An HRI Graduate Course for Exposing Technologists to the Importance of Considering Social Aspects of Technology

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This article illustrates how HRI can be a useful vehicle for exposing technologist students (e.g., in computer science or engineering) to social aspects of technology and to the concrete benefits that a socially aware perspective can bring to technology design, implementation, and use. The article details the strategy and layout taken with the graduate-level Human-Robot Interaction (HRI) course at the University of Manitoba, Canada, between 2011 and 2015, for the purposes of introducing students to social considerations surrounding technology. Further, this paper reflects on the results from three iterations of the course and demonstrates how students have engaged socially aware thinking and analysis in their course projects. This single, introductory HRI course can be a catalyst for encouraging socially aware thinking in technologist students.

Keywords: human-robot interaction education

1 Introduction

Human-robot interaction (HRI) has emerged as an interdisciplinary field of study: One can reasonably expect to find HRI courses in a range of departments, including Computer Science, Engineering, Psychology, Sociology, Linguistics, Health Sciences, and many others. This interdisciplinarity introduces challenges to teaching HRI, as a given student body is unlikely to have expertise beyond their single, core area. However, because of this, HRI provides an opportunity to expose students to broad range of new fields and new ways of thinking about their work.

In particular, HRI can serve as a useful tool for training students with primary education in computer science and engineering to be aware of how these related fields, e.g., sociology and psychology, deal with technology, and how these perspectives can be useful for practitioners in designing, implementing, and evaluating technologies. This broad perspective builds on the fact that the interhuman social world is important for understanding how technologies will be adopted and used (and ultimately, successful or not) and can further inform new ways that people can work with technology; this can be summed up as being generally more socially aware.

In this article, I explain why HRI is uniquely positioned and well suited for introducing technologist students to more socially aware perspectives on technology and briefly survey the existing teaching resources for HRI. Following, I detail the graduate-level introductory HRI course in the Department of Computer Science at the University of Manitoba, Canada, and reflect on the results from three instances of the course given from 2011 to 2015, demonstrating how students from computer science and engineering backgrounds, through the course, engaged with new ways of thinking about technology.

2 Background

The field of HRI involves a broad range of research areas: A quick survey of full papers published and presented at the ACM HRI conference in 2016 finds works from a range of departments including Computer Science, Engineering, Mathematics, Psychology, Sociology, Linguistics, Communications, Media, Design, Early Childhood Development, and Aging Research, in addition to a range of interdisciplinary labs and centers. Further, a full 38 of the 46 full papers explicitly deal with a broad range of social aspects of interaction, for example (citations indicate examples, not an exhaustive list), using social grounding to drive development of algorithms (Yi, Goodrich, & Seppi, 2016) or robot autonomous behaviors (Nikolaidis, Kuznetsov, Hsu, & Srinivasa, 2016), improve the efficiency or effectiveness of human-robot teams (Admoni, Weng, Hayes, & Scassellati, 2016), develop novel interaction techniques (Cauchard, Zhai, Spadafora, & Landay, 2016), increase user comfort with robots (Kraft & Smart, 2016) and maintain user motivation (Jacq, Garcia, Dillenbourg, & Paiva, 2016), or to explore application domains such as tutoring children (Kennedy, Baxter, Senft, & Belpaeme, 2016). Work also investigates public opinions of robots in various contexts (Sundar, Waddell, & Jung, 2016), how people will interact with the technology (Robinette, Li, Allen, Howard, & Wagner, 2016), and how the technology will integrate into people's spaces (Hebesberger, Dondrup, Koertner, Gisinger, & Pripfl, 2016), for the purposes of informing technology design.

While this is an indicator of the importance of the interdisciplinary fields in HRI, the general importance of being socially aware applies to technologies in general. For example, a wide range of examples exist in science and technology studies that highlight how social factors can determine if technologies fail or are successful, become re-appropriated, or even impede development. Social considerations are crucial for being able to understand and predict how a technology will fare and further develop once released. Extensive reading is available for those interested (e.g., A. Berg, 1999; A.-J. Berg, 1994; Bijker, 1995; Bose, Segui-Gomez, & Crandall, 2011; Johnson, 1988; Venkatesh, Morris, & Ackerman, 2000; Venkatesh, Morris, Davis, & Davis, 2003; Winner, 1986).

All of this research leads us to a simple message: Technologists should be trained to have an awareness of the social aspects surrounding the technologies they create and how the technologies will be integrated with the people who will have to use them. Unfortunately, technology training generally spends little or no time on this issue, apart from a potential general elective (e.g., introductory sociology or psychology course) that is not technology specific. HRI provides a powerful, unique opportunity for exposing technologists to more socially aware techniques and analyses of technology.

2.1 Using HRI to Expose Technologists to the Social Aspects of Technology

The topic of HRI is well suited for leading technologists into more socially aware discussions and discourse around technology: to consider the impact and adoption of their technologies, to explore broader ideas of how to better evaluate the success of a technology, and to consider how social considerations can inform their technology designs, algorithms, and interfaces. As I explain below, I believe that the intersection of HRI and social awareness is quite accessible and requires minimal motivation, and as such, HRI serves as an approachable gateway for technologists toward socially grounded thinking.

