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Animatronics and Emotional Face Displays of Robots

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Abstract

The subject of animatronics, emotional display and recognition has evolved into a major industry and has become more efficient through new technologies. Animatronics is constantly changing due to rapid advancements and trends that are taking place in hardware and software section of the industry.

The purpose of this research was to design and build an animatronics robot that will enable students to investigate current trends in robotics. This paper seeks to highlight the debate and discussion concerning engineering challenge that mainly involved secondary level students.

This paper explores the hardware and software design of animatronics and emotional face displays of robots. Design experience included artistic design of the robot, selection of actuators, mechanical design, and programming of the animatronics robot. Students were challenged to develop models with the purpose of creating interest in learning Science, Technology, Engineering, and Mathematics.

Introduction

Animatronics was developed by Walt Disney in the early sixties. Essentially, an animatronic puppet is a figure that is animated by means of electromechanical devices [1]. Early examples were found at the 1964 World Fair in the New York Hall of Presidents and Disney Land. In the Hall of Presidents, Lincoln, with all the gestures of a statesman, gave the Gettysburg's address. Body language and facial motions were matched to perfection with the recorded speech [2]. Animatronics was a popular way of entertainment that had proven itself in the theme parks and cinematography industry [3].

Animatronics is a subset of anthropomorphic robots which are designed drawing inspiration from nature. The most recent advancement in building an anthropomorphic robot is Kismet (earlier developed by MIT), that engages people in expressive face-to-face interaction. Inspired by infant social development, psychology, ethology, and evolutionary perspective, this work integrates theories and concepts from these diverse scientific viewpoints to enable Kismet to enter into natural and intuitive social interaction with a person, reminiscent of adult infant exchanges. Kismet perceives a variety of natural social cues from visual and auditory channels, and delivers social signals to people through gaze direction, facial expression, body posture, and vocalization [4].

There is a great deal of research around the world recently in Japan on developing of interactive robots with a human face. Development of interactive human like robot brings this research to the frontiers of artificial intelligence, materials, robotics, and psychology. Machines displaying emotions is a relatively new endeavor that goes far back to earlier times. The entertainment field is also overlapping new research on androids; the term android is derived from fiction relating to a complete mechanical automation [5].

An extension of the engineering challenge is to explore the effectiveness of the project's capability to display human emotions, and to design the physical mechanisms that display realistic human facial movements. The objective of this effort was to design and build an animatronic robot SSU-1 (Savannah State University-1). The SSU-1 will be controlled by a preprogrammed embedded microcontroller and will create human like motions for entertainment purposes [3].

The paper describes the following:

- Physical overview
- Hardware and software design;
- Performance by SSU-1;
- Engineering Challenge;
- Observations of the impact of the student outreach program;
- Future directions.

Physical Overview

SSU-1 is an animatronic puppet that is animated by means of electromechanical devices. The backbone of SSU-1 is the frame. A frame is needed to support any mechanical mechanisms for eyes, eyebrows, mouth and other facial gestures. Actuators such as solenoids, servomotors, stepper motors and others are supported by the frame. These actuators are responsible for the actual movement of the eye, mouth and other face mechanisms. The frame also is where the mask is attached to the animatronics head or figure. One can think of the frame as a skull though it need not have a human skull shape or look like a skull at all. Electronics and software provide synchronization of sound/puppet motion.

Control structure of the eye mechanism and other facial mechanisms are not visible to the audience. Springs are used in conjunction with DC motors to control the eyes position up, down, left and right. Class 2 levers can be used to increase the speed of movement of a facial gesture if connected between the actuator and control of the facial gesture [6]. There is a variety of mechanisms for both the facial gestures and enhancement of speed.
Frames may be implemented in one of the following ways:

1. 2D Sliders on flat mask
2. Side view
3. Simple cross design
4. 3D Bulk heads and stringers
5. 3D Mold

6. 3D Adapt a toy or model

There are two major sections to facial mechanisms for the animatronics figure:

1. Control of facial gesture mechanism
2. Machines to enhance mechanical advantage of actuator

Major physical feature of SSU-1 is a Styrofoam head made for storing wigs which was then hollowed out to make room for the mechanical controls, electrical actuators, and electronics. Holes were bored into the eye sockets of the Styrofoam head for placement of the mechanical eye mechanisms. SSU-1 is controlled by a preprogrammed embedded microcontroller that will create life-like motions for the engineering challenge.
Figure 1(a) shows a possible expression realized by configuration of the face hardware of SSU-1 robot head. Two ping pong balls were used to make the eyes. The hardware to control the eye and other facial mechanisms is shown in figure 1(b). The hardware and software design to control the animatronics puppet is discussed in the next section.

