Robot Musical Theater for Climate Change Education

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***Abstract*—The use of social robots has recently been investigated in various areas, including STEM (Science, Technology, Engineering, and Mathematics) education and artistic performances. To inform children of the seriousness of climate change and awareness that they can make change, we created the Robot Musical Theater performance. In this project, natural elements (wind, earth, fire, and water) were anthropomorphized and represented by humanoid robots (Pepper, Milo, and Nao). The robots were designed to motivate audience to participate in the action to prevent climate change. Because of COVID, only fourteen visitors as a single group were allowed to participate in real-time and posted to YouTube, where at the time of submission, 141 people have viewed the performance. The participants provided positive comments on the performance and showed their willingness to participate in the movement to prevent climate change, and expressed their further interest in STEM learning. This performance is expected to contribute to enhancing informal STEM and robotics learning, as well as advancing robotic arts.**

Keywords—robot theater, robotic art, STEM education, alienation effect, interactive theater, child-robot interaction

I. INTRODUCTION

Environmental issues have been a source of topic that inspired artists, scientists, and engineers for a long time. As people have suffered from the effects of our climate disaster, many contemporary artists have used their work as a platform to increase recognition and imagine a more long-lasting future [1]. For example, in "The Locust Wrath", the author designed software for interactive sonification of climate data [2]. The climate data were rendered as a piece of electroacoustic music.

As interests in social robots continue to increase, social robots have also been used to facilitate STEM (Science, Technology, Engineering, and Mathematics) education [3-7]. Specifically, these attempts were inspired by the application of robots in theater productions [8-12]. In the play R.U.R (Rossum's Universal Robots), humanoid robots have performed with human actors. They have investigated human-robot interactions and robot-robot interactions in the play to estimate whether robots can perform autonomously [10].

From this background, we created a novel Robot Musical Theater at the university Science Festival to promote the awareness of climate change for our audience and YouTube viewers.

Based on the social facilitation theory [11], we believe that it is important to develop a new platform where the performance can have a large impact on the audience using robots and technologies. In this performance, we integrated robotics, sonification, visualization, and motion tracking by allowing the audience to interact with multiple robots, while robots introduced the story about four natural elements (wind, earth, fire, and water) and how much these elements suffer from the climate change caused by human behaviors. Each robot played the role of each element. The audience members walked around the stage based on the robots' guidance, while viewing images and videos on the 360-degree display and listening to the robots' stories. The Science Festival usually hosts more than 5,000 people with 6,000 attendees in 2019, but due to the COVID, we had only one group consisting of a small number of participants. Also, the performance was live-streamed in real-time through the institutional YouTube channel (https://www.youtube.com/watch?v=ELrPZFlGXc4&list=PLXALtFuqIn6IuM3XdaZojwfWGmpLGBKnb).

In line with our effort to promote STEAM (STEM + Arts and Design) education in informal learning environment, our project aimed to create a new robot theater production within a new platform to facilitate climate change education by exposing our audience to robotics, theater arts, and immersive technologies. Through the performance of robots (instead of human actors), we expect that the audience members will be able to objectify the situation and understand the seriousness of climate change more (the alienation effect [13]). By suggesting an active role (i.e., "speaking up") to participate in actions to prevent climate change through communications with robots, the audience will be more engaged in the subject matter.

This work will significantly contribute to advancing embodied STEM learning by using robotics and theater and to testing the potential of integrating robotics with immersive technologies for higher learning effects and engagement in the performance.

II. Method

A. Participants

The Robot Musical Theater took place at the US University Science Festival. Because of COVID, the only pre-registered audience members could attend our performance in person. Fourteen people, including families with children, participated in our performance. Among them, six children provided comments after the performance. The performance was live-streamed via the institutional YouTube channel. As of December 1st, 141 people viewed the performance on YouTube.

B. Robot Actors

We used four humanoid robots in the performance (1 Pepper, 1 Milo, and 2 Nao's). Pepper (Fig. 1(a)) is a 4ft-sized humanoid robot with a touch screen made by Softbank Robotics [14]. Milo (Fig. 1(b)) is a social robot made by Acapela Group to help children with autism strengthen their communication skills [15]. Nao ((Fig. 1(c) and (d)) is a small programmable humanoid robot made by Softbank Robotics [16]. In the performance, Pepper played two roles as Wind and the narrator. Milo played the role of Earth. Two Nao robots played as Fire and Water each. We triggered the movement and speech of Pepper, Milo, and Nao robots by accessing each robot over a local wireless network offstage, which was provided by Softbank [14, 16] and Robokind [17]. We used each robot's text-to-speech for their voice. Four robots were placed in different quadrants to illustrate each element. Robots made gestures and facial expressions (Milo), but did not move around the stage. The faculty in Performing Arts created robots' choreography according to their speech and mood.

