Embodied Interactive Characters using Social Robots

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ABSTRACT
Much research has been applied to developing interactive characters. However, most existing work is designed for digital characters. In this work, we explore the use of social robots to embody virtual characters. Robotic avatars have great potential over traditional displays for engaging the user, especially children. Primitive movements of the robots can be used to express emotions, illustrate locations, and even suggest the social relationships among the characters.

We present a novel social robot for embodying conversational agents. This social robot combines a robotic lower body with a digital upper body. Thus, we can gain the mobility and presence of a robot without losing the expressive power of body movements and gestures that a virtual character can provide. We performed a preliminary evaluation on expressing emotions and intentions using such a robotic avatar. Our results indicate that the robotic avatar can intensify the expression of emotions over its equivalent digital form. We also observed the trend of subjects paying attention to different aspects of the character's movements when the character was digital versus when it has a robotic body.

Keywords
social robot, embodied conversational agent

INTRODUCTION
In recent years, games that emphasize the social and narrative aspects of the player's experience have become increasingly popular. This is evidenced in classical RPG games such as Sim City, and in the recent major titles such as Heavy Rain, Mass Effect and Bioshock. Game designers have been looking into ways to use rich characters and narratives to engage the player and to provide the central experience of the game. Such interactive characters are not only designed for games, but have also been widely used for educational and health intervention purposes, such as an assistant, or as a tutor.

Much research has been applied to developing such interactive characters. A brief overview is provided in the RELATED WORK section. Most of the existing work is designed for computer users. The virtual environment and virtual characters are displayed on a computer monitor or projected on a big screen, and the user interacts with the virtual characters using keyboard, mouse or microphone.

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One of the key differences between these virtual humans and people is that they do not have a physical body, and therefore cannot physically participate in people's lives. The virtual humans primarily exist and function in a virtual world, and invite people to participate in their world, e.g. practice language skills together in the virtual world.

In this project, we explore the use of cognitive and social robots to augment the display of the virtual characters and make the interaction more physical, natural, intuitive, and immersive.

Robotic avatars have great potential over traditional displays for being more expressive and engaging. Primitive movements of the robots can be used to express emotions, illustrate locations, and suggest social relationships among the characters. If a user is disengaged from the conversation and turns away from the robot, the robot can even move to the front of the user and try to initiate another conversation. Such robotic avatars can be especially useful for games and serious games designed for children because compared to adults, it is easier for children to suspend their disbelief and interact with avatars like they would with real people.

In this paper, we present a novel social robot for embodying conversational agents. This social robot combines a robotic lower body with a digital upper body. Thus, we can gain physical mobility and presence of a robot without losing the expressive power of body movements and gestures of a virtual avatar. We present preliminary results of expressing emotions and intentions using a mixed modality robotic avatar.

RELATED WORK

Embodied Conversational Agents

Emotion plays an important role in social interactions. Human emotions are expressed in a variety of ways, such as through voice, facial expressions, body postures and gestures. We constantly interpret cues from other people, and use these channels to express ourselves. From such emotional displays, observers can form interpretations of a person's beliefs, desires and intentions. They may also provide information about the underlying dimensions along which people assess the emotional significance of events: is it good or bad, was it surprising, which is to blame, etc. (Smith and Scott 1997). People are influenced by other's emotions. One such example is emotional contagion in which individuals' emotions can be "infected by" the emotions of those around them (Hatfield et al. 1994). Moreover, people often strategically use their emotional expressions to affect other people around them. Emotions can thereby be a means of social control (Campos et al. 2003; de Waal 2003; Fridlund 1997). For example, anger displays can be used to elicit fear in others; distress can be a way to elicit social support; and displays of joy or pity can be a way of signaling support to others. Thus, to create interactive characters, it is important that they can express their emotions in a natural and impressive way.