Figure 1a: SSU-1 Robot Head

Figure 1b: Hardware of SSU-1

Hardware and software design

Hardware and software control architectures have been designed to meet the engineering challenge. Assigned by the faculty, the project team was composed of two electronics engineering technology students. During the early execution stage the students handled the mechanical design portion of the project. The electrical and electronics concepts which included programming of the microcontroller was faculty led and the students were trained to program the SSU-1 in C programming language. Students also kept a record of their progress including design ideas and sketches, issues faced and their solutions in their individual notebooks. The hardware section of SSU-1 uses Cypress PSOC (CY8C26443-24PI) microcontroller [7]. The microcontroller is programmed in C language to control different facial mechanism of the SSU-1.

A standard micro-controller which is composed of a Cypress PSOC micro-controller eliminated the necessity of secondary students to program micro-controllers and keep their focus on the overall system blocks. The standard program implements a simple interface between the DMX

512 (**D**igital **M**ultiple**x**ed) interface and PWM hardware blocks configured on the Cypress PSOC micro-controller's digital bus. The role of the control electronics was to create a clean interface between the SSU-1 and the high level C++ programming language and FreeStyler512 software to control the SSU-1. The block diagram of the hardware and software interface is shown in Figure 2.

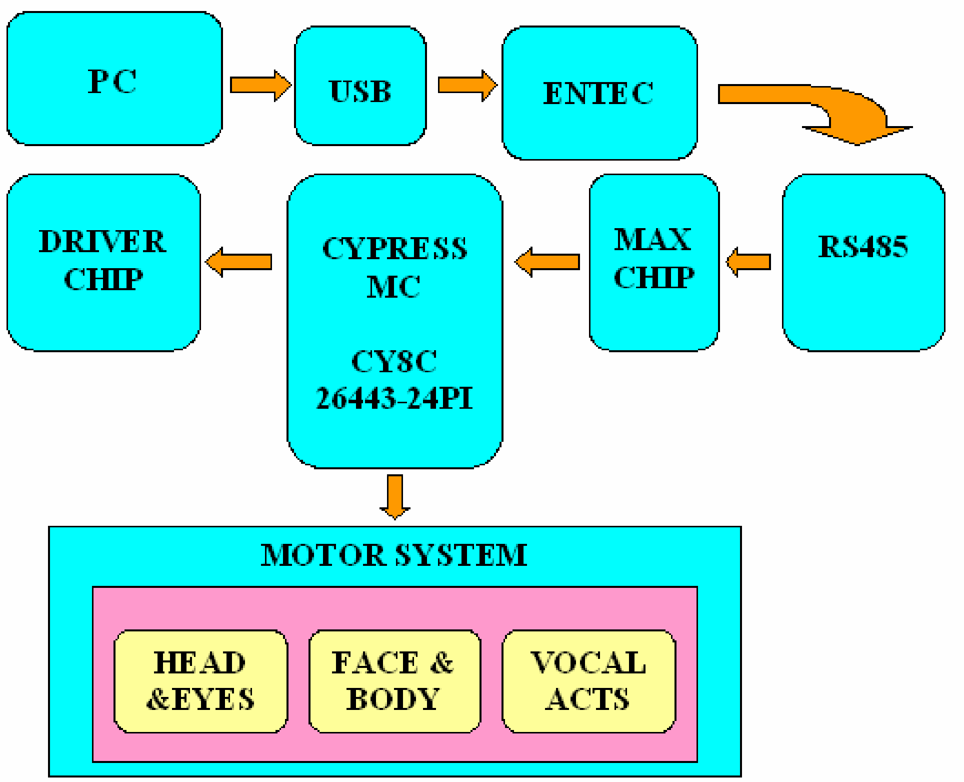

Figure 2: Hardware and Software Interface of SSU-1

The communication protocol used in SSU-1 is DMX 512. The DMX 512 and MIDI protocols are two major standards used by Hollywood, the music industry and theme parks. MIDI formatted files can be used to play music or voice over PC. DMX 512 has been traditionally used to control theatre lighting but has been adapted to control animatronic displays and robots.

