Human-Robot Interactions as Theatre

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Abstract— **Given the difficulty of social human-robot interaction (HRI), finding an appropriate conceptual model, as well as a useful venue to test the model, is key. While most work in social HRI draws insight and inspiration from the field of social psychology, this paper explores the philosophical backing and benefits of using ideas from theatre to frame social interactions. We present an analogy to Searle's Chinese Room argument to motivate the expressive challenges faced by human actors and by robots in social situations. We then compare the elements of theatre with the elements of HRI, and discuss techniques that we believe will lead to improved interactions.**

I. Motivation

Human-robot interaction (HRI) is a challenging problem. Determining socially acceptable and appropriate behavior is tricky, even for humans, who, despite a lifetime of experience, are still prone to making gaffes. Explaining, formalizing and translating the rules governing social behavior into control code for a robot is a daunting task.

Robots that socially interact with humans encounter three problems. First, there is the **articulation problem**, that robots are mechanically limited in their expressive range, due to fewer or different degrees of freedom than humans. This hinders their ability to mimic common physical human social cues.[1] For instance, it is unclear how a simple wheeled robot without arms or an expressive face should physically convey that it did not understand the last command in a clear way. This problem results in the robot presenting too little social information, causing humans to view the robot as unresponsive or unintelligent. Second, due to the **intentionality problem**, the robot's intentions are not always clear. Simple motions are often ambiguous, and complex movements do not always give enough consideration to the information the movement transmits to observers. For instance, if a robot photographer [1] stops in front of you, it is difficult to discern which of a number of plausible reasons caused it to stop. Is it taking a picture, waiting to move past you, or just broken? For a human interacting with that robot, it is frustrating to determine what, if anything, the robot wants the human to do. Third, there are myriad complex problems stemming from trying to correctly sense the human's actions and draw conclusions from them. Not only are they difficult to solve, but doing so is essential to making any encounter a truly interactive experience. It is a two-fold problem of not only recognizing a human making a particular gesture, a complex sensing problem, but then also contextualizing it to the current situation, which requires a sophisticated model of human behavior. We lump these problems together under the heading of the **interpretation problem**.

Additionally, HRI researchers must contend with the additional **evaluation problem**, facing unclear validation and evaluation techniques. The human element of the interactions is often unpredictable, making the results of interactions too situation specific to compare to each other. Furthermore, it is difficult to measure the quality of interactions. Surveys and interviews can only explain so much. The human experience is subjective and is not always easy to explain. There is no general way to quantify this experience, meaning that each experiment generally comes up with its own metric to measure with.

We propose using theatre both as the mode for modeling interactions and as the venue for testing the interactions. As discussed below, both theatre and HRI aim to replicate some elements of humanity. This common aim allows us to exploit the similarity in structure between the two by modeling robot interactions in theatrical terms.

Furthermore, HRI and theatre are both inherently interactive. Some might argue that the latter is not actually interactive, since theatre is scripted, everything is planned out and rehearsed beforehand. Furthermore, there is rarely interaction that crosses the so-called "fourth-wall" that separates the actors from the audience. Thus, theatre cannot possibly be a fitting model for social interaction because it lacks, for lack of a better term, interaction. This argument underlines one of the key points about good acting and good interaction: it must be constantly interactive. In both realms, participants must be constantly making adjustments to their actions based on the other's actions, even if all of the high level actions are scripted/specified in advance. Both will have to adapt to subtle differences in the situations. If the robot does not react to specific circumstances, by not making eye contact or by giving generic responses to questions, the sense that the robot is genuinely interacting with the humans is lost. For an actor, the experience of live theatre must be interactive. Actors who merely "go through the motions," and do not change their behavior in response to others fail to truly interact. Such performances are generally badly reviewed, labeling the actor "robotic." This is precisely the label from which HRI aims to break free by creating interaction that is not "robotic," but

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[1]This uses this assumption that we want human-like robots. There may be better ways to communicate, but we rely on this assumption here since we are largely dealing with traditional human interactions.

engaging.