Much work has been done on creating conversational agents in social contexts, and in particular in computer aided interactive narratives. Interactive narratives allow the user to participate in a dynamically unfolding story, by playing a character that interacts with conversational agents controlled by the system. Because of its potential for providing interesting stories as well as allowing user interaction, interactive narratives have been proposed for a range of training and entertainment applications. There is a large volume of work on dynamically generating the characters' dialogues actions, and managing their interactions with the users (e.g., Perlin 1996; Hayes-Roth and Gent 1997; Anstey et al. 1999; Cavazza et al. 2001; Swartout et al. 2001; Magerko 2002; Marsella et al. 2003; Braun 2003; Riedl et al. 2003; Louchart and Aylett 2004; Si et al. 2005; Riedl and Stern 2006). Research work has also been conducted on automatically creating gestures and non-verbal behaviors for digital avatars (e.g. Cassell et al. 1994; Ruttkay 2001; Hartmann, Mancini, and Pelachaud 2005; Kopp et al. 2006; Chafai, Pelachaud, and Pelé 2007).

Using social robots to interact with people have been explored in various contexts, such as information collection (Keysermann et al. 2012), tutoring (Castellano et al. 2013) and as life companions (see Leite et al. 2013 for a comprehensive survey). Though many social robots are humanoid, because of their hardware constraints none of them allow for the flexibility of expressing facial expressions and gestures like a digital character.

On the other hand, combining a digital display of one's face or upper body with a moving platform has been used as a tool for telecommunication, such as attending a conference remotely (e.g. Anybots; MantaroBot). However, this form of media has seldom been combined with work on social robots, the automatic generation of facial expressions and non-verbal behaviors, as well as for embodying fictional characters that can interact with people. In this work, we created such a robotic avatar and examined its expressive power over its equivalent digital form.

The Experience of "Presence"

More formally speaking, we want to examine whether the robotic embodiment of characters can elicit a stronger sense of social presence – the feeling of being with another person, or intelligent entity (Heeter 1992; Biocca 1997).

Many factors contribute to the experience of presence. In general, the more inclusive, extensive, surrounding and vivid the virtual or augmented reality is, the higher the presence (Slater and Usoh 1993; Mantovani and Castelnuovo 2003). Interactivity and the user's sense of agency have been shown to affect the experience of presence. The more natural and unconstrained the interaction is, the higher the degree of presence will be experienced by the user.

For providing social presence in particular, Short et al. (1976) believe that the saliency of information provided about the virtual character is an important factor for the degree of presence the user experiences. Biocca et al. (1997) define social presence as the user's sense of access to other intelligent entities. They believe that for the user to feel social presence it is important to have cues about other entities' intentions.

To create a sense of presence for the user, the virtual or augmented reality also needs to be able to shift the user's attention from the real world (Schubert et al. 2001; Witmer and Singer 1998; Slater and Usoh 1993). As the user devotes more attention to the virtual world, their experience of presence also increases (Witmer and Singer 1998).

Finally, "willing suspension of disbelief" is an important factor for the user to experience presence (Banos et al. 1999; Steuer 1992). This action/mental process enables the user to feel that the simulated environment and characters are real. How much the user can tolerate the lack of realism in the environment is related to the utility of the interaction (Klimmt and Vorderer 2003). For example, if the interaction is immersive and enjoyable, the user will be more willing to perceive the environment as real and ignore the imperfections of the simulation.

We believe that social robots can enhance the experience of social presence. Beyond having the potential to shift virtual experiences into physical ones, social robots can provide additional dimensions of interactivity, make the virtual characters' intentional cues more clear, and attract the user's attention.

DESIGN OF THE SOCIAL ROBOT

The goal of this project is to leverage the power of social robots towards creating interactive characters for pedagogical or entertainment purposes. Typically, the virtual environment created for interactive digital characters are displayed on a computer monitor, or projected onto a big screen, and the user interacts with the system using a mouse, keyboard or microphone. In this project, we attempted to create a more immersive presentation by using the combination of a social robot and an on-screen avatar for representing each character.

In this process, we want to gain physical mobility without losing the expressive power of facial expressions and gestures. Therefore, we created our robotic character by using a robot platform which carries a tablet computer on top. The screen of the tablet displays the face and the upper body of the avatar. This upper body and face allows the character to have the robust expressiveness of a virtual character tethered to the presence and physicality of the mechanical lower body. Figure 1 shows an example of our proposed character presentation. We used the Turtlebot (TurtleBot) with a mounted platform as our robotic platform.

