots in computer science and engineering, generally exhibits a "quantitative bias" [9]: evaluations of human-robot interaction are generally expressed in terms easily quantifiable measures (turns to task completion, number of mistakes made or people spoken to, length of interaction, etc.), and they generally rely on statistical and experimental results from psychology and cognitive science to inform and compare among robot designs. The majority of evaluations of robots is done in the laboratory, by the very people that have built them (although there are proponents of taking robots "into the wild" [22]). The results of qualitative, contextual, interpretive techniques such as ethnography are regularly called "anecdotal" by roboticists, sometimes in a derogatory fashion, although the acceptance of such analyses is increasing. Problems arise because the contextual nature of social interaction precludes reliance on quantitative measures of human-robot social interaction alone, as they lead to the systematic exclusion of social phenomena that are not easily amenable to quantification. It also decreases the interest of members of other fields in social robotics, since they cannot see a space within the field for the kinds of issues in which they are interested. Along with quantitative models and measures, qualitative analytical skills and situated contextual analyses of social behavior are legitimate, valid, and especially for social robotics, *useful* frameworks for thinking about the world. Reliance on quantitative metrics and controlled experiments alone has limited utility for understanding social interactions in contexts where the task boundaries and success criteria are not clearly defined.

Raising entrenched disciplinary hierarchies Social robots are expected to participate in real-world social interactions with humans in an autonomous and 'human-like' manner. Despite the centrality of 'the social'—social behaviors, interactions, rules, and uncertainties—to research in social robotics, social scientists hold a marginal position in the field. Habitual disciplinary hierarchies become salient through the assumption that anyone can easily become an expert in social interaction while it takes a special kind of technical education to build robots. Roboticists do not shy away from making forays into the social science literature, retrieving bits and pieces of theory and method that can be useful in their work, often combining them with folk theories about everyday social experience that fail to take into account the discrepancies between our conscious models of events and observed behavior [9]. Critiques of social robotics rightfully single out problematic assumptions about sociality displayed by social robots, as well as the over-reliance on the more "scientific" experimental results of psychology and cognitive science rather than the "anecdotal" interpretations of sociology and anthropology [21, 22]. These critiques often assign the responsibility for these deficiencies on the robotics community and overlook the difficulty most roboticists have with translating abstract, interpretive and qualitative research accounts into something that can be applied to building and programming a robot. Simple rules for operationalizing interaction criteria[1], various discrete lists of attributes[2], and easily quantifiable variables are eagerly embraced by social roboticists as more straightforward and easier to implement.

Tomato, tomato: Differences in terminology Due to these disciplinary differences, it is possible to experience confusion in terminology. Terms used in the different disciplines often carry a lot of cultural baggage depending on the way the term has been used in practice within the discipline. For example, early in our own collaborative experience, we discovered in the course of a frustrating discussion that the social scientist, the designer, and the roboticist on the project were using the term 'distributed' quite differently, one referring to "distributed cognition" and the other to "distributed sensors." Participants from different disciplines also had varying sensitivity to different concepts, such as referring to people interacting with the robot as 'users,' 'participants,' 'subjects,' 'interaction partners,' or even 'resources' used by the robot (which seemed to rob them of 'agency,' not to be mistaken for what computer scientists would call an 'agent'). While these language-related differences seem to be the easiest to pinpoint and solve, they also point to some of the underlying assumptions of the different fields and to the kinds of questions and issues that they choose to emphasize.

4 All for one and one for all: Beneficial exchange among disciplines

A common interest in understanding social phenomena means that social scientists and roboticists can work together to explore the social metaphor in more detail. Social scientists can contribute their detailed expertise in analyzing and describing social interaction, and roboticists can contribute their skills in making artifacts that work in the real world, that behave consistently, and that can provide a record of what they have sensed and done with respect to their environment. A benefit that can flow from social science to robotics, for example, is that the performance of such robots can (and should) be evaluated by social scientists outside the laboratory. In the other direction, social robots can serve as tools for social scientists to use in analyzing the interactions and relation-

[1]For example, the comfortable interpersonal distances in Hall's proxemics [12].