These "robotic" interactions are also quite prevalent in current HRI research. There is little or no low-level adaptation, just script following. Often, HRI experiments test the differences between discrete choices for robot reactions. For instance, the effect of dishonest robots has been studied by having robots play games with humans, and seeing what the human's reaction is when the robot plays fairly, cheats, or lies [2]. The conditions of the experiment depend on high-level differences in the robot's behavior. Little to no consideration is given to how robots do things, only what. In this case, a human's opinion of a cheat (human or robot) is very likely to depend on how they cheat. For effective interactions, it is important to consider not only *what* is done, but *how* it is done. The emphasis on acting is another reason to consider theatre as a model for HRI. In theatre, the 'what' is largely specified by the director and playwright. The 'how' is left to the actor. Even with the best writing and brilliant direction, a play will fail without a capable actor to interpret how to perform the action of the play. Similarly, in HRI, without a robot capable of doing the actions of the interaction with careful consideration of how to do them, the interactions will be lacking. Hence, not only is the robot cast as an actor in this work, but the humans to be interacted with are cast the other actors. This puts the robots and humans on equal standing in the interaction.

This work exists in parallel to Brenda Laurel's work viewing human-computer interfaces through a theatrical lens [3]. The primary difference between our work and Laurel's rests in the division between the human's world, and the computer's or robot's world. Human-computer interfaces generally rely on physical input and output devices, such as mice, keyboards, and graphics on a screen. In human-robot interfaces, the interaction takes place more on the human's terms, using devices like speech synthesizers and actuated movement in the "real" world. In both cases, the computer must define itself in terms easily accessible to the human, but in human-robot interactions, it is less about defining the interface, but defining the robot's role within the context of a normal social interaction.

In addition to some groundwork being laid in the justification of theatre's integration with computers, there also has been a lot of fascinating work in recent years involving robots performing theatre. While there have been several non-interactive robot-only performance pieces [4], [5], [6], there have been an increasing number of pieces with both actors and humans on stage together [7], [8], [9]. One of the main venues for people to see robots in a theatrical setting has been theme parks [10]; however, in the last few years, the animatronic characters have evolved to interact with guests on a personal level [11]. Murphy et al. provide a compelling example of a clever fusion of theatrical art and practical robotics research, presenting A Midsummer Night's Dream with robots as some of the fairies, while simultaneously exploring what actions create believability on stage [12]. Furthermore, the new opera *Death and the Powers* explores the relationship between people and technology, while human singers share the stage with custom-built robots controlled by human actors [13]. All of this work has resulted in interesting examinations of not only human robot interaction in a theatrical setting, but also how people react to it.

To better understand how such interactions would take place, we first examine the philosophical similarities between robots and actors.

II. The Searle Connection

The similarity between robot interaction and theatre can be viewed through a comparison to Searle's Chinese Room argument [14]. The essence of Searle's argument is that no system that simply manipulates symbols without truly understanding them can be said to be intelligent. The thought experiment starts with a person locked in a room. He receives messages in Chinese on pieces of paper pushed through a hole in the wall. He looks up these symbols in a book, copies the "answer" symbols that the book shows onto a new piece of paper, and then shoves this paper through the hole in the wall. The translator does not speak Chinese, but is simply manipulating symbols based on the book he has. However, an external observer who *does* speak Chinese can write a message on a piece of paper, push it through the hole, and get a perfectly valid response back, as if the person in the room *did* understand the original note.[2] This, Searle claims, shows that a system that purely manipulates symbols (the person in the room) cannot be said to be intelligent (understand Chinese), even though the outputs that it generates in response to inputs are exactly the same as those that a person (assumed to be an intelligent system) would.

While we will not argue for or against Searle's claim here, we note that he draws a distinction between two types of systems, those that are "intelligent" (or understand Chinese) and those that are merely manipulating symbols without understanding, even though these two systems generate the same input-output mappings (respond in exactly the same way). One system has *true* intelligence, and the other only *appears* to be intelligent.

We can extend Searle's line of thinking to robots in social situations. Instead of manipulating Chinese symbols on pieces of paper, the system takes in social cues as input, and generates social cues as output. People do this naturally, and can probably be said to be "social," in the sense that they understand these cues and what they mean. Robots, on the other hand, are like the person in the Chinese room; they are presented with a set of social cues, and they give a response calculated to be appropriate. If we accept Searle's argument, then we must also concede that truly social robots are an impossibility; a robot can only give the appearance of social behavior while actually only manipulating symbols.

