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Playing Games with Robots – A Method for Evaluating Human-Robot Interaction

Min Xin and Ehud Sharlin
University of Calgary
Canada

1. Introduction

Some of the acute technological challenges of the near future may relate to the coexistence of intelligent robots and humans. Robotic technology is quickly advancing and some believe that this rapid progress will have a huge effect on people and societies in the coming few decades (Moravec, 1999). Norman (Norman, 2004) suggests that we are already surrounded by simple robots, such as computerised dishwashers and cars. However, these devices still lack the capability and intelligence required for us to recognize them as "robots". Forlizzi and Disalvo (Forlizzi & Disalvo, 2006) demonstrated that even the introduction of the simple, popular and almost ubiquitous Roomba robotic vacuum cleaner had raised important human-robot interaction (HRI) questions, and changed social structures and patterns within domestic environments. Following, it is crucial that we understand the various issues and problems surrounding interaction with robots and be able to design effective interfaces that will allow us to work collaboratively with robotic interfaces.

Current designers of HRI paradigms no longer see robots as fully-controlled subordinates but rather as colleagues of sort, with a spectrum of social and emotional abilities (see for example (Breazeal, 2002)). It is logical that humans will find future autonomous robots more effective and collaborative if the robots act according to behavioural patterns that humans can easily recognize and relate to. Obviously, the challenge of creating robotic interfaces that will be fully aware of rich social settings, roles and proper action is enormous. However, future social robots may be integrated into everyday life tasks if they successfully exploit the human inclination to anthropomorphize animated phenomena and objects (Moravec, 1999), in a sense providing a task-limited illusion of social awareness and supporting a sociably accepted set of actions. Robots can use various methods in order to enhance their social acceptance skills, from the use of natural language, human-like or animal-like appearance and affordances, to animated movement and even cartoon art expression (Young et al., 2007).

How can we rapidly and efficiently design, implement and test sociable and other human-robot interfaces? The straightforward approach would be to design, implement and test for the actual, fully realistic robotic task. However, with robots being used for tasks such as space exploration, urban search and rescue, and battlefield support, developers may find themselves unable to be engaged in meaningful sociable HRI design in academic and

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other laboratory settings. Many of the sociable HRI design dilemmas can be answered only after extensive testing and carefully controlled repetitive experiments. Since current robots are often engaged in difficult, dangerous and dirty (DDD) tasks, designing and testing sociable HRI paradigms can be a challenge which will arguably have to wait till sociable robotic platforms are more common and affordable.

In this paper we propose a meaningful and controlled HRI experimental testbed approach based on collaborative gameplay between robots and humans. We argue that our testbed approach supports rapid design, implementation and testing of various meaningful sociable robotic interaction techniques in relatively simple settings. How can we evaluate the validity of our suggested testbed? Similar to the psychology concept of *transfer* of cognitive skill (Singley, 1989), we consider the *transfer of robotic skills* from the testbed to real life. Humans can *transfer* cognitive knowledge from one experience to the other in various ways, with *transfer* being categorized as being either positive or negative; with the original experience enhancing or hindering the target experience, respectively. Similarly, we can assess the quality of an HRI testbed through its ability to *transfer* a set of robotic abilities from one experience to the other. A "good" testbed will be able to provide positive *transfer* of robotic abilities to its target application and inform of right answers to design dilemmas and challenges. On the other hand, a testbed can provide negative *transfer* of robotic abilities, pointing to design decisions that appear proper in experimental settings but fail once tested in real settings.

In the next sections we discuss the notion of human gameplay and its mappings to social interactions and tasks. We discuss the benefits and limitations of using games as HRI testbeds and suggest a set of simple heuristics for designing "good" HRI game-based testbeds which we believe will provide positive *transfer* to real-life settings. We then review several related efforts of using gameplay in HRI and attempt to analyse them using our suggested heuristics. Finally, we reflect on our own experience of designing, implementing and evaluating an HRI testbed based on a board game called *Sheep and Wolves*.

2. Gameplay and HRI

In order to design an effective testbed for human-robot interaction, we look to one of the most frequent human activities that have persisted through the development of civilization: playing games. Games are a staple of everyday life. Whether it is battling through a few games of Mario Kart, participating in a game of Bingo, or dressing up a Barbie doll, we play regardless of age or gender. Although many do not often consider playing games as an essential part of life, it is never the less a critical factor in human development. Through playing games, we interact with our world, communicate with other humans, and even explore brand new environments and experiences. Games are ripe with opportunities for interaction. What if we involve robots within our games? How will we design them to play with humans? What will we learn about human-robot interaction by playing games with robots? These questions motivate our exploration for using games as effective testbeds for evaluating human-robot interaction.

