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A Study on Human-Robot Interaction and Future Application

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Abstract.

Human–robot interaction (HRI) is a growing field of research and application. The field includes many challenging problems and has the potential to produce solutions with positive social impact. Human-robot interaction is a recently emerged area of research. In this article, we discuss the field of HRI studyhow humans collaborate and interact and use those studies to motivate how robots should interact with humans.

Keywords: Human-Robot Interaction, Robot, HRI study.

1. Introduction

Human–robot interaction [1] [2] is the study of interactionsbetween humans and robots. It is often referred as HRI by researchers. Human–robot interaction is amultidisciplinary field with contributions from human–computer interaction, artificial ntelligence, robotics, natural language understanding, design, and social sciences. This paper presents an overview of the field and a review of recent work of the author in three parts. The first part introduces the reader to the topics of human-robot interaction and sociable robotics. This is followed by a discussion of current applications of interactive robotic technologies. The second portion of the paper presents recent work by the author in the field of human-robot interaction. The final section presents a series of ideas on future applications of socially interactive robots.

2. What is a Robot?

- A **robot**[4]is a physical artificial agent
- It can **perceive** the world around him,via its sensors (camera, lasers,microphones, etc.)
- It can also **act** on its environment, via itsactuators (usually motor-drivenmechanical devices)
- Some robots are also able to **interact**with other agents (human or robotic) intheir environment.
- Robots are typically developed to accomplish particular **goals** in their environment
- Most industrial robots today are either remotely controlled, or preprogrammed to execute only a fixed sequence of actions Others (so-called "cognitive" robots)
- integrate **reasoning** capabilities to cope with new situations

3. What is Human-Robot Interaction?

Human–robot interaction [1] [2] has been a topic of both science fiction and academic speculation even before any robots existed. Because HRI depends on knowledge of (sometimes natural) human communication, many aspects of HRI are continuations of human communications topics that are much older than robotics per se.

Thus, communication and, therefore, interaction can be separated into two general categories:

• Remote interaction — The human and the robot are not collocated and are separated spatially or even temporally (for example, the Mars Rovers are separated from earth both in space and time).

• Proximate interaction — The humans and the robots are collocated (for example, service robots may be in the same room as humans).

The origin of HRI as a discrete problem was stated by 20th-century author Isaac Asimov in 1941, in his novel I, Robot. He states the Three Laws of Robotics as,

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

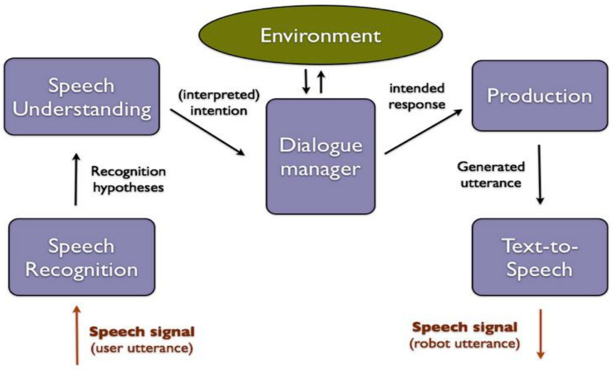

Figure 1: Example of human-Robot interaction

These three laws of robotics determine the idea of safe interaction. The closer the human and the robot get and the more intricate the relationship becomes, the more the risk of a human being injured rises. Nowadays in advanced societies, manufacturers employing robots solve this issue by not letting humans and robot share the workspace at any time. This is achieved by the extensive use of safe zones and cages. Thus the presence of humans is completely forbidden in the robot workspace while it is working.

The basic goal of HRI is to define a general human model that could lead to principles and algorithms allowing more natural and effective interaction between humans and robots. Research ranges from how humans work with remote, tele-operated unmanned vehicles to peer-to-peer collaboration with anthropomorphic robots.

Many in the field of HRI study how humans collaborate and interact and use those studies to motivate how robots should interact with humans.

The field of human-robot interaction is still a new area of research, although there are a growing number of people interested in this topic. HRI stems from several existing fields of inquiry, primarily human-computer interaction, robotics, and artificial intelligence. It also draws on, albeit to a lesser extent, other areas of work such as psychology, embodied conversational agents (animated agents), and communications theory. The work presented in this paper will acknowledge work in several of these areas and it is becoming easier to find research that ties together these and other fields of investigation.