Robots elicit a great deal of anthropomorphism from people, much more than other technologies, such as personal computing devices (e.g., see Forlizzi & DiSalvo, 2006; Garreau, 2007; Kahn et al., 2012; Sung, Guo, Grinter, & Christensen, 2007; Young et al., 2010); people have tendencies to treat robots in some ways like living things, attributing them with emotions (Sharma, Hildebrandt, Newman, Young, & Eskicioglu, 2013) or human-like intentions (Short, Hart, Vu, & Scassellati, 2010). Following, it is reasonable to expect technologist students to likewise experience these social reactions to robots, and to positively respond to robots that use human-like social interaction techniques to communicate. Little motivation is then needed to introduce social aspects when studying how robots work with people, and students can be expected to quickly understand, for example, why it may be useful for a robot to have eyes for communicating to people, and why we should study how a robot can use these eyes to give gaze cues to inform a human collaborator of where it will move next (Admoni, Hayes, Feil-Seifer, Ullman, & Scassellati, 2013). Therefore, HRI can be a particularly effective tool for initiating and engaging socially grounded discussion.

This relatability is strengthened by common robot applications where the robots enter into people's spaces as assistants, professional collaborators, or teammates, such as on assembly lines, in search and rescue, or in the military, examples that are commonplace in the media and the public consciousness (e.g., Garreau, 2007). In these cases, the argument is easy to make that robots can benefit from being able to use human-like social communication (e.g., gaze, gestures, speech), and that roboticists should be broadly aware of the social situation and consider this in their technology.

Further, robots themselves—and the field of robotics—are steeped in hard technical problems to which technologist students can relate. In addition to the basics of robotics, such as locomotion and motion planning, the socially related problems of a robot monitoring a human state or social situation, and executing a complex behavior model to work within this, requires a great deal of technical expertise (with many open problems). Thus, social HRI challenges can be grounded in technological problems, providing a familiar catalyst to help students engage the social material and learn how the technological and social are inextricably linked.

HRI provides an approachable, easy to motivate, and easy-to-understand introductory view into social aspects of technology and can serve as a gateway and foundation toward deeper, socially grounded inquiry. This can lead toward less accessible discussions, such that robots can use social interaction techniques to shape social structures and situations (Jung, Martelaro, & Hinds, 2015; Sakamoto & Ono, 2006), or persuade people (Chidambaram, Chiang, & Mutlu, 2012; Cormier, Newman, Nakane, & Young, 2013). Gender issues should also be considered (Eyssel & Hegel, 2012), and students can be initially exposed to more nuanced, broader ideas that are not typically engaged by technologists, such as the impact of robotic technology on people's lives (Young, Hawkins, Sharlin, & Igarashi, 2008), society as a whole (Winner, 1986), or ethics surrounding robots (blame, impact on society, etc.; Malle, Scheutz, Arnold, Voiklis, & Cusimano, 2015).

Finally, getting started in beginner social HRI courses does not require technologist students to be experts in the related fields, unlike many multi-disciplinary efforts. While expertise is clearly important (see, e.g., the range of author backgrounds listed above) and crucial for moving to advanced topics, many of the social ideas, such as how robots may interact with people, are accessible, enabling students to develop simple social HRI projects and plans early in their training.

Overall, while the goal of any HRI course is to educate students on HRI, HRI additionally provides a powerful opportunity to push students to be more socially aware. The material is approachable, and by working through fundamentals and emerging research in the field, students can gain experience considering the social aspects of technology throughout the design, implementation, and evaluation cycle; this perspective can apply for any technology, not only robots, and ranges from the micro level (how a user feels, what social language they use, and how a technology can play into this) to the macro (how a technology impacts social structures of a small group or large community).

2.2 Teaching Resources for HRI

There is a lack of well-accepted resources or accepted practices for teaching HRI, in part due to the relatively young age of the field, and to the broad range of interdisciplinary topics and perspectives that an HRI course can cover. There are several HRI books available, but these are generally structured as a curated set of topics essays or targeted themes (e.g., Cifuentes & Frizera, 2016; Kanda & Ishiguro, 2012; Prassler et al., 2005; Sarkar, 2007; Wang, 2011), and there are no textbooks with curricula to be followed or used to structure a course.

There are fundamentals and methods papers from within the HRI community that help unpack and explain the core challenges, motivations, and methods used in HRI (e.g., see Drury, Scholtz, & Yanco, 2003; Fong, Nourbakhsh, & Dautenhahn, 2003; Kiesler & Hinds, 2004; Olsen & Goodrich, 2003; Riek, 2012; Young et al., 2010, 2008). While these are foundational and very useful resources, they need to be packed and curated into a class format to be effectively used to teach HRI.

The related field of human-computer interaction (HCI) boasts a vast range of teaching resources and textbooks (Dix, Finlay, Abowd, & Beale, 2004; Preece, Rogers, & Sharp, 2015). Much of this falls under the umbrella of user-centered design and desktop (and, more recently, tablet and smart-phone) interaction, helping technologists become more sensitive to the person who will interact with their software. This includes exploring cognitive models of how people engage technology and often takes a design-centered approach to improving these interactions. This can include some elements of social-aware training but is not a core focus as provided by HRI.

