Potentials of Robot-Theater as a Platform for Integrated Art, STEAM Education, and HRI Research

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ABSTRACT

With rapid increase of interests in robotics and AI, robotic art or AI art is also becoming more popular. Robot-theater is an integrated art platform, including theater play, singing, dance, etc. When this multimodal art is combined with STEM contents, it can also serve as an educational program for promoting STEAM, robotics, and computer science. Moreover, implementing the robot-theater programs can contribute to advancing robotics and HRI research. After briefly describing the practice of robot theater and other robotic arts, the present paper introduces the iterative robot-theater programs for promoting STEAM education and the on-going HRI research projects, which have been conducted to implement the new professional robot-theater productions. I hope to further discuss plausible research directions and new ideas for the robot-theater applications with researchers and designers at the workshop.

CCS CONCEPTS

• Social and professional topics~Professional topics~Computer science education

• Applied computing~Arts and humanities~Performing arts

KEYWORDS

Human-robot interaction, Robot-theater, Performing arts, STEAM Education

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1 Introduction

Given that the origin of the word, "robot" comes from efforts to create a worker to help people, there has been relatively little research on making robots for non-work purposes. However, researchers have explored robotic arts since Leonardo da Vinci's "Automaton" in the 16th Century. Robot-theater is an attractive test bed for HRI research in that it incorporates numerous aspects of social interaction in a relatively constrained environment. At the same time, since children's theater is accessible to a wide variety of ages and skill levels, it is attractive from a STEAM (STEM + art and design) education perspective. Based on this background, the present paper attempts to explore full potentials of robot-theater in various application domains – performing arts, STEAM education, and HRI research. This paper is expected to spark lively discussions about the full potentials of robot-theater at the workshop.

2 Robot Theater as an Integrated Art Platform

Robots have been used in theater productions by some research groups [1-6]. The focus of these projects tends to be improving the social interaction of robots and producing artistic performance. This type of research can vary, by having robots play different roles, such as a "robot," "human," or "animal." Based on the various roles robots play and the storylines, theater productions can also serve as parables about human existence. For example, Ishiguro's Robot Actors Project tried to naturally depict in-house family situations where people ponder socio-cultural problems in the near future, by playing theater with robots [3,5]. Theater integrates all types of art forms, including music, dance, drawing, as well as acting. Thus, with the robot-theater production, we can practice and understand each genre of arts, and conduct research on it. For example, researchers have developed a robot system that can learn dancing styles from human expert dancers. By employing an interactive version of the Simple Genetic Algorithm (SGA) [7], Augello et al. [8] developed a learning and evolving dancing robot. Dance involves visual, auditory, and tactile modalities, and it is familiar and fun to most people. Because of these characteristics, we envision that dance can be used for many theater plays.

Robot musicians, such as Cog [9] or Shimon [10] can already detect human musicians' presence, gesture, or position of the instrument and accordingly notice and respond to the musical context. Robotic musicianship consists of two primary research domains, musical mechatronics and machine musicianship. Musical mechatronics is the study and construction of physical systems that generate sound through a mechanical means [9]. Machine musicianship focuses on developing algorithms and cognitive models about music perception, composition, performance, and theory [11]. Many musical robots try to mimic human instrumentalists. For example, the Waseda Flutist Robot No. 4 Refined IV consists of a mouth mechanism (lips), air supply mechanism (lung), and fingers [12], which can give liveness to the theater.

Artists and researchers have also made drawing robots [e.g., 13-15]. Drawing robots involve two processes, observation and drawing, just as in traditional drawing. To make creative artworks, students or apprentices need deliberate practice and systematic training with good teachers. To make this happen in robotic arts, researchers and artists have made a feedback system to make a closed loop (e.g., using a neural network-based learning model [16]). As a result, the drawings that robots have produced seem to provide comparable emotional, aesthetic, and artistic effects on the observer. Drawing per se is not often the part of the live play, but we can use robot drawing as scenery in the live theater play.

3 Robot-Theater as a STEAM Education Platform


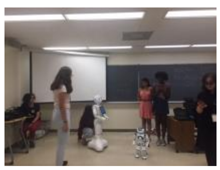

Figure 1: Robot-theater programs in an afterschool program for socio-economically underprivileged elementary school students (L) and in an international summer exchange program for ages 15-17 high school girls from all over the world (R).