4. The goal of friendly human–robot interactions

Robots are artificial agents with capacities of perception and action in the physical world often referred by researchers as workspace. Their use has been generalized in factories but nowadays they tend to be found in the most technologically advanced societies in such critical domains as search and rescue, military battle, mine and bomb detection, scientific exploration, law enforcement, entertainment and hospital care.

These new domains of applications imply a closer interaction with the user. The concept of closeness is to be taken in its full meaning, robots and humans share the workspace but also share goals in terms of task achievement. This close interaction needs new theoretical models, on one hand for the robotics scientists who work to improve the robots utility and on the other hand to evaluate the risks and benefits of this new "friend" for our modern society. Dautenhan refers to friendly Human–robot interaction as "Robotiquette" defining it as the "social rules for robot behaviour (a 'robotiquette') that is comfortable and acceptable to humans" The robot has to adapt itself to our way of expressing desires and orders and not the contrary. On the other end of HRI research the cognitive modelling of the "relationship" between human and the robots benefits the psychologists and robotic researchers the user study are often of interests on both sides. This research endeavours part of human society.

5. What Defines an HRI Problem?

The HRI problem [2] is to understand and shape the interactions between one or more humans and one or more robots. Interactions between humans and robots are inherently present in all of robotics, even for so called autonomous robots after all, robots are still used by and are doing work for humans. As a result, evaluating the capabilities of humans and robots, and designing the technologies and training that produce desirable interactions are essential components of HRI. Such work is inherently interdisciplinary in nature, requiring contributions from cognitive science, linguistics, and psychology; from engineering, mathematics, and computer science; and from human factors engineeringand design. Although analysis of anticipated and existing interaction patternsis essential, it is helpful to adopt the designer's perspective by breakingthe HRI problem into its constituent parts. In essence, a designer canaffect five attributes that affect the interactions between humans androbots:

• Level and behavior of autonomy,
• Nature of information exchange,
• Structure of the team,
• Adaptation, learning, and training of people and therobot, and
• Shape of the task.

Interaction, the process of working together to accomplish a goal,emerges from the confluence of these factors. The designer attemptsto understand and shape the interaction itself, with the objective ofmaking the exchange between humans and robots beneficial in somesense.

5.1. Autonomy

Designing autonomy [3] consists of mapping inputs from the environmentinto actuator movements, representational schemas, or speech acts. Autonomy is not an end in itself in the field of HRI, but rather ameans to supporting productive interaction. Indeed, autonomy is onlyuseful insofar as it supports beneficial interaction between a human anda robot. Consequently, the physical embodiment and type of autonomyvaries dramatically across robot platforms.

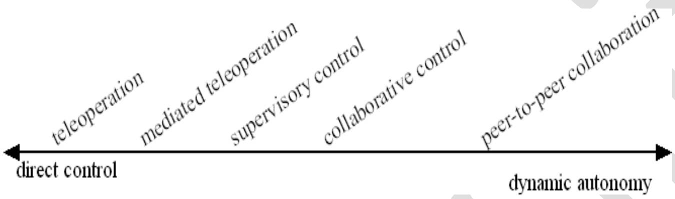

Figure 2: Levels of autonomy with emphasis on human interaction.

5.2. Information Exchange

There are two primary dimensions that determine the way information [4]is exchanged between a human and a robot: the communicationsmedium and the format of the communications. The primary media aredelineated by three of the five senses: seeing, hearing, and touch. Thesemedia are manifested in HRI as follows:

• Visualdisplays typically presented as graphical user interfacesor augmented reality interfaces.
• Gestures, including hand and facial movements and bymovement-based signaling of intent.
• Speech and natural language, which include both auditoryspeech and text-based responses, and which frequentlyemphasize dialog and mixed-initiative interaction.
• Non-speech audio, frequently used in alerting, and
• Physical interaction and haptics, frequently used remotelyin augmented reality or in teleoperation to invoke a senseof presence especially in telemanipulation tasks , and also frequently used proximately to promote emotional,social, and assistive exchanges.

5.3. Teams

HRI problems are not restricted to a single human and a single robot,though this is certainly one important type of interaction. Robots usedin search and rescue, for example, are typically managed by two or morepeople, each with special roles in the team [5].

5.4. Adaptation, Learning, and Training

Although robot adaptation [6] and learning have been addressed by manyresearchers, training of humans appears to have received comparativelylittle attention in the HRI literature, even though this area is veryimportant. One reason for this apparent trend is that an often unstatedgoal of HRI is to produce systems that do not require significant training.