The goal of human-robot interaction is to investigate how to design robots for a variety of applications such as search and rescue or performing domestic duties. Compared to the other more important and practical applications, designing robots to play games seems like a trivial exercise. How does playing games relate to other application areas? Although each application of robots in the real world has its unique challenges in terms of the mechanical controls required for operation, many applications share commonalities in the social aspects of interaction such as working together in a team. For robots of the future which will exist and work alongside us, the social aspects of interaction are as important if not more important than the electromechanical controls used to operate the robots. Certainly, the activity of playing games also includes such social aspects of interaction. For example, in team sports, teamwork and leadership are concepts often talked about and are critical for the success of the team. Therefore, we believe that by looking at the interaction involved in gameplay, we can explore the common social aspects of human-robot interaction shared with other application areas.

Huizinga and Caillois, two humanist theorists of play, detrivialized the idea of play by making it a central part of the history of human behaviour and culture. Huizinga states (Dovey, 2006):

> "Social life is endowed with suprabiological forms, in the shape of play, which enhances its value. It is through this playing that society expresses its interpretation of life and of the world."

The idea that playing is a reflection of culture, of life, and of the world serves to support our suggestion that games contain many of the essential aspects of interaction present in other applications of the real world. Through games played, we can get a glimpse of how people interact in real life. However, games are also more than just a mimicking of the real world. Playing games and the culture of the real world are in a formative relationship. Not only do games reflect existing cultural practices, but they also serve as a catalyst for generating new cultural practices. Turner calls play "the seedbeds of cultural creativity" (Dovey, 2006), where the generation of alternative social orders, political interventions, and utopian imaginings can take place. Online role playing games are good examples, where virtual societies are created with their own culture of play.

The generative and creative characteristic of games can be beneficial for the development of a human-robot interaction testbed. Although robots have been in use for decades, future robots will need vastly different ways of interacting with humans, in our homes and in our work places. Currently, little is known as to how such interaction will take place. Therefore, playing games with robots provides an excellent opportunity to explore a new social order and new culture of coexisting with robots. Silverstone mentions (Dovey, 2006):

> "Play enables the exploration of that tissue boundary between fantasy and reality, between the real and imagined, between the self and the other. In play we have license to explore, both ourselves and our society. In play we investigate culture, but we also create it."

The duality of playing games as both a way to take into account existing social practices and also to generate new ones is an important point for our suggested use of games as testbeds for human-robot interaction.

Now that we have established the importance of playing games for everyday life and for our human-robot interaction testbed, we will take a deeper look at exactly what is involved in games and what characteristics make playing games a suitable approach for exploring human-robot interaction. Huizinga offers the following definition (Dovey, 2006):

> "Play is a voluntary activity or occupation executed within certain fixed limits of time and place, according to rules freely accepted but absolutely binding having its aim in itself and accompanied by a feeling of tension, joy, and the consciousness that it is 'different' from ordinary life."

First and foremost, games are played within a restricted domain. As indicated, games have fixed limits in terms of time, place, and rules. This is different from many other real life applications where the possibilities for interaction are endless. For example, a game of hide and seek can be set to be played only within a house, but a search and rescue mission requires a survey of a much larger space. These limits make games favourable for use in experimentation because they help to narrow the scope of exploration both in terms of implementation and also in terms of what is to be investigated. Rather than dealing with all the environmental variables in a real life application, it is much better to target an interesting point with a more focused experiment within a more controlled environment. Although games have many limits, it does not mean that they are rigid. In fact, games can be played however people wish them to be played. Certainly, there needs to be rules, but these can be created by people themselves, or in our case, the HRI application or experiment designers. Depending on the purpose of an experiment, new games can be created, and the rules of old games can be adapted to fit the needs of the experiment. Rules are also unquestionably accepted by the players of games. This is critical because it allows completely new social orders and playing practices to be imposed on the players for exploration. For example, in games, robots can play the role of superiors to humans, a scenario that is unlikely to happen in the interaction experiences of current real world HRI applications. Once again another duality of games in which they can be both rigid and flexible makes them a sensible choice for our testbed.