Introducing the idea of acting to the Chinese Room scenario reveals some useful parallelism. The way that actors

[2]As with many arguments in philosophy, this example is meant to prove a point, rather than suggesting that it would be practical to construct such a system. As a result, it glosses over many details, such as how to write the translation book in the first place.

approach their craft is quite similar to the types of exchanges seen in the Chinese room. The input to the actor's "system" is the situation of the play unfolding in time, and the output is what the actor chooses to do and how they do it. At any point in a play, the actor is presented with a set of circumstances, a scenario composed of the actions of the other characters. Instead of a book of rules for symbol translation, the actor is given a script that outlines what they should be saying and doing. The actor then weighs the various qualities of the character, i.e. what the character wants, what the character is likely to do, how the character is likely to change as a result of the actions, and so forth. The actor then chooses their next action as a result of the circumstance and considerations. These actions then affect the other actors, causing them to respond in kind, generating more actions to respond to.

Consider the titular character in the Shakespearian tragedy, *Hamlet*. Throughout the play, the character of Hamlet is presented with many dramatic situations, such as his dead father appearing to him as a ghost. Given all of the factors in the situation, such as Hamlet's likely fear of ghosts and his grief over his father's death, the set of valid responses/actions is constrained. In most cases, it would be wrong for Hamlet to rush forward and hug his father; that is a wrong output for the given input. Instead, a hesitant step backwards before questioning the apparition would be much more appropriate in the context presented to him.

There is the question of what the actor portraying Hamlet must do in order to best give the "correct output." Is it merely enough that the actor *appear* to be fearful, or does he actually need to *be* fearful. This is a question of acting methodologies. The famed school of Method acting generally suggests the latter, where the actor must internalize real emotion in order to correctly portray it [15]. However, it does not matter to which philosophy the actor subscribes. The actor will never actually *be* Hamlet. In Searle's terms, he is just "manipulating symbols" in his head, determining the best way to portray the role. Furthermore, the audience watching him does not care what he is doing in his head. All that matters to them is whether he *appears* to be the Prince of Denmark. The quality of the actor can be measured not by how close to actually being Hamlet the actor gets, but how well the audience understands and believes the actions of the actor within the context of the production. As with the Chinese Room, the method for evaluating the output is assumed to exist and need not be defined.

The similarity of the relations between actor and play and between robot and interaction presents a strong case for using theatre as a model for HRI. The goal for both is to get as close as possible to the unobtainable ideal (normal social player/actual character) by giving the correct outputs. The robot/actor must appear to be something it is not, in order to provoke the desired response. Each has a goal, and ways to achieve and communicate that goal.

III. Theatre as Model

The parallelism described in the previous section is a useful analogy, but only if it leads to a concrete model for use in HRI. Thus, we use the idea of robots as actors to introduce elements of the theatre into robot architecture. Since actors are more successful in convincing others that they are something that they are not, using the same techniques to convince people that robots are social seems a clear choice. The techniques for using actors as a model for robot interactions fall into two categories. The first uses actors and their movements as an explicit model for robots, integrating the actors' actual movements onto the robot. This includes strategies such as motion-capturing actors and transferring those behaviors into the robot's movements. The second category relies on using the general approach that actors use to approach interactions in order to give purpose to robot action and give it clear structure.

A. Explicit model

The use of actors as a means of capturing specific human behaviors is widespread (see Busso et al [16] for one example). Skilled actors are flexible and are good at working under constraints. In the theatre, actors must be capable of and willing to do very specific and complex actions in order to achieve the desired effect. In working as a model for robots, experimenters can constrain an actor's performance to fit the needs of the situation. The actor's motion can be constrained to only movements that particular robots can perform, for example. Plus, through the rehearsal process, actors can repeat their performances with high precision.

Motion capture technology is a vital tool for analyzing actors motions, and can be used in two ways. The first is for specific gestures that can be replicated on the robots. This is most effective on anthropomorphic robots which are designed to move in the same way that humans do. Transferring motion capture data onto a robot allows them to move like humans actually move, not the way that the programmers think that humans move, resulting in more appropriate and believable motion. Secondly, in addition to capturing actual positions, there is important work to be done learning about the generalizable properties of the motions. It is necessary to not only understand *what* the actors do, but *how* they do it. By learning the aggregate qualities of the captured motions, the motions can be generalized to similar situations and to robots that can not physically replicate the original motions due to their articulations.