While choosing a robotic system to work with, our main considerations are safety and the unit's ability to "embody" a human-like character. We also want the robot system to be affordable and easily programmable so that more people can afford using our system once it finishes development. More specifically, when moving around, the robot should do so at a medium and well controllable speed. It can't be too slow, since it needs to embody a character the user can relate to, but it can't move too quickly for safety reasons. Likewise, the robot should also be stable for safety reasons. Two-legged robots, in particular Aldebaran's NAO robot (NAO), are in fact not the most desirable to use. While they may function adequately on their own, physical interaction with a human makes them too prone to falling over. Also, a NAO robot does not support the display of facial expressions. Of course, robots with more than two legs quickly start to look like non-human animals, which may negatively affect the social experience of the user.

Eventually, we chose the Turtlebot, which has a Microsoft Kinect on top of an iRobot Create, and which also has an elevated platform onto which a netbook can be placed. Figure 1 shows our overall system architect. In addition to the Kinect on board of the Turtlebot, another camera is installed on the ceiling to track the user's and robot's locations.

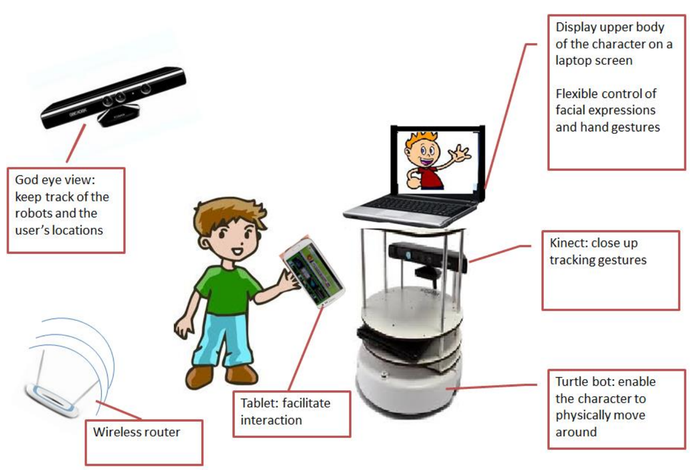

Figure 1: Next Generation of Robotic Avatar

The evaluation of our proposed social robot needs to be conducted at two levels. The first one is how effective the movements of the robots can be used for illustrating the character's internal states, and the second one is how well the overall system is for increasing the user's experience of presence in various modalities such as storytelling, or training scenarios.

Currently, we have conducted an initial user evaluation at the first level – how much/whether such robotic avatars have advantages over the traditional computer screen display for expressing a character's emotions. To gather an understanding of what features are relevant to humans in this mixed modality embodiment, we performed qualitative evaluations for two salient affective states: anger and shyness.

EXPERIMENT SETUP

For each affective state, participants were shown a purely digital representation of a female character performing a scripted set of animated body gestures and movements along with audio synced to simple lip movements as shown in Figure 3. In this condition, the subjects sit in front of a computer screen. They were also shown a mixed modality representation with a robot base, and a virtual representation of the upper torso, arms, and face of the character depicted on a screen atop the robot stand. This setting is shown in Figure 2. The mixed modality condition consisted of the same speech and gestures, but the body movements, e.g. moving forward and turning around are conducted through the robot body.

The scripts of the speech used for each affective state are:

- Anger: "You know what nothing that comes out of your mouth has ever had any value."
- Shyness: "Um excuse me, I – I was wondering, do you have the time?"

We used recorded voices for the character in both conditions. The 3D model of the character was taken from USC/ICT's VHuman Toolkit (Virtual Human Toolkit).

Figure 2: Robotic Avatar

Figure 3: Full Body of the Digital Character

In this study, the character did not have facial expressions. They do have gestures and body movements that accompany their speech. The way we set up the virtual character and the robotic avatar for each affective state are depicted as the following. When designing these scripts, we tried to match the virtual conditions to the robotic conditions as closely as possible.

Virtual Character Expressing Anger:

For this condition, in the beginning of the animation the character is facing to the left of the screen, with the camera zoomed out. The character then turns to the center while the camera quickly moves closer such that the virtual character is capturing a larger part of the screen. The character's gaze faces the screen. The character, while speaking the described lines gazes and slightly turns to her upper left. At the same time, in the same direction, the character raises her arm in the air in a waving, dismissive pattern. The character turns back to face the user, and points her finger to her chest and then returns her arm to rest at her side. Finally, at the end of the audio, the animation ends with her gaze shifting slightly downward and nodding once. The character pauses for a second, and then the camera zooms out while the character rotates away from the camera.