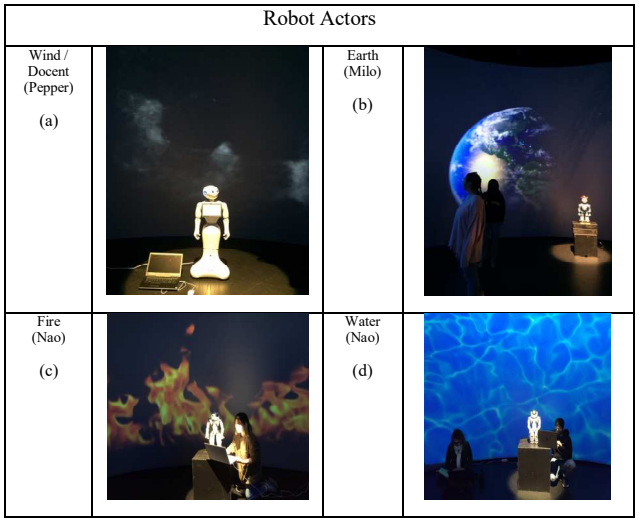
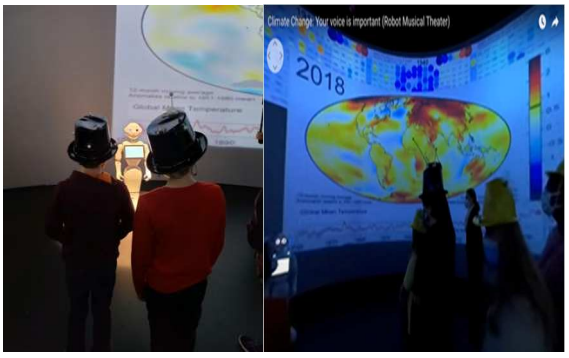


Fig. 1. Robot Actors in the Robot Musical Theater.



(a) (b)

Fig. 2. Audience members' hats for motion tracking (a) and the world map showing the increasing temperature of the globe (b).

C. Procedure

On entering the theater, the audience members were encouraged to wear hats with reflective markers (Fig. 2(a)). The motion capture system detected these markers, which reflected the audience's location and generated the pre-recorded sounds depending on their location. Before the robots introduced their story, the audience viewed the world map on the entire screen

(Fig. 2(b)), showing the increasing trend of the global temperature as a function of year. Following Pepper's guide, the audience members moved along the theater stage consisting of a 360-degree display screen, called "Cyclorama", and appreciated the robot's choreography and visualization on the screen, respectively. While the audience moved from one robot (element) to another, they heard pre-recorded children's voices, saying that "We can make a difference," or "We can stand up" in different languages. After they visited all quadrants with four robots, Pepper asked them to speak out, "I can make a difference." When they spoke up, the entire screen was filled with the same world map again, but at this time, it demonstrated the reversed trend, which showed the decreasing temperature thanks to the audience's voices. The entire performance lasted around 7 minutes, followed by the Q&A session.

III. The System of Robot Musical Theater

A. Design of Robot Technologies

According to a three-factor theory of anthropomorphism [18], people are likely to understand an agent's behavior when the non-human agent is anthropomorphized. Based on this theory, we made storytelling from the perspective of wind, earth, fire, and water by using humanoid robots. For instance, to begin the performance, Pepper said, "I am the wind. When I get upset, I can blow down structures, uproot trees, and send objects flying. I don't want to hurt people..."

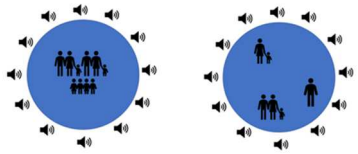
We created a series of movements to illustrate each element using robots' arms and facial expressions based on choreographing. According to prior research [11], facial expressions, outfit, voice pitch, head movements, and gender could have effects on the robot's attractiveness and the quality of interaction and specifically, facial expressions could provide people with additional information. We adjusted the voice pitch, speed, and facial expressions to express each robot's emotional states.

B. Design of Immersive Technologies

We utilized 140 speakers, Cyclorama, and the optical motion tracking system at the theater. We tried to use these technologies so the audience members could more actively participate in our theater play and feel more visceral impressions.

For the sound design, we recorded a sentence, "We can make a difference" in 11 different languages (Korean, Chinese, Hindi, Marathi, Sindhi, Telugu, German, Italian, French, Spanish, and Arabic) and located them in four quadrants to convey the message that everyone from all over the world should participate to reduce global warming. After the audience watched the performance of each element, they could hear the spatialized sounds assigned to each quadrant.