Some HCI resources include discussions on affective aspects of computing, for example, about interfaces that detect and deal with frustrated users, the use of emoticons, or even some HRI (Preece et al., 2015). This can be supplemented by more-targeted resources, for example, on affective computing (Hudlicka, 2015; Picard, 2003) or design (Norman, 2002; D. Norman, 2005). Other relevant areas of HCI are in core evaluation strategies, methodologies, and analysis techniques that help people focus on the user, and sometimes, their social context (e.g., Preece et al., 2007; Strauss & Corbin, 1998). Some of these resources start to help students to be more socially aware and can be tightly integrated into HRI curricula: This leverages the existing, well-developed tools, while wrapping students into the accessible, socially-loaded HRI context.

In summary, while teachers of HRI can and should draw from the existing literature, there is still a clear need for ongoing development of curricula and teaching resources.

3 HRI Course at the University of Manitoba

The rest of this paper deals specifically with the graduate-level Advanced Introduction to Human-Robot Interaction course given in the Department of Computer Science at the University of Manitoba. This is a thirteen-week course, with the student count in any class ranging from 6 students to 30, with the more likely number being 12–15. The students are primarily holders of bachelor’s degrees in computer science or electrical and computer engineering. Students can be enrolled in a thesis-based MSc program (the majority), PhD program (minority), or course-based MSc (rare), and a full course-load is considered to be two courses per term plus a low-effort research methodologies course. In addition, all thesis-based students are expected to simultaneously work on their research. These factors dictate reasonable expectations of work.

Prerequisites to enter the course are heavily discouraged by the Department, due to the limited number of graduate courses offered and that all MSc and PhD students have a course requirement. Given students’ limited background, existing experience in related fields such as human-computer interaction or robotics is uncommon and cannot be relied on, which limits the depth of methodologies and material that can be covered.

3.1 Pedagogical Goals

The primary superficial goal of the course is to expose students to the field of HRI and a range of problems, solutions, and methodologies employed within. However, given the mixed student body with most not aiming to become HRI researchers, the course is aimed at the general technologist. As such, the course has been designed to impart more general knowledge and skills beyond the specifics of HRI.

A main goal of the course is to introduce students to thinking toward considering the social, human-centered elements of technologies. This course uses HRI as a means by which to get technologist students to engage this way of thinking about the technologies that they design and build, as detailed in the previous section. Topics in HRI are used to introduce students to a broad range of social perspectives on technology, from the micro to the macro, and to illustrate how understanding people, their social interaction strategies, their environments, and society is important for building successful technologies, informs the development of algorithms, and helps one determine how to evaluate the impact and use of a technology.

This focus on the social requires a shift in how students approach, discuss, and work though their problems and ideas. Technology training heavily emphasizes absolutes, such as mathematical systems, measures of efficiency and capability, facts about architecture and performance, and common technological techniques and paradigms. For practice, technologists often build prototypes and small systems with extensive trial and error. This does not directly support the more nuanced, often contentious, ideas and concepts that arise when injecting social elements into the equation. Many ideas can be subjective, culturally grounded, and based on uncertain and ongoing study results. Instead of providing concrete truths that students can intimately study (as in much of technology training), socially grounded methods can rather provide evolving perspectives and techniques that provide subjective “lenses” to help analyze in a more textured, nuanced way. This not only falls outside of most of technologists’ training experience, but students cannot engage with the material by using their standard techniques of trial-and-error building and iterative implementation. As such, students need to learn new techniques for engaging with the material. In this course design, I aim to train students on new methods for exploring, engaging, and developing their ideas, namely, using oral discourse, iterative writing, and feedback.

I have found that having a group of students engage each other in a (moderated) discussion on social topics is extremely effective for helping the students to deeply learn the material. The process of either criticizing an idea or highlighting an unclear aspect provides an opportunity for other students to provide counter arguments or to offer explanations. Through this process, students change and shift through ideas and stances, see and can learn to respect a range of perspectives, and can gain a nuanced, rounded view that is much less likely when studying a concept individually; in my experience, these methods are not commonly employed in technology programs.

In technology training, students get hard feedback from the technology they are trying to harness: Code will not compile; bugs are hard to fix; machines do not act as intended. Feedback on more subjective and nuanced ideas, such as social interfaces for robots, is not so easily encountered. As such, I encourage students to conduct iterative writing of their ideas with peer feedback, to serve as a trial-and-error paradigm. Writing is a powerful forcing function that makes students detail their ideas and plans, and such a process can illuminate logical and motivational errors or limitations within the work. Receiving peer feedback on the work further provides an external account of the idea, which a student can take to improve their writing.

Finally, an additional goal of this course is to help sensitize students to the research-side ethical issues of working directly with participants. While the institutional ethics review board procedures and policies are covered in a separate, required course (titled "Research Methodologies"), social HRI provides a wealth of grounded opportunities for students to consider participant well-being, and what impacts participating in a study may have on them. As such, participant ethics is a regular topic of discussion as various study designs and instances are encountered.