In SSU-1 24 DMX 512 channels are used to interface 2 servomotors and 10 LED's. Each servo motor uses 2 channels to control mouth and neck rotation. The hardware interfacing diagram to connect various actuators is shown in Figure 3. The ULN2003AN could be eliminated if no solenoids or relays are involved with the design. Stepper motor controls can be directly connected to the output ports designated in the standard micro-controller interface specification.

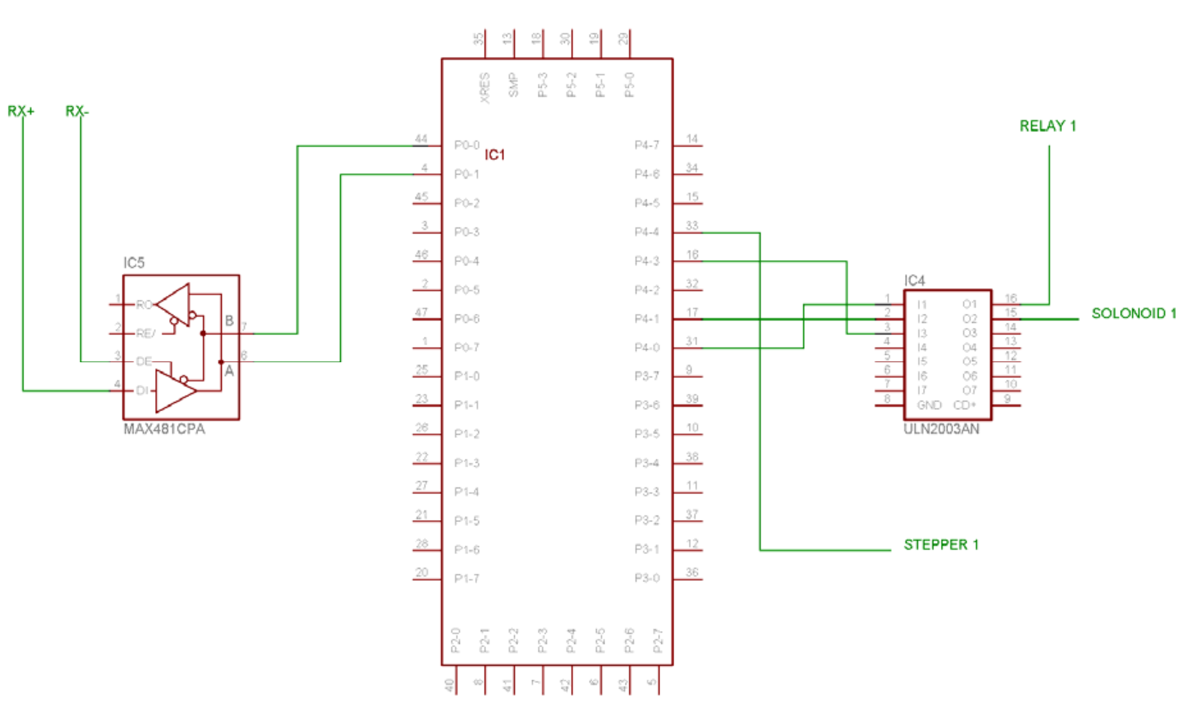

Figure 3: Hardware Interfacing Diagram

The PC provides software for students to synchronize and record movements. In the animatronics world synchronizing sound track and movements is referred to as programming. There are several software systems provided free of charge that can be used to synchronize sound tracks to movement. For many years the movie, theater, and concerts have relied upon PC based systems to control lighting systems. Modern lighting systems used for concerts, plays and movies use light fixtures moved through servo-motors or stepper motors connected to PC's through the DMX-512 RS-485 protocol [8].

The FreeStyler 512 is a freeware program that is used to primarily control theatrical lighting fixtures [9]. The FreeStyler 512 is used by the students in this engineering challenge to control the SSU-1. Adapting the existing DMX 512 standard and the existing software gave the students a rich user interface and eliminated the need to develop software for the PC side of the system.

In the standard micro-controller several PWM signals may be generated using the digital blocks. Specific pins on the Cypress PSOC can be attached to several digital and analog output bus lines. The standard interface specification defines the output port lines for DMX channels 1-9.

Table 1.0: RS485 DMX-512 Channel Byte

Channel #	*Control #*	*Byte Value*	*Function*
0	**1**	**0-2**	**TYPE OF OUTPUT CONTROL SIGNAL (0 – PWM, 1-DIGITAL, 2-PULSE).**
1	**1**	**0-255**	**PWM value or pulse in ms value.**
2	**2**	**0-2**	**TYPE OF OUTPUT CONTROL SIGNAL (0 – PWM, 1-DIGITAL, 2-PULSE).**
3	**2**	**0-255**	**PWM value or pulse in ms value.**
4	**Repeat of above for all channels**		
5wire	**Repeat of above for all channels**		

The DMX-512 channels must both match the fixture definitions as well the physical wiring to the corresponding channels on the standard PSOC that uses the interface shown in table 1.0.