In order to give an interaction between the audience and the performance, we utilized the mapping between the audience's movement and the sound parameters using Max/MSP. For this mapping, the motion capture system observed the location of the audience by the hat's reflective markers and made abstract electroacoustic sounds accordingly as part of the soundscape of the entire theater play. Thus, when the audience members gathered together in the center of the stage, the sound became louder; when the audience members were scattered, the sound became softer (Figs. 3 and 4).



(a) (b)

Fig. 3. Examples of sound configuration ((a) When the audience gathers in the center of the stage, the sound becomes louder; (b) When the audience is scattered on the stage, the sound becomes softer).

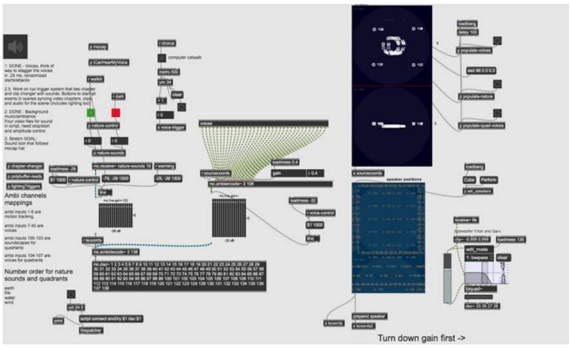


Fig. 4. Robot Musical Theater Max/MSP patch for visualization and sonification.

IV. Results

After our performance, we briefly interviewed six children (mean age =9.17, 4 girls, 2 boys) among the in-person audience members about their experience. Five respondents answered that they learned more about climate change and showed their willingness to participate in the action to prevent climate change. Two respondents answered that they became interested in the STEM fields more than they were before attending our performance. We found that five respondents answered that their favorite robot was Pepper, while one of the respondents answered that Milo is creepy, which might reflect the uncanny valley effect due to Milo's facial expressions.

V. Discussion

Research has shown that the use of robots as an educational tool for children can encourage them to have more interest in STEM [20, 21]. In line with our continuous efforts to lower barriers to entry for all and recruit minorities to STEM and robotics in informal learning environments [3-7], we created the novel Robot Musical Theater play. We expanded it by integrating with immersive technologies.

Research has also shown that climate change education plays a significant role in students' attitudes and views that could be taken to alleviate it [21, 22]. Thus, we aimed to encourage people to understand the influence of global warming through our Robot Musical Theater performance. The children's interview results and their parents' positive comments made us believe that this performance successfully encouraged them to change their thoughts and attitudes towards environmental

issues and climate change. We expect that this approach can also be used in other STEM education fields beyond climate change.

In terms of robotic arts, we tried to promote creativity and elaborate artistic culture, while enhancing robotic arts by combining them with other advanced technologies. Moreover, the audience members participated in the performance directly, and it allowed artists to expand the way they create their work [12].

According to the alienation effect [13], Brecht explained that the audience could understand the complicated link of historical development and societal relationships by applying the alienation method. It allowed the audience members for an active role in the performance by pushing them to ask questions about the artificial environment and how each individual element related to real-life events. By doing so, the audience would distance themselves emotionally from problems that demanded intellectual solutions. Through our performance, the audience became interested more in climate change, felt a connection with robots, and showed interest in STEM education.

This cross-disciplinary performance was possible through a collaboration among the multiple departments across the campus [24]. Our collaborators include students, staff, and faculty from the Institute for Creativity, Arts, and Technology, the Center for Human-Computer Interaction, the Department of Human Development and Family Science, the School of Performing Arts, the Department of Industrial and Systems Engineering, the Department of Computer Science, and the Center for Educational Networks and Impacts.

VI. Conclusion and Future Works

This project shows multiple applications of Robot Musical Theater. It bodes well for the potential for enhancing STEM learning, as well as advancing robotic arts. The audience spontaneously responded not only to the robot's movement and speech, but also sounds and visuals from the immersive system, which further advanced earlier productions.

We have plans to update our performance in terms of robot technology, immersive technology, and audience engagement. We will introduce drones to the performance in the future works so that drones, robot actors, and the audience can interact more actively and emotionally. We will try to create an advanced form of sonification based on the actual climate data [2, 24]. Through this sonification, we will convey information about climate change as well as increase the aesthetic aspects of the performance. Finally, robots can play a role as the audience [8] to cheer up the robot actors and encourage the audience members to provide more active feedback by hand clapping, waving, or laughing.

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