3.2 In the Classroom

The class format is a 90-minute slot, twice a week. The class follows a theme model where each class (and sometimes multiple classes) has a topic with associated readings and presentations, and the topics follow a progression over the term. Each actual class can be broken down into three components:

- The professor provides a 5–10 minute presentation on the topic and emphasizes the tone or importance of the work from a higher-level, meta-perspective that is not obvious from the papers themselves. This helps set the tone for the class.
- A student provides a 15-minute presentation on an assigned reading, followed by a 20–25-minute discussion led by the student.
- A second student follows the same procedure to present a second paper.

The heavy focus on student presentation greatly restricts lecture time but creates room for oral discourse on the ideas.

3.2.1 Student presentations

Students are required to give several presentations throughout the term, with the actual number being decided by the given class size; the aim is to have two students present a paper every class.

Students are marked harshly on their presentations. In addition to core marks for style (presentations should be professional), students are instructed to take an analytical view on the paper and are marked for insights and meta-comments. Simply explaining the paper is insufficient; students must explain why the work is useful and what needs to be done follow-up. Extensive criticism is heavily discouraged.

This task, of summarizing work, and presenting it from a research-minded perspective, is non-trivial, but provides first-hand practice on how to properly read and analyze research work from a higher-level perspective, moving beyond simple memorization of results and criticisms.

3.2.2 Discussion moderation

Students are required to engage in in-class discussion (thus class sizes should target around 15 students), to challenge the ideas, take stances, and discuss with other students to explore nuances.

While the presenting student is told that they must lead the discussion, which usually entails prodding questions and providing direction, the professor's job is to moderate at a higher level. This includes the mechanics, such as stopping over-talkers and prodding under-talkers directly, but more importantly, provides opportunities to make targeted, contextual lessons. For example, if a student makes a false statement based on poor understanding of statistics or study design, the professor can correct the misunderstanding and highlight the importance of the particular nuance, in context. One challenge is to keep the classroom positive; The professor must watch for this, be very positive in framing criticisms, and avoid blocking opinions, for example, by working through and exploring an idea to arrive at a conclusion rather than simply stating that an idea is wrong.

3.2.3 In-class examinations

Fundamentally, I believe that in-class, written examinations are a poor mechanism to evaluate understanding and progress in this class. However, examinations are highly effective at giving students pressure to study and keep up with material. As such, I employ simple, multiple-choice midterm and final exams, with low grading weight, where any reasonable student should be able to achieve an 80–90% mark. Further, I include a short statistics quiz early in the class to encourage students to refresh their knowledge. I provide an online resource (Heffner, 2004), and give the test within the first week.

3.3 Student Projects

Students are given a project with the requirement that it must be original research on an HRI topic. While sample topics are provided, students are encouraged to develop their own, perhaps using the reading list. Students are free to decide where to put the energy in their projects, for example, by doing an extensive, reflective survey, a novel interface design with solid methodology, or an implementation and user study. Across instances of the class, I have tried both individual and group projects and have found that group projects result in more impressive results, but individual projects have a better learning impact due to the writing load.

The primary goal of the project is for students to learn first-hand how difficult and time-consuming it is to properly frame, develop, and initially prototype a project. I believe that this is important for developing respect of other research and a trained, critical eye for appreciating the benefits of the work and not just the flaws.

Students are encouraged to conduct a formal study as part of their project, and it is made clear that doing so would constitute a major portion of the project substance. In this case, students are informed that they would need to complete a free, online course required by our national funding body (the TCPS CORE 2 tutorial[1]) and to receive an approval certificate from our institution's research ethics board (application with my sponsorship and assistance). Students are also allowed to conduct pilot studies with friends and lab mates, although the obvious drawbacks of this are discussed, and this constitutes a much lower contribution to the project weight (unfortunately, no team to date has elected to do a formal study).

The primary deliverables for the project are a final paper, a final presentation, and, if applicable, a final working demo. The final demo and presentation are as may be expected, but the paper is quite unique as it involves iterative submissions and peer review.

3.3.1 Peer-reviewed paper submissions

Students are required to submit a total of four drafts of their final research paper, with one draft due at the end of each class quarter. Additionally, I provide feedback informally on proposals. For all papers, students must submit a breadth-first complete paper draft that includes all relevant sections, including framing, related work, and, if applicable, study designs. Sections that are not yet possible (e.g., study results) in early drafts should instead have a detailed plan of how that component will unfold.

For the first and third paper submission, students use Easy Chair[2] to submit anonymized papers, and the professor assigns papers to other students for review: Each paper should have two or three peer reviews, depending on the class size. As peers cannot give each other marks, the professor marks the reviews only, and students are marked on the quality of their reviews of others' papers. The submissions themselves are not marked at these points.

Students are expected to build on feedback and improve their paper for the next deadline. For the midterm deadline, the professor marks the paper, taking into account feedback already given in the peer review, and gives additional feedback. Finally, the professor marks the final paper after the second round of peer review.

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[1] http://www.pre.ethics.gc.ca/eng/education/tutorial-didacticiel/
[2] Easy Chair has been extremely supportive of setting up instances for in-class use.