This may be because many robot systems are designed to be usedin very specific domains for brief periods of times.

5.5. Task-Shaping

Robotic technology [3] is introduced to a domain either to allow a humanto do a task that they could not do before, or to make the taskeasier or more pleasant for the human.

Task-shaping is a term that emphasizesthe importance of considering how the task should be done and willbe done when new technology is introduced. Compared to the otherways that a designer can shape HRI, there is little written abouttask-shaping [7].

6. Future of Human-Robot Interaction

Challenges: Speech, Vision, Sensing, and More

Some of the greatest difficulties faced in building robots that interact with people in natural, social ways are those inherent in building any kind of multi-modal interface. In order to have a robot that interacts naturally, we expect it to be able to see us, hear us, have a sense of touch, and understand everything coming at it through all of these senses. This is a tall order given the current state of many of these areas of research.

6.1. Constructing a Socially-Aware System

The most foreboding [6] [7] challenge that must be addressed in creating a sociable robot is developing a computational model that serves as the basis of its interactions. The concept that we are working towards has been called "theory of mind," (Gopnik and Meltzoff) "naïve psychology of action," (Heider 1958) and "folk psychology" (Greenwood) by various researchers. It has been described as "the conceptual framework that helps people perceive, explain, predict, and change human behavior by reference to mental states" (Malle and Knobe). Essentially, this is what will allow the robot to interpret human actions, respond in an appropriate manner, and learn new knowledge or behaviors when necessary.

There are two imposing challenges in this endeavor. First, the way that the human mind works in this respect is not yet fully understood. Second, even with what we do know now about the human abilities to comprehend other people's intentions and actions, we are not sure how to implement this in a robot. As psychologists elicit more of an understanding of the human abilities, we (among others) are working to implement a model of this system in the computer and use it in our robots.

While this is only one of the challenges facing designers of sociable robots, it is currently one of the more difficult problems that we face. As we continue the quest to build more socially capable robots, we are proceeding in steps towards this goal. Let us now turn to some of the potential applications of robots that we can begin to construct.

6.2. Future Commercial Applications

The more compelling and interesting applications are further away and somewhat more challenging to achieve. The science-fiction-inspired vision of the personal robot for performing our mundane household chores will be a difficult one to achieve without the advances sought after through sociable robotics. Imagine trying to explain to another person how you clean your kitchen or fold your laundry using a traditional graphical interface. Even if it's not impossible, it hardly seems desirable.

6.3. Human-robot teams for scientific exploration

A near-term project of this type of robotic assistant is the Robonaut project [7] that is currently in progress (NASA 2002). Researchers at the National Aeronautics and Space Administration in the United States (NASA) are currently working with a number of other research groups to build a robot that will assist astronauts with various tasks in space. The purpose of this robotic astronaut is "to develop and demonstrate a robotic system that can function as an EVA [extra-vehicular activity, or space walk] astronaut equivalent." (NASA 2001)

Another key design feature of this robot (and for social robotics in general) is for the robot to be able to learn through natural interaction with a human.

The second reason that social interaction capabilities are desired is that training the robot will be simpler from the human teacher's perspective. Similar to the problem of controlling each of the degrees of freedom on this robot, programming the robot can be equally challenging.

The final reason for implementing social interaction in this robot is that "the social aspects [of] human pedagogy will allow the robot to learn more effectively from fewer examples and generalize better." This aspect of learning takes the example of imitation learning a step further. Instead of learning particular actions and then being told when and where to carry out those actions, the robot could learn higher-level goals concerning the type of work that it is supposed to conduct. For example, the robot could learn that it should look for anomalies in particular systems and then correct them whenever they occur.

6.4. Human-robot teams for search and rescue

Another currently developing [7] use of robotics is in search and rescue missions. In these scenarios, we can think of a robot in much the same way as we would a dog. They must also have the intelligence to carry out this search on their own without constant direction by a human, moving completely throughout a space that may be too hazardous or too small for a human to search .