Having actors model and perform behaviors serves two purposes. It gives a model on which the robot can base its movement and it provides a training set with which to train the perception half of the interaction problem. For instance, if we find that when an actor is portraying a character who is hungry, they move in patterns X and Y, with quality Z, not only do we know that the robot should move in pattern X and Y with quality Z when it needs to convey hunger, but also, we know that if a human the robot is interacting with moves with pattern X and Y in a Z way, that human is also likely to be hungry. We draw on the fact that not only are actors highly skilled at moving the same way normal humans do, but that humans perceiving this motion understand the objective behind the movement. This

creates a further equivalence between the actor's actions, the robot's actions and the human's actions, all of which should derive from the same principles of acceptable social behavior. With this equivalence, an explicit model can be constructed that relates any motion to an equivalent motion in another embodiment.

B. Implicit Model

The second approach (which does not preclude the first) is more philosophical, in which the problem of interaction is approached as though it were a piece of theatre. This follows from the fact that both theatre and human-robot interaction are directed exchanges of information. Theatre is about the communication of ideas from the creators of a play to the audience, with the goal of entertaining or affecting the audience in a particular way. HRI involves an exchange of ideas from the human to the robot and vice versa, with the objective being either a tangible goal being accomplished, such as getting the human to do something, or something similar to theatre, with the human being entertained or socially engaged.

Accomplishing such communication in theatre involves a more focused effort than real social interactions. Theatre produces a directed thematic narrative not found in normal interactions. As Laurel mentions, certain ideas are artistically selected from all possible actions in order to produce a clean narrative. Actual social situations are much noisier, where the information communicated by actions is less clear. Actors in a play work to ensure that their actions are true to their character, and to the play as a whole. Thus, the actors must work to not only perform the action, but perform it in a way that clearly communicates to the audience.

There are ways for robots to accomplish this as well. For instance, consider the intentionality problem: when a robot is not actively seen doing something, or is doing something for unclear reasons, it is viewed as unintelligent. However, rarely would you come across such a problem with actors. Actors recognize that, if they are on stage, they have a specific role to play and must be playing it at all times. The constant refrain heard from directors is that "everything is a choice." This is intended to encourage actors to be constantly engaged and making good choices to ensure that they are constantly involved and committed to their objective. Thus, not communicating information is a choice. Therefore, not doing something, i.e. lack of activity from the robot, is in fact a communicative act. This is already seen in how robots are often programmed to have "idle animations" which serve no explicit purpose, other than to communicate to others that it is active and ready, not dead. We must program robots not only to be more active to combat that perception, but also so that those actions are meaningful.

This ties into the larger issue of goals and objectives. The clichéd question heard from actors is "What's my motivation?" The reason they ask is because it is clear what they should be doing, but not why they are doing it. Much of the motivation in certain schools of acting is objective-based. Actors must constantly ask what it is that their characters want, and use that motivation to drive what they are doing in each scene in order to obtain that objective.

This is beneficial to robots seeking to emulate humans, since it is easy to formulate problems in goal-based terms. At its core it reduces down to a planning or objective-evaluation problem. A robot must decide what its objective is, and then come up with a plan on how to achieve it, figuring out along the way what the most effective way to achieve the objective is. It is easy to see the actor/robot parallelism here, since both actors and robots naturally formulate their plans in this way.

It is also necessary for actors to find the right balance between communicating too much information, and too little. If the actor does not perform actions in a way consistent with their character's objective, the information does not come across. If the actor exaggerates all of their motions, it results in information overload, and becomes untruthful in the to the circumstances of the play. Either way, the actor moves further from appearing to be their character. The need for balance holds true for robots as well. With the intentionality problem, the robot must find the proper amount of social information to show in order to avoid confusion. With too little information, the robot's motions are "robotic" and the human does not gain any knowledge about the robots intentions. However, if it presents too much information, the robot becomes unpleasant to deal with since it overloads the human with too many signals.