The idea is that students should be working early on paper drafts and detailed plans, as writing can be a very effective tool for developing and unpacking an idea (and highlighting conceptual holes in a project). Further, they will learn the importance of writing early and often—and involving external opinions, as they can see how their paper improved over the course. In my experience, computer science and engineering students can be quite weak in writing, particularly for non-technical topics, making this a valuable experience.

3.3.2 Platforms

I have made a range of platforms available to students, including Sony AIBO robotic dogs, the Aldebaran NAO, and iRobot Roombas, with some students bringing or building their own devices.

3.4 Required Readings

The required readings are the heart of the topical material provided to students in this class. Students are expected to read 2–5 papers per week, in addition to the papers that they present in class. I provide a long list of topics with papers, students select ones to present, and the required readings are chosen from what is left over, allowing the professor to curate the reading list. The remaining papers are listed as optional, and some students bring them in to augment presentations or use them for their projects.

The particular themes provided for papers change slightly with each class iteration, matching the changing field and current interests. This is by no means suggested to be a complete or correct selection, and the themes themselves have blurred lines, where a paper can serve several purposes. My approach has been to include interaction and research fundamentals, and to cover a broad range of HRI topics, with a particular focus on social HRI.

The full reading list for the last course iteration is included in the Appendix. The rest of this section serves as an annotation helping to explain the purpose and rationale for the choices.

3.4.1 Introduction

The introduction of the course has the aim of getting students started on what exactly HRI is and developing an initial understanding of this unique and interdisciplinary topic. In addition to introductory readings, students are asked to watch the first episode of "Real Humans" ("Äkta människor"), a Swedish science fiction series based on androids in people's lives; this episode is extremely well produced and does a great job of introducing people to many concepts surrounding HRI.

3.4.2 Fundamentals

Students are exposed to a range of fundamentals throughout the course.

Methods. Students are required to read an extensive research methods chapter on human factors. For many, this will be the first time they encounter the problem of study designs that involve people (versus, e.g., computer simulations); this material is important for basic literacy as they read the papers in the course. In addition, the course covers the challenges of evaluating HRI and presents several specific papers and methods on the problem.

Embodiment. The concept of embodiment, and embodied interaction, is a very useful tool that is continuously referred to throughout the course. The aim is to have students start thinking about how robots necessarily see the world differently than us and how this impacts interface design. Also, developing an initial understanding of how our own (humans') interactions are necessarily embodied within our own physical and social contexts (Dourish, 2001) helps to set the stage for themes on social HRI and tangible interfaces.

Sociology of Artifacts. Students are given a crash course in selected core science and technology studies concepts, including the importance of understanding the interplay between social factors and technology: Society impacts the development of technology (and indeed, what is considered progress), and inversely, technology is not neutral and has social implications. The goal is to encourage students to move away from deterministic framings of technology (e.g., faster is better, technology is neutral, progress is clearly defined, etc.) and to start to think about the wider social structures around technology, along with the more nuanced realities of progress. This discussion spans the macro societal issues and the micro interpersonal social issues.

Social Interaction with Robots. Students read work illustrating why social interaction with robots is natural, to be expected, and an effective phenomenon that can be leveraged by robots that work with people. Students are exposed to core affective computing, as well as media pieces illustrating unexpected social interactions with robots.

3.4.3 Robot control

Students learn about the problem of controlling a robot, from a classic human-computer-interaction perspective.

Teleoperation. Students cover the operator-side challenges of teleoperating a robot, where an operator has constrained awareness of the remote environment but is often sitting at a powerful console. The fundamental challenges of HRI awareness are addressed and students are exposed to selected frameworks that unpack some teleoperation issues. Students also see examples of teleoperation interface designs that aim to improve upon the problem.

Collocated Control. In comparison to teleoperation, collocated control is often inverted: The person is within the environment but may have limited means to direct the robot, as they may not be at a console. Students learn about a range of techniques and strategies for this problem, including the concept of human-robot teams, programming by demonstration, mixed-initiative approaches, and other clever interface designs. Social aspects of interaction are downplayed here with a focus instead on the control problem.

3.4.4 Robots in spaces

Students learn how, unlike classic computing where a user sits at a console and enters a virtual world (e.g., command line, windowing system, or a game), roboticists need to consider the robot's environment more carefully. A successful autonomous robot that enters a social space must socially integrate into that space, in addition to being technically capable. In the class, particular attention is paid to qualitative and ethnographic-style work that helps the reader deeply understand the social integration and design requirements.

We cover domestic vacuum robots in detail, given their unique position as a widespread, successful product. In addition, students read about older-adult care robots, both in private residences and care centers. We also cover robots in public spaces, as they have extremely challenging requirements, and students cover a range of topics, including how a robot should use space while in public and how it should engage people.

3.4.5 Robots as social actors

Naturally following from the fundamentals material on embodiment, sociology, and social interaction with robots, is the exploration of robots themselves being social actors in our world. This is a particularly important topic for students as it illustrates the importance of considering the technology design problem from the human perspective—the humans that the robots need to interact with—and not solely from the machine perspective.