Another approach to robot-theater is using it for promoting STEAM (Science, Technology, Engineering, Arts and Design, and Mathematics) education (e.g. http://stemtosteam.org). We have developed and conducted four different robot-theater programs for elementary school students, high school students, and college students across several years [17-20]. We used multiple robots with various types and different capabilities in our programs (e.g., humanoid: Nao and Pepper, animal: Pleo and Aibo, mechanical or imaginary: Romo, Lego Mindstorms, etc., Figure 1). In the robot theater program, we tried to provide "computational thinking" experience to young students. In addition to traditional storyboarding procedures used both in script development and interface design, we devised tangible elements for students to iteratively refine their storytelling ideas. For example, elementary students created their own robot models using sculpting material. We also attempted to have our students create and implement their ideas by an event-based approach (e.g., touching the robot's back can generate the next action) rather than the paper and pencil-based text diagram. In the elementary afterschool program, the actual coding was performed separately by experienced programmers (graduate and undergraduate students), but rehearsals with both the programmers and students allowed for interactive debugging of readily observable problems. In high school summer youth programs, students had a session for learning about the robot programming and they hard coded robot action and speech using the visual programming language. From the iterative programs, we have learned that using the familiar fairytale (e.g., Beauty and the Beast) is more appropriate for elementary school students, but high school students were able to make their own story in a short amount of time. While in the first afterschool program for a local elementary school, we used a serial process for making a live performance, in the second afterschool program, we made different activity modules – acting, music and sound, dancing, and drawing. This modularized program allowed students, who could not attend the program regularly, to follow up different part of the program more easily. Each module included different STEM contents in activities. To illustrate, students could learn robot control and text-to-speech in the acting module and physics, balance, speed and velocity in the dancing module. This embodiment of computing process allowed children to experience the concept of computing and robotics more effectively and comfortably. The program for college students were similar to one for the high school students, but it included more of basic robotics and HRI research, as well as robot taxonomy, physical constraints, and the debugging process.

4 Current Phase: Creating Professional Theater Productions

In addition to continuing the STEAM education programs for various students, we are trying to make professional robot theater productions at Virginia Tech in collaboration with Performing Arts and Humanities. Again, we try to include all forms of arts in our theater productions, such as acting, dance, music and sonification, and drawing and visualization. In addition to using our humanoid and animal robots, we are using drones in our work. We will utilize the Cube at the Moss Arts Center. The Cube system is equipped with 124 speakers, 360° large display (Cyclorama), and the full motion tracking system. Implementing the robot-theater play requires considerable research and implementation of the robot technologies.

5 Potential Research Thrusts through Robot-Theater Productions

Not only trying to model the human artists of each genre of art (e.g., observation and performance), we also envision that we can advance theory and practice of fundamental robotics and HRI research through the iterative robot theater productions, such as sensing (e.g., facial emotion detection, speech detection, or distance detection), communication (e.g., emotional gesture and conversation), and mobility (e.g., preprogrammed and autonomous movements). In the same line, Knight [21] has identified critical components to better design social robots from robot theater: relatable gestures, affect expressions, movement metaphors, outward emotion communication, social intelligence, multi-agent interactions, audience feedback, and machine humor. Some of the work-in-progress research projects are described below.

5.1 Design of Robot Acting Technology

Robot acting can be preprogrammed and so, robots can perform a pre-scripted play. In the next stage, users can control robot acting in real-time. Robot control technologies, including a remote control for acting, speaking, and locomoting are developed. The goal of the remote control app is to have robots move according to the theater script. We have developed a preliminary remote control app for Nao [22]. We will expand it and develop a more comprehensive remote control app for additional robots, including Pepper and other robots. The remote control will allow users to type text for the robot to say, and bring up a dialog for creating a different action. This dialog will contain controls for Volume, Rate, Pitch, Pose, and Gesture actions. For communication with the robot, we will use the APIs provided by Aldebaran (now, SoftBank) [23], as they allow for real-time control of the robot without the need of another computer or another program running on the robot side. We will use Android layouts, libraries, and frameworks where possible, drawing on the Android support libraries provided by Google. Scripts will be saved to the phone's local file system in JavaScript Object Notation (JSON). JSON allows us to save scripts in an easily human-readable format for testing and ease of reading/writing. In addition, it is extensible in case we want to save additional data values.