Performance by SSU-1

There are a number of web sites for entertainment companies which provide animatronics for television, movies, theme parks, etc. A typical structure of such companies is to break development of animatronics down through separating the tasks into art, mechanics, electronics and programming departments. An example of how a task may be performed and brought through its fruition is described below:
A customer requests services from the company. The customer and artists work together to develop characters and identify information the characters need to convey to an audience. A storyboard is developed that breaks down the steps of the performance. A storyboard usually consists of a picture and perhaps text for each section of the show especially character movements [10]. Knowing how the characters need to move allows the mechanics department to determine the relative number of actuators needed, relative size of the character, and other features that will affect cost. The electronics departments can make some estimates of effort related to the number of channels to control the characters. The programming department can make an estimate of the cost of programming based upon the length of the performance and number of characters and movement sequences that need to be set up and synchronized.

A group of 7th grade students built a talking audio-animatronics head to encourage other students from grades 6 to 12 to learn more about technology. Each student worked on a different task and after a great deal of thoughtful consideration, consensus was reached that an alien would be a good choice to make the presentation. One student worked on the dialog, while a second student worked on facial expressions of the alien and a third student designed animation for the computer screen behind the alien head. To analyze the effect of the talking head, two experimental conditions are shown in Figure 4.

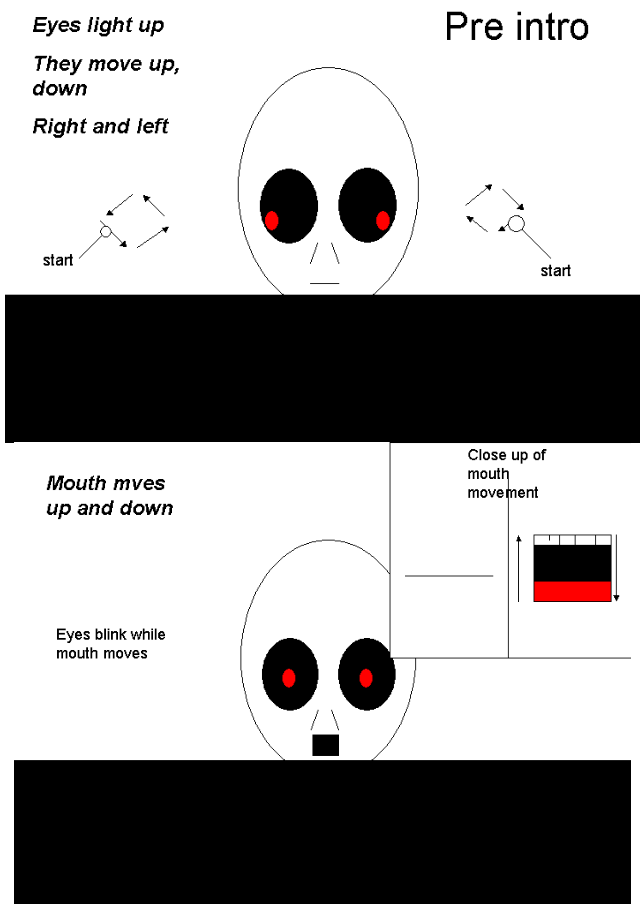

Figure 4: Experimental conditions of SSU-1

The background PC screen was utilized to show animations to enhance the main performance given by the talking alien head. Performance by SSU-1 presented an example of the modeling of the components of audio animatronics robot. This example motivated the students to build their own robot for the engineering challenge.

Engineering Challenge

Engineering Challenge provides the opportunity for students interested in art, music, robotics and entertainment to combine their interests building an animatronics display. Evaluation of the results of this effort will be determined mainly from documentation, workmanship, programming, and most important audience reaction to the performance. This engineering challenge is designed with a high degree of flexibility, and can be implemented at the middle school, high school and college levels. Graphics organizer for a typical animatronics project is shown in Figure 5 [11].

Life Formations Inc. provides a great deal of useful information at their web site including 10 guidelines to creating a good Animatronics performance [12].