Ethics. Students are briefly exposed to ethical questions of HRI. This includes the perspective of how people will react to robotic actions, if robots should be persuasive or deceptive, and how people react when bad things happen to robots.

Social Mechanics. A wide range of work, covered over several weeks, illustrates how robots can use social interaction techniques or socially driven design to work with people. Examples include using gestures (gaze, pointing, etc.) or voice style, hesitation, or its height. This includes one-way (robot to human broadcasting) or more responsive techniques. We cover how robots can fit particular cultural norms to impact interaction or how robots can be seen as animal-like and can leverage this for interaction. Finally, students see how robots can modulate their movements to mimic humans, animals, or insects to communicate their state in a social framework. We also cover the eeriness problem, casually referred to as the Uncanny Valley (Mori, 1970) problem, and discuss the complexity of the issue, also touching on how eeriness may sometimes be desirable.

Android Science. Students are exposed to the difficulties of android science, the goal of making a robot pass for a human. Students learn about how android science is important for both building robots that work with people and for researching human psychology.

Gender Studies. If robots are perceived as human- or animal-like social actors, then it is important to consider how gender plays a role in interaction. This topic is particularly important given the gender disparity in computer science and engineering: A predominantly male workforce (Y. Wang & Young, 2014) designing and creating devices for everyone has clear risks for problems of interaction and adoption (e.g., see Adam, 1998; Berg, 1999; Cassell & Jenkins, 2000; Clegg & Mayfield, 1999; Cockburn & Furst-Dilic, 1994).

3.5 Reflections After Conducting Three Instances of the Course

I have conducted three instances of this course from 2011 to 2015, with minor variations throughout. Here, I provide a retrospective look at the results of the course instances, focusing primarily on results from student projects and anecdotal professor impressions. These reflections offer initial insights into potential successes of the course and future areas for improvement. Further, investigating student project results, at least informally, provides a glimpse into how students are opting to engage social topics surrounding their technology. It is important to note that this initial analysis is not a substitute for more formal study that will be needed to evaluate the ultimate impact of this course on student sensitivity to social aspects of technology.

3.5.1 Reflections on the classroom environment

Overall, with some management the class format worked well and did not have any evident issues. One place where students struggled was with early presentations and writing. Students generally had poor presentation style and found it challenging to appropriately abstract the work rather than simply criticizing it. However, this would greatly improve throughout the term. For instance, in the 2015 iteration of the course, students had to each conduct six presentations, spaced throughout the term. The class average for the first presentation was an abysmal 51%, despite students receiving detailed instruction and guidance on how the presentations would be graded. The grades steadily improved, with 65% for the second presentation, and for the final (sixth) presentation, the average rose to 83%. While inevitably part of this shift is due to students learning how to better match the marking metric, it is also a reflection of student ability improving, regarding being able to reflect on the benefits of a paper, and to clearly communicate that to people.

The discussion model can be difficult to manage at times. In several instances, early in the course some students have indicated that they did not feel that they are learning from the method, which adds some negativity to the classroom. However, this has been mitigated over time, particularly as students find that they can relate back to prior material and discussion and realize how well they learned the material. Another issue is that some students can be quite negative, and sometimes aggressive, to other students. I have been quite strict in dealing with this, with out-of-class meetings, making statements in class highlighting how negative a comment was, or asking students to try and find a more productive way to express their opinion that is conducive to discussion.

With respect to the topics covered, students reported that they found the robot control work to be very easily relatable, making it well suited for early in the course. Many students have told me that they initially struggle with the sociology fundamentals, and this has regularly involved additional out-of-class time, although this has decreased as the terms progressed with more in-class experience. Conversely, one reading in particular (Winner, 1986) has consistently garnered a strong, positive reaction (and interesting discussion) from students, suggesting that it may be particularly accessible.

Finally, the gender studies topic is extremely challenging, particularly when faced with an all-male class; some students demonstrate aggression, for example, claiming that there is no gender issue in technology. Developing clear strategies and example cases of where gender is important has helped. One specific technique that I use is to have a slide with an all-Caucasian team (with blond hair and all in white clothes) smiling for a photo. I tell the story that this company just launched and are making a new smart-phone product for use by Chinese people living in Beijing, to help them find parking. When I ask if there is any problem, students generally laugh, indicating how absurd it is for a company with a plan to enter the Chinese market to not have any Chinese people on their team. Then I ask: Why is it okay to design a product for both men and women, but have almost no women on the team? This works well as a discussion starter.

Finally, the exam model appears to be effective. In the one case where I did not have exams, students were clearly not keeping up with the material in comparison to the with-exam cases.

3.5.2 Student feedback

Only anonymized student rankings are available; overall, these point to the course being successful. Student rankings were overwhelmingly positive and were higher than for many other graduate classes in our department. Less formally, there were several students (who are not in HCI or HRI) in each term who took the time post-course to contact me to express their excitement for HRI and to note how much they felt they learned through the course.