One clear key feature of theatre that we can take advantage of is dramatic structure. Theatre should engage the audience, draw them in and elicit a lasting response from them at the conclusion . This makes it a complete experience, due in part to its inherent structure. Traditionally, the dramatic arc of theatre involves four distinct parts: the initial exposition, rising action, the climax, and the resolution. In a manner similar to Laurel's exploration of "dramatic potential", we can see how human robotic tasks can be structured into these distinct parts as well. In both cases, the goal is to create a cohesive interaction, where one action follows logically after the previous ones. If this experience is broken, then it creates a jarring context switch that takes the audience/user out of the interaction, lessening the overall quality of the experience.

In a play, the initial exposition is when the setting and characters are introduced. In Laurel's terms, this is when "the potential for action in that particular universe is effectively laid out" [3, p. 64]. This is analogous to the initial introduction of the robot and human in HRI settings. The two must meet and become acquainted with each other. In particular, the robot, which the human is likely to be unfamiliar with, must be very explicit in introducing its "character" and what its "potential for action" is, i.e. what it is capable of doing and what it is likely to do. In this phase, it is crucial to explain the context and set the expectations for the rest of the interaction.

Then, as the play progresses, the characters' objectives and how they plan to accomplish their objectives is revealed, hopefully continuing in the same vein as the potential laid out in the exposition. This sets up the primary conflict, and results in an increase in tension, called the rising action,

leading to the other characters (and the audience) becoming more engaged. In HRI, the goal is not to have rising tension, but to increase the engagement by making each action causally follow the previous one, with the actions building on one another. If this causality is broken, the direction of the interaction becomes unclear, and becomes less effective as a result.

Ultimately, the dramatic arc reaches its climax. At this point, the characters' objectives are met, and the only thing that remains is a short resolution to close the piece. A similar moment happens when a human and robot achieve their goals, and then part ways after the interaction.

Consider the robot receptionist installed at Carnegie Mellon University [17]. Engaging interactions with such a character need to have the four parts of the dramatic arc. The robot's actions at the beginning need to have clear clues as to what capabilities it has. If it initially looks at people when they arrive, it necessitates that the rest of the interaction should include eye contact. The exposition for this interaction specifies what modes of communication it has and is willing to accept. The robot receptionist does this through locating people, greeting them and prompting them to use the keyboard to type to it. As the interaction progresses and the interacting person specifies their goal (to obtain directions, get the weather forecast, etc.) the robot attempts to keep them engaged by providing the requested information, telling stories and avoiding the default response. These all help the user maintain the belief that they are interacting with a social actor. Then, once the goals have been achieved and the climax reached, the robot and human must conclude their interaction, usually with the human walking away and the robot bidding them farewell. This allows the interaction to gracefully be resolved, and finish appropriately.[3]

IV. Theatre as Venue

One further benefit of the analogy to Searle is that it becomes clear that the actor's task and the social robot's task are similar. However, if we take the robot out of real social situations and instead place it in a theatrical context, its task becomes identical to the actor's. A human actor playing Hamlet is attempting to perform actions which will convey the needs and goals of Hamlet best. A robot actor's task is essentially the same. Neither the human actor or robot actor can actually be Hamlet. The task is more about what the human or robot appears to be, and less what they actually are, and both are theoretically equally capable of accomplishing the task. This gives us a suitable arena where the human and robot start on equal footing.

Hence, in addition to taking ideas from theatre and putting it into robots, we also believe there is substantial benefit to putting robots into theatre. The idea of using theatre as a testbed for HRI was first discussed by Breazeal et al [10], and has been explored more recently under the name Theatre HRI (THRI) [18]. Hoffman et al explains it in terms of the big picture.

> We also believe that stage performance can be a promising implementation platform and testing ground for many important ideas in human-robot interaction research. It is a relatively constrained yet rich environment in which a robotic agent meshes its actions with a human partner. Surprising as it may sound, robotic theater may prove to be a new "grand challenge" for fluent human-robot joint action, dialog, collaboration and practice. [7]

By making robots participate in theatre, we have the opportunity to experiment with algorithms for normal human robot interaction in a controlled environment.