Finally, games are also a good choice for an HRI experimental testbed because good games are fun and engaging. When people play games, they are actively involved with the activity at hand, and some even become completely immersed in the game world. Games are also more accessible to most people because of their limited rule set. Often, no extensive training is required to play games. This can be beneficial for evaluating the common social aspects of human-robot interaction because if a more demanding, application specific activity is used we would need to account for the skill level of the participants. Plus, to realistically simulate real world social interaction, we need participants to believe that they are in such situations. Since people are used to playing games even in non-realistic scenarios, games can allow us to immerse participants in an envisioned setting even if it is less believable.

Although electronic games are becoming popular, many traditional games are played in the physical world and require tangible interaction. The physicality of games is important because robots are physical entities, and people will eventually interact with them within the physical world, but robots also have access to digital information and are capable of acting in the digital domain. Games can support this physical and digital duality. For example mixed reality techniques can help to design games that will allow interaction with robots in both the physical and the virtual realms.

We have outlined many advantages of using games for exploring human-robot interaction; however, there are certainly limitations to our approach. Most games are started and finished in a relatively short amount of time. This limited duration may not be enough to fully replicate some of the complex social scenarios present in the real world. Also, in games, people sometimes suspend their real world social beliefs and completely submit to the rules and goals of the game, pointing to a questionable quality of transfer to a realistic setting. For example, in games such as Grand Theft Auto (GTA, 2007), players actively participate in violent acts which would be completely disagreeable and detriment in their real life because this is how the game is played. Therefore, we must be careful as to which social aspects of interaction can and cannot be evaluated using a game-based testbed.

Based on the discussion above, we offer the following simple set of heuristics on how to design a "good" game-based testbed for HRI:

1. Tailor the game experience to the HRI design dilemma

When designing a game-based HRI testbed it is crucial to remember that the game is being played above all in order to reflect on the HRI experience. Game rules can and should be altered in order to allow the robots and the humans to interact in a manner that will inform on the HRI design question. A good game-based testbed will integrate into the game environment various aspects of the HRI problem at hand in order to provide better probability of transfer of the learned robotic skills from the game testbed to the target application.

2. Design a fun and engaging game experience

An effective game-based testbed should ideally provide an engaging and fun experience so players become immersed within the social scenario constructed. Highly engaged users will provide interaction insight that will better inform design decisions within the testbed, and will have a better probability of informing design decision in the real-life experience.

3. Design a game played within a bounded space with clearly defined rules

The game should be played within a bounded environment, where undesirable external variables can be filtered out. The game should also have clearly defined rules as this will help with both implementation and testing.

4. Design with the physical and digital robotic duality in mind

We believe good HRI testbeds will enable effective reflection on the robotic physical and digital duality. True, HRI testbeds can be designed to examine only the physical or only the virtual aspects of a specific interaction scenario. We however argue that good HRI testbeds are the ones capturing in their design the robotic "innate" ability to perceive and act in both the digital and physical realms. Without sensitivity to this duality the testbed is, arguably, either an electromechanical environment measuring physical-only aspects of the interaction, or a classic-HCI, software platform testing the virtual-only aspect of the interaction.

3. Game-Playing Robots

In this section we briefly overview a few current examples of the use of games in HRI, and reflect on each of these efforts using our heuristics. Probably the prime example for the use of games in the domain of robotics and HRI is Robocup. Robocup (Robocup, 2007) is an international project to promote AI, robotics, and related fields. This project makes use of the soccer game to investigate many technical and social aspects of interactive gameplay with robots, exploring issues such as multi-agent collaboration and autonomous agents. Its goal is to develop a team of fully autonomous humanoid robots which by the year 2050 "can win against the human world soccer champion team" (Robocup, 2007). Technologies researched for Robocup are used in more practical applications such as search and rescue.

A related effort, Argall et al.'s work (Argall et al., 2006) with Segway Soccer between human-robot teams builds on the Robocup vision. In this effort, autonomous Segway Robotic Mobility Platforms (RMPs) play soccer alongside humans. The project explores a variety of technical challenges as well as issues which arise in peer-to-peer human-robot teams such as team coordination.