3.5.3 Results of student projects

Students were free to select their own project ideas and directions, and to decide what methodologies and foci they would employ. Here, I briefly analyze the student project results, the topics covered and techniques employed, to investigate the extent to which students attempted to engage the social aspects of robots in this aspect of the course work. Student backgrounds are noted in parentheses.

Remote Control Robots

A number of projects (7 projects, 25%) focused on robot remote control, for example, comparing control paradigms or methods for displaying sensor data, with an emphasis on HRI awareness; these projects dealt strictly with the control issue, and there was no social HRI involved. One such project resulted in an HRI Late-Breaking Report (Nagy, Young, & Anderson, 2015), as the student (from Computer Science, CS, swarm intelligence) explored a future in HRI. Although these were not social HRI projects, there was a strong focus on the user experience and comfort (e.g., by measuring user enjoyment or frustration along with task outcomes or cognitive load), with half of these projects employing open-coding qualitative techniques (with two citing Grounded Theory, Strauss & Corbin, 1998), for example, with one project mining participant feedback on prototypes to help design future iterations. Thus, these students attempted to take a rounded, nuanced, user-centric look at their interfaces, and did not just focus on task measures such as efficiency.

Social Communication With Robots

Three projects (11%) incorporated social elements of communication for robots that work with people and involved building working prototypes. This included a robot that uses a dog tail to communicate its state to people; this project conducted an initial evaluation that employed an affect model (Russell, 1980) to investigate what emotions people interpreted a robot as having, based on how the tail moved (CS, HRI). This student joined my group and conducted an MSc on this topic (Singh & Young, 2013). One project, titled "Frustrated Delivery Robot," developed a delivery robot with cartoon-like facial expressions that display frustration for the purpose of encouraging people to get out of its way. In addition to evaluating how effective the robot is at getting people to move, this project further investigated participant comfort with the robot and how polite they felt the robot was, through a mixture of questionnaire and video analysis (CS, robotics). Finally, a similar project had a robot dog use emotional communication to encourage engagement and interaction (CS, parallel algorithms). These projects demonstrate students both looking toward social techniques to help solve robot communication issues and looking at the social impacts (e.g., politeness) on the people with whom the robots interact.

Social Acceptance

Some projects (5, 18%) focused specifically on social acceptance as the topic of inquiry, including some taking a theoretical approach to unpacking what factors may make a domestic robot acceptable. One paper had a particular focus on comparing results from zoomorphic and anthropomorphic robots in the literature. This project analyzed the participant pools and tasks that have been studied and synthesized some initial guidelines (CS, course based). Another developed a taxonomy of social robots, with an emphasis on emerging examples of robots and social agents (such as Apple's SIRI) and on the psychological effects on users (CS, computational finance)..

Other projects built prototypes and investigated specific interaction techniques. A project titled "Can We Be Actual Friends?" investigated how a robot can induce empathy, and whether this can encourage companionship and acceptance within a human-robot team. This project analyzed participant verbal responses while interacting with the robot and coded for friendship-style language (Electrical and Computer Engineering, ECE). The project "A Robot That Moves and Acts Differently" investigated how a robot's use of language (slang versus formal) and social body language (waving, eye contact) impacts the level of perceived anthropomorphism, using the GODSPEED (Bartneck, Kulić, Croft, & Zoghbi, 2009) questionnaires (ECE). Finally, a project titled "Personality-Based Robot Design" investigated how and why a robot should monitor personality types and then adapt its own personality to match a person. While this did not include an implementation, it provided an analysis of personality models and mapped them for use in HRI (CS, combinatorics).

The students involved in these projects demonstrated their ability to think beyond the technical requirements of a robot and to consider how the robot engages within the social space of people who will work with it.

Robots as Social Actors

A common theme (7 projects, 25%) was for students to more broadly explore what it means for robots to be social actors, and, what new kinds of resulting interactions and use cases emerge.

One project, titled “Robots as a Social Service for Children,” surveyed and analyzed a series of roles where social robots may work with children, including emerging research and the toy market. This project discussed the potential benefits and negative impacts, including the potential for inauthentic social interactions and how this may impact a child’s development (CS, HCI). More generally, the project “The Impacts of Anthropomorphism” surveyed HRI, psychology, and sociology literature and developed a taxonomy of consequences (positive and negative) of anthropomorphism, linking it to a series of design properties and considerations (CS, HCI). Another project, “Factors of Human-Robot Bonding,” explored the conditions under which people form bonds with robots, comparing social with “non-social” robots, such as the Roomba vacuum or the iRobot Packbot, and developed a taxonomy of robot design characteristics that impact bonding (CS, networks), while a similar project, “Social Awareness in Robotics,” created a taxonomy describing different types and forms of social awareness that robots need (CS, robotics).

Some projects prototyped new robot interaction scenarios that leverage the fact that robots can become social actors. For example, the project “Can a Robot Player Engender Competition?” developed a scenario where a humanoid robot (Aldebaran NAO H25) sat next to a person and interactively played a competitive video game. This compared how players interacted with this socially and physically embodied robot, versus a classic, virtual-only AI opponent, and employed several user experience questionnaires to unpack the impact on the gaming experience, and simple, qualitative methods to gain insight into players’ reactions (CS, databases).