The more advanced form of robot acting would be having robots improvise performance based on the structure of scenes and characters. Researchers have investigated robot autonomy and used comedy improvisation to create believable agents [6]. They tried to make robots that could improvise scripts on the fly instead of using a predetermined scenario. The robot can be designed to have different personality and accordingly, each character can have different types of behavior patterns. However, researchers thought that dramas are not driven by characters with indefinable emotions, but rather driven by the character's objectives, goals, actions, and tactics. Therefore, they created scenarios which can be easily formalized (e.g., there are a hero, goal states, obstacles, and given circumstances, etc.). Even though their attempt was in an early stage, it provided a high potential for improvisation of the robot theater. We will also pursue the robot autonomy in our next version robot-theater production.

5.2 Design of Robot Drawing Technology

As described above, the current drawing robots are able to observe an object and sketch it. Alternatively, the observation stage can be omitted. For example, ArtSBot swarm [24] is composed of small turtle-type robots that have two pens and a pair of RGB sensors. Once the robot makes the initial random color spots, which serve as a seed for the next reactive mode, where the robot traces the presence, shape, and intensity of color and plans the emergent composition. The outcomes look much like Jackson Pollock's drip/action paintings. The idea inspired us to make similar swarm robot systems in the robot-theater education program. As part of the drawing module, we tested MICROMVP, an open-source vehicle robot platform. Specifically, it has strength in robot path planning, which we can easily adopt and utilize for our drawing module. MICROMVP is composed of Arduino and ZigBee for communication and control and fiducial marker for system tracking. It has multiple vehicle-type robots and a web-cam. The web-cam queries the configuration of the vehicles, upon which planning decisions are made and translated into control signals that are relayed wirelessly to the vehicles. We modified its hardware and thus, each vehicle carried a color marker to draw and paint. MICROMVP's Graphical User Interface (GUI) path planner allowed students to easily draw robots' paths on the laptop, which the robot vehicles would follow. We will actively use the motion capture system at the Cube and so, the movements of human actors, robot actors, and drones will be tracked and so, the data can make visualizations on the Cyclorama.

5.3 Design of Robot Sonification Technology

We are devising poem-based, gesture-based, and scene-based sonifications for our professional robot-theater. The client-server architecture program was developed for robotic sonification in the previous research project [25]. We will develop and modify this program for use in the new robot-theater program. Two-way interactions are possible with this system. On one hand, we can use the pre-made mapping between the robot's movements (or the image on the big screen) and the sound parameters. For this mapping, we have developed software for non-programmers so that they can make a mapping between the movements and sonification variables. On the other hand, the motion capture system of the Cube and embedded robot cameras will observe the movement of the counterpart (or audience) and make sound accordingly, as part of soundscape of the theater play.

5.4 Design of Drone Dancing Technologies

Drones are one of the core platforms we will integrate in our theater play. We will explore drone movements for natural and emotional acting and dancing based on control theory. The actors will be able to control drone based on gesture technology we will develop. A Thalmic Labs Myo armband, which can track EMG signal and detect a variety of gestures, will be used to capture the actor's direction. The directions are sent to a computer, which calculates the resulting velocities occurring when the actor moves his or her arm. These velocities will be then sent to the drone, which will utilize them to fly in a circle at a set distance around the actor. The system will be implemented in Python, utilizing the Robot Operating System (ROS: a framework that standardizes common controls for robots [26]) and PyoConnect (Python library to connect to the Myo) to communicate with the drone and Myo, respectively. For creating the smooth mapping between the gesture types and drones' movements, we will use neural network using Wekinator, (an open source software tool for real-time interactive machine learning) [27].

CONCLUSION

The present paper showed multiple applications of robot-theater. Combining robotics with multiple forms of arts will inspire not only students, but also, researchers, artists, and practitioners. This type of integrated art will advance theory and practice of robotic arts and bring about new types of arts with cutting-edge technologies.

Formalizing an age-appropriate robotics education program (specifically, informal learning) will promote STEAM education to underrepresented students, including girls and minorities by maximizing students' exposure to STEM, robotics, and arts. These programs will also facilitate making new robotic interfaces and tools for multiple purposes. Finally, this collaborative effort is expected to build the transdisciplinary research community across different departments and even different institutions and contribute to the wide dissemination of the education program and software infrastructure through publications, workshops, and the open-source code repository.

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