This application of robots blurs the distinction between viewing the robot as a tool or as a partner. In some sense, it is simply a tool that we are using to complete a particular task that may not be desirable or even possible for a human to accomplish alone

6.5. Household robots

Although there are no existing robots that fall into the category of social household robots, there have been attempts to create commercially viable, but simpler, robots that assist with household tasks. The most recent of these is the Roomba vacuum cleaner robot from iRobot (iRobot 2003). According to the iRobot web site, the Roomba "is the first automatic vacuum in the U.S. It uses intelligent navigation technology to automatically clean nearly all household floor surfaces without human direction." While this robot does not demonstrate the viability of the ideas presented in this thesis, its commercial success does show that there is a growing acceptance of robots as a household assistant.

6.6. Informational robots

One type of robot that is being studied but does not yet have a good name is robots that interact with people in public spaces and convey information. One example of this could be a robot that greets visitors in an office building or lab and gives directions or other information. Another example that has been implemented by a team of researchers at Carnegie Mellon University is a robot that guides visitors around a museum and tells them about the exhibits. This robot, called Sage, wanders around the exhibits in Dinosaur Hall at the Carnegie Museum, telling visitors about the exhibits that they are near and helps direct them to other displays.

6.7. Communicative robots

Many technologies have been developed to enable, support, and extend communication capabilities between people. The telegraph, telephone, television, and e-mail are all examples of these kinds of technologies. Each has its benefits, but there are also limitations to each of these means of communication. If we concentrate on two-way interaction between individuals, two of the most widely used of these technologies are currently the telephone and e-mail. The greatest difficulty encountered in interactions across either of these media is the lack of non-verbal channels of communication. There is extensive research showing that these channels (such as facial expression, body posture and movement, and eye gaze) are extremely important to engendering trust, liking, and other factors that are greatly important in any social task and important, albeit to a lesser extent, in non-social interactions. For many years (over 75 years, in fact) people have thought of using videoconferencing as a solution to these problems. The belief has been that the ability to see the other person (or people) involved in a conversation would open up these other, non-verbal channels of communication for use in a conversation.

This kind of interaction certainly holds promise for the future of remote communication and collaboration. There remains a great deal of work to achieve these goals, but more research should be focused in this direction to understand not only what is possible, but what is desirable and beneficial in using robots for this kind of mediated communication.

6.8. Educational robots

Another very important application of sociable robotics is in education. There are currently a plethora of computer-based tutorials for students on a wide range of subjects. An important aspect of the mentor-student relationship is the shared reference through cues such as directing attention, mutual gaze, pointing, and displaying and reading facial expressions, features that computer-based tutorial systems do not currently possess. These social aspects of the mentor-student relationship are an important part of the learning process, so understanding how to create these as a part of an interaction with a robot is an important step towards creating robots that will successfully fill this kind of a role. When it is not possible to have a human mentor, or when the human mentor is at a distance (such as in remote learning scenarios), a robot may prove to be more engaging and easier to interact with than a computer-based tutor because of the shared physical space.

6.9. Healthcare robots

No less important than employing robots in education is their potential use in health care. As the population of the world is aging (UN 2002), the number of elderly needing regular attention is growing. With the shrinking number of working-age caregivers available, robots are a logical alternative for providing some portion of this care.

A different aspect of health care related to robotics is the use of robots in pet therapy. The idea behind pet therapy is that people are happier, healthier, and recover faster from ailments when they have the company of a pet . One problem with a typical situation in which a pet might be beneficial is that the person who might benefit from the pet has difficulty taking care of a pet, either because of difficulties keeping a regular schedule, because of health reasons (allergies, etc.), or because their care environment does not allow pets (hospital or nursing home, for example). In these cases, it may be beneficial to have a robotic pet that could be cared for by the person. It may still be possible to make the emotional attachment that is desirable in this kind of relationship without some of the detriments that come with a living pet, especially in a clinical environment. There are already examples of companies trying to create and market this kind of robotic pet. A leading company in this respect is the Japanese company Omron with its NeCoRo pet (Corporation 2003). The development of improved interaction capabilities could make this kind of robot more beneficial to its intended recipient and allow those who cannot have pets to attain the benefits that doing so would give.

7. Conclusion

Much work has been accomplished in the few years since human-robot interaction has become a cohesive discipline. There is, however, much more that must be done before this is a mature field. This paper has presented only a few of the recent research findings that will contribute to the creation of more successful sociable robots in the coming years. As we continue to work to make our vision of the helpful types of robots presented here a reality, we must overcome both the research and integration challenges that were discussed. The pace of progress is promising and we hope to see some of these systems successfully built in the coming years.

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