Theatre also gives us the flexibility to work on a reduced version of the HRI "problem." One of the biggest obstacles in HRI is unpredictable human behavior, which is a tough variable to deal with and makes repeatable testing difficult. Without this element, there are still many interesting sub-problems. For instance, there is the immense problem of determining the correct actions to convincingly appear to be interacting with the others on stage.

Theatre gives us a venue for removing some of the constraints for the problem. Traditional theatre is heavily scripted, which removes much of the unpredictability of the actions. A robot in the theatre still has to be a part of interactions with humans, but one of the major obstacles is gone. The controlled environment of a stage also can make using sensors easier, since elements such as visual landmarks can be added to the surroundings. Furthermore, this interaction can be repeated with minimal variations in order to test different ideas and parameters, in order to see which works best.

The variety in theatre also gives a number of opportunities to work on other reductions of the problem. As Breazeal suggests, introducing limited improvisation can further unconstrain the problem [10]. Working with more abstract theatre or types of theatre with very constrained ways of moving can also be used to work on elements of interaction without worrying about elements that may be hard for the robot to perform. We have done work introducing the robot into the Viewpoints acting exercise to focus on moving with a specific motion vocabulary in a reactive way [19].

Finally, there is an established way in which theatre is judged and evaluated. Most people have some intuition of whether they believe what is going on on stage. Showing an audience a piece of theatre with a robot and asking their opinions in a theatrical context is more natural than similar evaluations in a constructed observation in a lab. If a robot can be programmed to convey its intentions on stage, then we can be sure that the robot is at least conveying some of the right social cues, which can then be transferred to more traditional human-robot social situations. The caveat is that, while the theatre provides a natural venue in which people are likely to have an intuitive feel for how well the robot is performing, this type of judgment does not necessarily lend itself to clear, quantifiable data. It remains an open research

[3]The Roboceptionist at CMU is also a great example of using theatre as an implicit model for a robot interaction. The roboceptionist was programmed to use stories and vocalizations provided by the School of Drama in order to effectively engage people.

problem, and invites further collaboration between the arts and sciences to figure out the best data to collect.

V. Conclusion

In this paper, we have explored four key problems that HRI researchers face, and have introduced one promising interdisciplinary approach to tackling them through techniques originally developed for the theatre. Through an analogy to the Chinese Room argument, we explored how actors and social robots are conceptually working on the same task of trying to appear to be something they are not. This requires that all of the robot's physical actions be properly motivated in order to convey information clearly. Ultimately, all social interactions can be viewed as acting roles which the robot must perform.

Looking at interactions through this lens of theatre gives a number of ways to solve the four HRI problems. To overcome the articulation problem, we must learn how human actors move, in a way that can be translated to the limited degrees of freedom on a robot. Using skilled actors as a model presents a way to get a limited amount of motion to be subtly nuanced, intended to convey the actor's intent. In general, bringing in theatre professionals (actors, directors, choreographers, etc.) to provide a feedback loop about how they see a robot's motions should also be useful, as they are trained in a way that roboticists generally are not to view movement with a more precise eye. They can use that knowledge to overcome the robot's mechanical constraints and help overcome the intentionality problem as well. Further, by realizing the movement's position in a larger dramatic arc, treating an interaction like a theatre piece can help disambiguate a robot's motions. While a particular movement can be ambiguous, consciously putting it in a larger context can help make it specific and clear. Also, sensing becomes slightly easier by using labeled human motions performed by actors as a way to help interpret what the humans are doing, solving one small portion of the interpretation problem. Additionally, controlled theatrical experiences can often eliminate the need for a precise sensing metric. Finally, we can unleash the judgments of theatrical criticism and untrained audience reactions to help evaluate how well the robots perform.

William Shakespeare wrote in *As You Like It*, "All the world's a stage, And all the men and women merely players," in which he analogizes the the relationships between men and women to that of actors in a play. Whether art imitates life, or vice versa, there is a strong connection between the interaction that occur on stage and those in the world as a whole. The action and conflict of one mirrors the other.

The introduction of robots into the equation furthers the analogy. Inserting robots into the theatre will provide many useful lessons for the world as a whole, in the many contexts which HRI presents. Furthermore, the study of HRI and all of the interactions robots have with the men and women of the world present interesting ideas which may in turn provide captivating drama for the stage.

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