The long-term Robocup vision can be viewed as a strong example of our first design heuristics: robots that will play soccer alongside or against human players will provide illuminating insight to the nature of HRI, and can help explore fundamental robotic interaction challenges such as collaboration, task distribution and leadership. That said, Robocup currently is hardly an HRI effort as it challenges robots to play soccer-like games against other robots with no human interaction or intervention. As an essentially non-HRI effort, currently Robocup places higher emphasis on high fidelity to the game of soccer and its rules (our second and third heuristics) than to an HRI goal.

Bartneck et al.'s work (Bartneck et al., 2006) investigates the factors which influence the way people perceive robots as being alive. In their user study, the game of *Mastermind* is used to create an opportunity for the human participants to become engaged with the robot. The goal of the game is to select the right combination of colours. This task is completed by the robot and the human participant through cooperation and not competition. The robot would make suggestions to the human player as to what colours to pick, and the intelligence and agreeableness of the robot are manipulated for the purpose of the experiment. For example, Bartneck et al. found that humans tend to be more reluctant to switch off a robot that demonstrated intelligence and agreeable behaviour during the *Mastermind* gameplay.

Bartneck et al.'s use of gameplay is an excellent example of tailoring a gameplay experience to an HRI question (our first heuristic). The game being used, *Mastermind*, is very simple and so is the robot involved, limited to non-physical gameplay advice. However simple, the gameplay is sufficient for humans to directly perceive the robot's intelligence and agreeableness, and to act upon this behaviour. Since these, the robot's intelligence and agreeableness, are the experiment's independent variables, the gameplay allowed the designers to simulate a potentially quite complicated social setting through a very simple and engaging game. Since the game is simple, our second and third heuristics are obviously also satisfied in this example: the original *Mastermind* game is played according to its original rules using the original board and providing an, arguably, engaging experience (at least as engaging as the classic *Mastermind* gameplay goes).

Trafton et al.'s work (Trafton et al., 2006) on computational cognitive models for robots uses the children's game hide and seek as a way to understand how young children actually learn how to play hide and seek. This information is then used to create a robot which understands how to play hide and seek from a human perspective. Hide and seek allows the authors to work in a complex and dynamic environment and also allows them to explore embodied cognition issues. Practically, robots that will be able to understand how to hide or seek can be extremely useful in various security and defence applications.

The hide and seek game provides, arguably, little interaction other than visual one (which can lead to the termination of the game in case the It spotted the hider). Reflecting on our simple design heuristics, Trafton et al.'s efforts seem to be directed more to the gaining insight and developing robot cognitive models based on a proper hide and seek gameplay (that is, our second and third heuristics) rather than a specific HRI question.

4. Sheep and Wolves

The *Sheep and Wolves* testbed (Fig. 1.) is our attempt to evaluate human-robot interaction through the use of games (Xin & Sharlin, 2006). We are particularly interested in the social aspects of collaboration between humans and robots such as teamwork and group dynamics. These social aspects of interaction are important for many applications where humans and robots must work together to solve problems. At the start of this exploration, we wanted to simulate real world scenarios of human-robot collaboration within the lab which motivated the construction of a human-robot interaction testbed. What we needed was an interactive environment where humans and robots can collaborate and also a believable interactive task which will facilitate collaboration. We chose not to follow a real world application such as investigating teamwork in search and rescue because of the scope and complexity of the implementation. Also, we wanted to explore collaboration between humans and robots in general and not just for one particular application. Therefore, our goal was to find a more universal interactive activity which can serve as a metaphor for a large set of human-robot interaction applications and encompass their common interactive qualities.

Figure 1. *Sheep and Wolves* testbed

The eventual inspiration for the testbed was the magical game of *Wizard's Chess* from the popular movie, *Harry Potter and the Philosopher Stone*. In the movie, human players played the game of chess on top of a large chess board moving and acting as game pieces. Not only did the game involve actual physical movement and battles, players also engaged in active communication with each other. For example, one child would use gestures and speech to tell another child to make a certain move. In concept, *Wizard's Chess* serves as an excellent metaphor for the interactive environment of our testbed. The large chess board offers a regular and bounded physical space where interaction can take place, and with the grid-like appearance of the chess board, board games were a natural choice to be used as the interactive task. When it comes to computers and technology, board games have been well explored. They often have well-defined domains and rules and allow for a multitude of potential tasks. Traditionally, interest in board games originated from a mathematical, game theory and AI research point of view, but with *Wizard's Chess* and the unique way in which it is played, we can use these games to construct realistic social HRI scenarios as well. However, chess is usually played between two players facing off against one another. In such a setup, there is very little potential for collaboration. Alternatively, if we attempt to place humans and robots as chess game pieces on the board we may end up with 32 entities which can make for a cumbersome and pricey apparatus. Therefore, we looked toward other board games which were simpler and could still support collaboration.