A similar project, “Pair Designing With a Robot,” placed a robot next to a person working on a creative task (e.g., coloring graphs and info grams) and compared this to an on-screen text tip; the thesis was that the physically collocated robot could leverage social interaction strategies similar to a colleague, unlike non-agent, on-screen version. The evaluation compared the two in regard to how useful people felt the tips to be and how annoying they felt the suggestions were. Further, qualitative methods were employed to gain insight into what factors may impact results (CS, HCI). Finally, the project “Would You Trust a Robot to Take Your Photo?” aimed to investigate how people may feel if they ask a robot in a public setting (e.g., during sightseeing) to take their photo and what may impact whether they trust the robot to do a good job (CS, HCI).

In these projects, the students clearly engaged the broader idea of how a robot can be a social actor and what this may mean for how it can and will interact with the people in its spaces.

Surveys and Fundamentals

One group of projects (5, 18%) took an even broader view and reflected on the fundamentals of social HRI. Some of these projects explored the roots behind social HRI, including one project (titled “A Journey From Laboratories to our Surroundings”) conducting a detailed historical survey of machines, myths, and early robots up to current robots. This project theorized about how history has shaped our current view, and what this may mean for future robots (CS, robotics). A similar project, “Learning From the Future,” explicitly surveyed science fiction literature, with discussions on how it may have impacted current robots and how it can provide insights into how people and robots may integrate in the future (CS, robotics).

Some projects explored anthropomorphism specifically, such as analyzing why robots may be more effective if developed with emotions (“Emotional Robots: What Makes Them Work Better?”, CS, course-based student). One project (“Exploring Social Interactions With Roombas: Alternate Explanations”) explored explanations for user reactions that do not rely on pure anthropomorphism, such as novelty, or simply following a design (e.g., using life-like pronouns on a robot that has a name, CS, parallel algorithms). Finally, one project explored a breadth of ethical issues surrounding social robots, ranging from deception, to social robots being used for military purposes, to sex robots (e.g., for the general public as well as targeted populations such as pedophiles, CS, course based).

These projects had no technical, engineering, or computer science components and relied entirely on students engaging the psychological and social elements surrounding robots, and how people perceive them based on their social and psychological contexts.

Overall, the broad range of projects listed above that students elected to engage illustrates the usefulness of teaching social HRI as a mechanism for exposing students to social factors of technologies.

4 Conclusion

This paper illustrates why teaching HRI can be a useful mechanism for exposing technologist students to a broader, socially-embedded view on technology. Students are exposed to readings and discussions that illustrate why it is important to be aware of social considerations, as such competence can inform algorithm and technology design and dictate how a technology is used, integrated, and ultimately, decide on whether it is successful or not. These are perspectives generally not covered in a technologist curriculum such as in computer science or engineering. Following, one such HRI course (over three instances) was detailed, including class format and potential readings supporting the social focus.

The brief overview of student projects indicates that students, from a range of backgrounds including electrical and computer engineering, and combinatorics, elected to engage the social material and used the class as an opportunity to explore a range of social perspectives on technology. Student projects ran the full spectrum from reflecting on their technology from a societal perspective, to investigating how robots fit into social situations (such as taking a photo for a stranger), to robots using specific social techniques to interact with people. Further, a large number of students designed and conducted evaluations, with many attempting qualitative methods with an approach of using detail to convey the results of how people interacted with their robots.

Overall, I believe that this paper illustrates the potential of HRI, as an accessible topic, for providing technologists with education on how to be more socially reflective regarding their work. Looking forward, it will be important to longitudinally evaluate the impact of this education on long-term student perspectives.

5 Acknowledgements

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7 Appendix

Here below is attached the reading list and schedule used for the most recent iteration of the course discussed in this paper. The numbers indicate class number.

Introduction and Fundamentals I

1. Introduction

Kiesler, S., & Hinds, P. (2004). Introduction to this special issue on human-robot interaction. *Human-Computer Interaction*, *19*(1), 1–8. doi:10.1207/s15327051hci1901&2_1

Young, J. E. (2010a). A Snapshot of the Social HRI Landscape. In *Exploring Social Interaction Between Robots and People, PhD Thesis* (pp. 19–34). Department of Computer Science, University of Calgary.

2. Fundamentals

Wilkens, C. D., Lee, J., Liu, Y. D., & Gordon-Becker, S. (1998). Research Methods. In *Introduction to Human Factors Engineering*. Pearson.

3. Embodiment

Fischer, K., Lohan, K., & Foth, K. (2012). Levels of embodiment: Linguistic analyses of factors influencing HRI. *Proceedings of the 7th ACM/IEEE International Conference on Human Robot Interaction - HRI '12*, 463–470. doi:10.1145/2157689.2157839

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Robot Control and Programming

4. Robot Control

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5. Robot Control II

Guo, C., & Sharlin, E. (2008). Exploring the use of tangible user interfaces for human-robot interaction : A comparative study. In *Proceedings of the SIGCHI International Conference on Human Factors in Computing Systems - CHI '08* (pp. 121–130). ACM. Retrieved from http://doi.acm.org/10.1145/1357054.1357076

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