Robotic Avatar Expressing Anger:

The robot base and screen are initially in front of the user, but facing to the right of the participant. The robot base rapidly turns such that the screen is facing the user, and quickly moves towards them until it is approximately six inches from their legs. At this point, it abruptly stops. Then, while generating the gazing and arm movements described in the virtual animation condition, the base of the robot turns in the same corresponding direction as the animated upper body. Once the audio stops, the robot base pauses for a moment, then quickly accelerates and turns from the participant, and moves away from them.

Virtual Character Expressing Shyness:

The character stares at the center of the screen for a moment. Then it moves both arms to its center with each arm brushing past the other. The character leans slightly to its right while gazing downward. The right arm then extends slightly while the head shifts to the center. The hands briefly touch for a moment as the head once again shifts, this time facing to the right. The arms and torso then fidget and shake for a moment. The pose returns to normal, and the character once again has their face and body towards the center of the screen.

Robotic Avatar Expressing Shyness:

The robot base and screen are in front of the user, but facing to the right of the participant. The robot base gradually turns so that the screen is facing the user. The robot base then moves slowly forward while decelerating. It then pauses, and then once again moves forward briefly. A second later it slowly backs up a slight distance. The robotic avatar is now approximately 1.5 feet away from the participant. At this point, the audio speech and animated movements described in the virtual shyness scenario begin to play. In tandem with the turning of the character's upper body, the robot turns right slowly, then turns and decelerates to its left. The robot base pauses and turns again so that the screen is facing the user. At this point the audio speech ends, and the robot base backs away slowly for about a second. The robot-base along with the screen then turn right slowly to face away from the participant, then briefly turns back left (as though looking back), and then quickly returns to shifting right so as to be facing away from the participant. It then moves away from the participant.

EXPERIMENT PROCEDURE

We conducted this qualitative examination using 11 individuals from the Rensselaer Polytechnic Institute. Of the 11 individuals, 8 were exposed to both affective states, 2 were shown anger, and 1 was shown shyness. For each affective state, subjects were always exposed to both the mixed-modality condition and the virtual condition with the order of exposure being randomized.

For the virtual character conditions, participants were asked to view the recorded animations while seated in front of a 25 inch monitor. For the mixed modality condition, participants were seated at a distance of 2.5 feet from the robot. We used a 10 inch tablet for the display. The overall height of the robot avatar is around 3 feet.

After being exposed to each condition, participants were asked a series of questions. They were asked to identify what affective state the character was trying to express to them, the level of valence and arousal they felt was being expressed, what features of the character's expression made them feel this way, and what features diminished their experience. They were also prompted to provide their general thoughts and comments about the character's expression. In addition, after being exposed to both conditions that depicted the same affective state, each participant was asked to judge which version (virtual versus mixed-modality) did a better job of expressing that affective state.

PRELIMINARY RESULTS

Expressing Anger:

In relation to the anger condition there were several consistent findings from participants in regards to the effectiveness of the virtual character and robotic avatar. For both types participants consistently described the state as angry, frustrated or both. For both character types, they observed roughly equal levels of negative valence. They observed high arousal levels in both conditions. However, arousal typically felt stronger in the robot condition. Moreover, 8 of the 10 participants viewed the robot as expressing anger to a stronger degree. When providing an explanation for their impression, they commented that both the sound of the robot's movements and the physical acceleration of it moving towards them accentuated that perception.

For the robotic avatar condition the bodily qualities that aided in the subjects' perception of anger largely emphasized the way the robot moved, such as the speed of approach, the abrupt movements, and the way it entered and stayed within their personal space or area. Although, occasionally discussing the virtual animations, participants largely seemed to focus on the robot base when discussing the mixed-modality robotic avatar. In contrast, in the virtual condition, the features that enhanced the subjects' perception of anger appeared to emphasize the arm and hand gestures.

Expressing Shyness:

In relation to shyness, participants largely described the movements in both conditions in terms of a series of related descriptions such as "timid, hesitant, shy, and nervous". The ratings of valence were typically described as somewhat negative, and with medium levels of arousal for both character types.