Following our goals, we decided on the use of another classic board game, *Sheep and Wolves*. This turn-based game is played on a checkerboard, and game pieces can only occupy and move on squares of the same color. The game involves five game pieces, four of which are the wolves, and one is the sheep. The wolves start on one end of the checkerboard, and the sheep starts on the other. The team of wolves are only allowed to move one wolf forward diagonally by one square during each turn. The team's objective is to surround the sheep so it cannot make any legal moves. Meanwhile, the sheep is allowed to move forward and backward diagonally by one square during each turn. Its objective is to move from one end of the checkerboard to the other. Obviously, while the sheep is more flexible in its moves, the wolves' strengths are in their numbers and ability to move as a pack. Traditionally, *Sheep and Wolves* is also played with two players, one playing the sheep and the other playing the team of wolves. Again, to make the game a more interactive and collaborative task we took a similar approach to *Wizard's Chess* and separated the team of four wolves into four separate player positions. This way, we can have humans and robots playing as independent members of the wolves' team.

We chose this game because it is simple yet able to support collaborative gameplay. The metaphor of the game can be extended to various applications where humans and robots are required to share information, opinions, and resources in order to effectively complete a task. By performing a collaborative task in a controlled physical game environment instead of the complex physical world, we are able to focus on interaction. Also, since implementing artificial intelligence for the game of *Sheep and Wolves* is relatively simple, we are able to easily adjust the intelligence of the robots in order to develop varying robotic behaviours.

In our game we have elected to use Sony's AIBO ERS-7 robot dogs as our robotic participants. These fairly capable commercial robots allow us to rapidly build prototype interfaces for evaluation. For the physical environment of the game, we elected to use a 264cm (104'') by 264cm RolaBoard™ with the standard black and white checkerboard pattern. Each square measures 33cm (13'') by 33cm, providing sufficient room for an AIBO wolf to sit on or humans to stand on. This confined shared space is ideal for robots to navigate in. The lines and corners of the checkerboard serve as readily available navigation markers for movement on the checkerboard, and camera calibration can also be achieved using corner points to allow for augmented reality interfaces and localization of humans on the checkerboard.

In the first game we have created using this testbed concept, all four wolves are represented by the AIBOs and the sheep is a virtual entity (Fig. 1). We decided to include virtual entities within the game to highlight the multimodal nature of robots, being able to interact both in the physical world but also to percive and act in the digital domain. The use of virtual entities also serves to level the playing field for robots since humans must rely on the robots' senses when it comes to the virtual sheep, but for the robots the virtual entities are as real as the physical components of the game. The AIBOs physically move and sit down on the checkerboard to indicate movement of the wolves in the game. A human player controls a single AIBO wolf at a remote computer using a telepresence interface, personifying the robotic entity within the game. Other uncontrolled AIBO wolves are autonomous robotic teammates which the human player must collaborate with. Live video of the physical game environment from the controlled AIBO's point of view is provided to the remote human player, and mixed reality is utilized for visualizing the virtual sheep on top of the physical board. Winning the game as wolves requires teamwork. The human player has to provide suggestions to the team and consider propositions made by other teammates in order to help the team reach intelligent decisions on the moves the team should make. This setup effectively generates the collaborative scenarios intended.

With the first iteration of the testbed complete, we used it to perform a simple user study to evaluate the effect of two extreme robot behaviours on different aspects of collaboration. This study was exploratory in nature, we wanted to see if the game-based testbed is sensitive to the social aspects of interaction we wish to explore. The study involved two extreme robot behaviours for the autonomous AIBO wolves. In one test condition, all the AIBO teammates were programmed to be always submissive to the human player, and in the second condition they were programmed to be always assertive and make the human player feel inferior. We asked participants to play one game in each condition and assessed the gameplay experience with post-test questionnaires. We performed the pilot study with 5 participants and the actual study with 14 participants (Xin & Sharlin, 2006). One of the interesting results found in the pilot study was that human players trusted the assertive robots more than the submissive robots when it comes to decision making. However, this finding came up inconclusive when we performed the actual study. The other interesting finding was that when we asked the human players to evaluate their robotic teammates at the end of the game, most of them assessed their teammates as individuals and gave them different scores. This was surprising because all three autonomous AIBO wolves were programmed with the same behaviour. This finding was promising for our game-based testbed concept because it indicates that the game is able to produce a sociably immersive experience where players believe that they are participating in a collaborative game with realistic team members even when in actuality the game is based on rather simplistic robot behaviours.