[2]For example, Laurel's breakdown of human-computer interaction into "action, character, thought, language, melody, spectacle" [14].

ships people have with each other and with techno-scientific artifacts. Conflicting perspectives notwithstanding, the discipline-traversing potential of social robotics, epigenetic robotics and human-robot interaction are being put to good use by researchers that defy disciplinary confinement and opt for collaborative problem-oriented approaches.[3]

Behavioral video analysis In our collaborative work, we found that a valuable role that social scientists can play in social robotics projects, especially already existing projects, is in the rigorous and objective evaluation of the resulting systems. Video analysis can reveal problems as they occur in an interaction, which can later be reflected in manipulations of the robot's design. Fine-grained behavioral video analysis, usually conducted on a frame-by-frame basis, entails formulating a coding schema for labeling a set of primitive behaviors or states for the people and robots involved in a recorded interaction. Statistical analysis of the resulting labeling provides quantitative descriptions of the interaction that can be used to support or generate qualitative analyses. Such analyses can show us how interaction emerges in particular contexts, as well as how small variations in the social and physical environment can change the nature of the human-robot interaction. With the robot GRACE [16], we showed that interactivity was not merely inherent in the robot as an isolated artifact, but that it emerged from an interaction between environmental effects, both predicted and unpredictable, and the robots sensory and behavioral capabilities. With the robot Tank [18], we found problems in both the robot's sensory model of human engagement and in the behaviors used toward people in different states.

Artifact for controlled/consistent observations for social scientists Collins [5] argues that a fundamental issue in the social sciences is the lack of a genealogy of research technologies that can be pragmatically manipulated and modified to produce new phenomena and a rapidly moving research front. Social robots can be such a technology. They are autonomous, they can be much more reliable in repeating the same behaviors time and again, and they can be used to both develop and test models of human social interaction, as well as human development [some epigenetic robotics citations here].

Importance of good design In creating socially assistive robots for research, roboticists often spend time developing functionality to the exclusion of appearance and aesthetics. Yet collaboration with the design discipline is important not only for aesthetic purposes; it is crucial that questions of form, functionality, and appearance are appropriately addressed for the scientific inquiry through such artifacts to be valid and productive. There is perhaps a widespread faith that, in a controlled experiment in which a single variable is manipulated, any observed difference between conditions can be used to make general statements about the variable under study. In a domain as complex as human social interaction, however, the potential for confounding factors to appear is great, and the design of a robot's appearance is as important as the design of the experiment. For example, early in the design of GRACE's pink-hat-finding task, a roboticist suggested a touch-screen interface that would allow people to enter a set of directions (in the manner of writing a sequential program) for GRACE to find the hat. A designer on the team saw that this would detract from the goals of the project, which was to encourage and observe as many social interactions with people as possible, and proposed a much simpler interface in which arrows were selected to point GRACE in a general direction. The roboticist is able to use an artifact that is more comfortably used in the interaction under study, and the designer has the opportunity to develop and test ideas about interactive, embodied technologies.

5 Collaborative project inception

While interdisciplinary collaboration can revitalize existing projects and obtain new results from existing systems, its potential can be most fully realized when it is used early in the project; indeed, when the project itself is born of a discussion between members of different disciplines in order to investigate mutual interests. We have begun such a project, and it would not have been possible without equal contribution from multiple fields.

Roillo [17] is to be a small, stationary, nonverbal robot that interacts with children in playrooms. First, it is based on a solid theoretical basis that draws from four decades of social science research in rhythmicity and interaction synchrony, which are related to rapport and are proposed as foundations of social interaction. It uses an iterative design process (theory, design, evaluation in situated interaction, back to theory, etc.). It is to be used to critically study, for the first time in a controlled manner, rhythmic interaction as an emergent phenomena between interaction

[3]See work by Brian Scassellati [23, 24], Michio Okada [26] and Kerstin Dautenhahn [6, 19]

partners, and at the same time has the potential to establish interaction rhythms as an important component of natural socially interactive robotic systems. The robot also has the potential for assistive applications. Children with autism and other developmental disorders often exhibit difficulties in establishing rhythm, so a rhythmic robot could be used for diagnosis and, perhaps, for therapy, as is being done with dance and music therapy for children with autism. If we can get children to interact rhythmically with a robot in minimally social ways, then we might see how this can be transferred to more open-ended social interaction with people. For example, Kozima's robot Keepon was used to mediate interaction between a human operator and a child until the child used the robot as a focal point in interaction with her mother.

6 Conclusion

By inhabiting the same space, working on common problems, and developing a shared language and conception of social robotics (as roboticists, designers, and social scientists), we are continuously traversing and deconstructing disciplinary boundaries through our everyday practices. At the same time, our research continues to change through dialogue, debate, and cross-pollination. From the social scientist's viewpoint, the critical aspects of our work on social robotics have been changed by a deeper understanding of the technical limitations of technology and the kind of work involved in building and programming robots. At the same time, our robotics research became informed by some of the methodological and theoretical commitments coming from the social sciences. A commitment from all sides to friendship, respect, and open-minded inquiry, as well as a willingness to value differing backgrounds, ideas, and perspectives [7], enables practitioners from very different epistemic communities to "'muddle through' together toward mutual understanding and even practical ends" [10].

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