The robotic avatar shy condition revealed that there were several consistent features which aided in their perception of its affective state. The features typically described were the slow, gradual swaying, the gradual shuffling of forward and backward motions, and avoiding having the screen and body directly face the participant. Overall, a consistent theme was the need for slow movements that varied from moving away and toward the participant.

In contrast, for the virtual character condition, the primary aspect that seemed to repeatedly occur in qualitative assessments was the character's gaze constantly looking away, and avoiding the center of the screen. Indeed, this observation fits in line with research on expressive gazes in digital characters (Lance and Marsella 2010). The other two qualities were described as fidgetiness of the hands, and the lack of visibility of the head (head facing a downward direction).

Preferences between the two character types were largely equally split, with 4 preferring the robot condition, and 5 preferring the animated condition. Explanations were varied. However, a common statement for the preference towards the animated condition seemed to partly relate to the fact that the robot movements and motor noise distracted from their perception of the animation. This is consistent with research on the experience of presence. Slater and Usoh (1993) demonstrated the more often “break” (user's attention switches between the virtual world and the real world) happens, the less presence the user experiences.

DISCUSSION AND FUTURE WORK

This preliminary evaluation has partially confirmed our hypothesis that embodying a digital character with a movable robotic body can enhance its ability of expressing its intentions. Though this is not equivalent to a stronger sense of social presence, we view this as a positive indicator. Note that the display used for the robotic character is much smaller than for the virtual character (10 inch vs. 25 inch). Research on the experience of presence has pointed out that in general the larger the display, the more impressive it appears (IJsselsteijn et al. 2001). The character’s whole upper body and arm movements are displayed through the tablet. Therefore, the fact that there were nearly an equal and greater number of subjects that preferred the robotic avatar illustrates how much expressive power the robot movements can add.

On the other hand, being able to express salient emotions does not necessarily mean the robotic avatar can bring a higher sense of presence to the user. We are currently working on extending the robotic avatar’s capacity for expressing more emotions, and for conducting social interactions such as through conversational interactions with the user, and performing storytelling. We plan to conduct follow up evaluations once the next iteration of development is completed.

This evaluation also reveals new factors that we need to consider. We did not expect the noise created by the robots to significantly impact the perception of the robot character’s expressions. In addition, some subjects reported that it was hard for them to focus both on the robot’s body movements and the character’s upper body. In general, we observed that the subjects were attracted to different aspects of the character’s movements when the character was digital versus when it had a robotic body. This may affect how we are going to design these two forms of characters in the future. Future experiments are needed to evaluate the generality of these observations.

In general, we expect that once fully developed, the robot-character combination of the robotic avatar we created (Figure 1) will create a stronger sense of presence for the user than using computer monitors or even large projection screens. This is not only because of the novel display accompanying the social robots, which will naturally attract the user's attention, but also because the environment allows the user to interact more naturally through physically interactions. They do not need to face the display all the time. They can walk around, turn around and as with human conversation still maintain the interaction. Further, the augmented environment allows activities that are not possible in traditional games. For example, a robotic avatar can block the user's way and thus prevent the user from talking to another character (robot). Similarly, the user can turn his/her back toward a robot/character to indicate he/she does not want to talk to the character. Alternatively, the robot can move to the front of the user and be persistent for the duration of the conversation. Additionally, while conveying a story, or interacting with the user, robotic avatars can direct or move towards physical props such as toys to accentuate a point or shift the user’s attention.

On the other hand, incorporating these functionalities makes the design of the conversational agents a challenging task. The agent design has to be tolerant to potential errors from the robots’ vision and motor systems. Moreover, unlike digital avatars, whose verbal behaviors and body movements can be precisely coordinated by the agent, the agent has to consider the physical capacity, e.g. moving speed of the robot when planning the character’s behaviors. Finally, and most importantly because the robots we choose to work with have a different body shape from people, mapping the style of human body movements to the robots' moves becomes a challenge. In the current work, we manually encoded the movements. This procedure is time consuming and it will not work well when we need to dynamically chain a large set of expressions when interacting with the user. Future work has been planned on creating automated approaches for these issues.

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