5. Discussion

From the description of our game-based HRI testbed above, we would like to provide some lessons learned in terms of the benefits and challenges of our approach and application. First and foremost, this testbed is relatively simple to construct and cost effective. Using readily available products such as the AIBO and the RolaBoard™, we were able to rapidly construct and prototype our testbed. This again speaks to the flexible nature of games which can be created with whatever is easily assessable or modified to make implementation easier. Second, because the game has simple and well defined rules and is played within a bounded environment, we can rapidly prototype new games and design new user studies. In fact, we are currently in the second iteration of our testbed which will feature a slightly modified game used to investigate a different research question. Third, we found the use of both physical and virtual entities to be useful for experimental design. Humans currently still have the advantage when it comes to interaction in the physical world. Robots, however, have the advantage when it comes to interacting with digital information. By playing with these factors, various social relationships can be generated such as trust. Finally, although our initial goal with the current testbed was to look at collaboration, we found that having a game which involves collaboration is beneficial for increasing the potential of other forms of social interaction. For example, when humans and robots need to collaborate, they are required to communicate with each other in a much more complex manner than simple command and execution.

Certainly, there are a couple of stumbling blocks with our testbed exploration as well. The biggest problem with using games for experimentation is that we can not really control how the game is played. Each participant will have a different gameplay experience based on the outcome of the game and the way the game was played. Therefore, it is difficult to compare data. For example, on the issue of trust, the outcome of the game played significantly affects the participant's opinion since winning tends to build trust. Scripting games is one solution to this problem, but this leads to the dilemma of having to disguise the scripting process to the participant, and in some situations, scripting is not possible. The other problem with our game-based testbed is that evaluation of game experiences in general is a difficult problem by itself. Generally it is hard to collect quantitative data for games, and most forms of gameplay evaluations are often vague. With exploratory studies, these issues are not critical, but with more focused studies, they can skew the data. Currently, we can not offer great solutions to these problems, but we are looking at methods to strike a balance between restrictive and more freeform styles of games. We also have not attempted to transfer the primitive results from our user study to other applications since more rigorous experimentation needs to be performed, but we feel the few results that we do have make sense for other applications as well. However, it is promising to see that the game-based testbed approach is able to explore critical social issues of human-robot interaction such as trust which can assist robot designers in developing future domestic and sociable robots.

6. Conclusion

The road for full integration of sociable robotic interfaces into the fabric of society is probably still long. However, robots with varying degrees of social ability are predicted to have a larger role in our everyday life in the near future. Arguably, many sociable HRI paradigms and ideas that seemed to belong not so long ago to science fiction literature can already be tested in lab settings. In this paper we suggested the use of gameplay and games as practical and attractive testbed platforms for the design, implementation and testing of sociable HRI concepts. We presented our simple set of heuristics for designing "good" game-based HRI testbeds and reflected on our heuristics' strengths and weaknesses vis-à-vis a number of recent related game-based sociable HRI projects. We discuss our ongoing efforts towards a sociable HRI game-based testbed using the mixed-reality *Sheep and Wolves* board game. We described the project technical realization, experimentation and current findings and discussed *Sheep and Wolves* strengths, drawbacks and future directions.

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Human-robot interaction research is diverse and covers a wide range of topics. All aspects of human factors and robotics are within the purview of HRI research so far as they provide insight into how to improve our understanding in developing effective tools, protocols, and systems to enhance HRI. For example, a significant research effort is being devoted to designing human-robot interface that makes it easier for the people to interact with robots. HRI is an extremely active research field where new and important work is being published at a fast pace. It is neither possible nor is it our intention to cover every important work in this important research field in one volume. However, we believe that HRI as a research field has matured enough to merit a compilation of the outstanding work in the field in the form of a book. This book, which presents outstanding work from the leading HRI researchers covering a wide spectrum of topics, is an effort to capture and present some of the important contributions in HRI in one volume. We hope that this book will benefit both experts and novice and provide a thorough understanding of the exciting field of HRI.