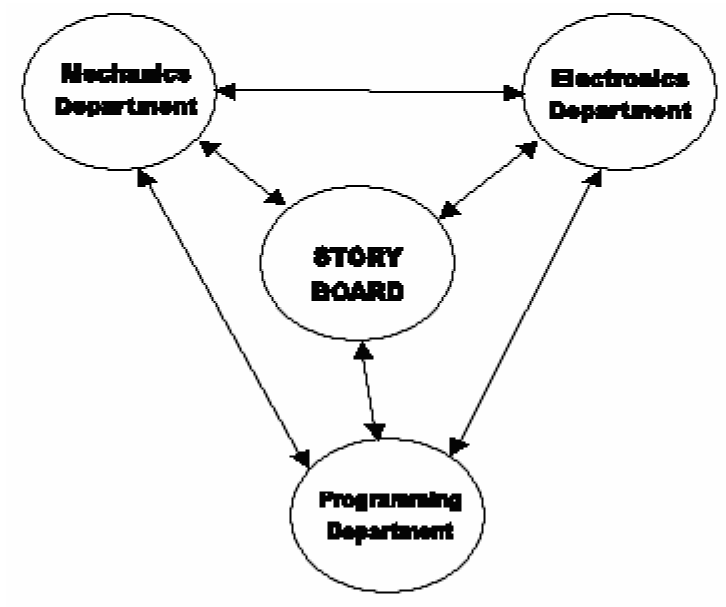

Figure 5: Typical Animatronics Project

These laws for animatronics performance are:

1. Law of Distance – the further away the less realism for the character is needed
2. Law of Time – with shorter time you get away with less realism in character
3. Law of Numbers – multiple characters hold attention of audience longer than one
4. Law of Non-Human – Non-human characters are not judged as critically as human characters
5. Law of Surprises – Character doing something unexpected keeps audience attention
6. Law of Singing – Audiences like singing Animatronics characters
7. Law of Personality – Scripting, Voice, Personality are essential to success
8. Law of Brevity – Keep presentation to 1 minute or less or less is more
9. Law of Scale – Making small things large or large things small grabs audience attention
10. Law of the Edge – grab audience attention (make it funny or crazy)

Animatronics is a cross discipline field; therefore good communication across all departments is needed. Once an initial performance is created, changes can be requested to make it more effective.

The architectural layout for the engineering challenge is shown in Figure 6.

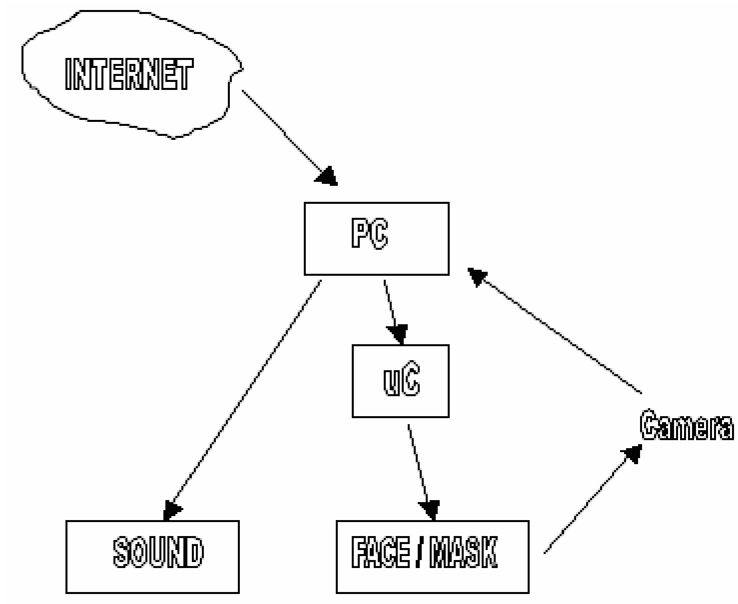

Figure 6: Animatronics Engineering Challenge

There is great flexibility in implementation. Sound can be produced by the PC or simply by turning on a CD player at the same time as starting a program to activate motions on the face or mask. The video camera is not a requirement but is advisable for program evaluation and for student portfolio and project documentation.

The video camera does not have to be connected to the PC. The PC can be used to control a micro-controller that interfaces to the face or mask. To simplify the challenge the face/mask can also be manually driven directly by students acting as puppeteers. Using puppeteers is especially effective if there is a video camera to record a successful performance. An USB/RS-485 interface exists between the PC and the microcontroller, which provides great flexibility in communications. There are other alternatives to connecting the PC to the microcontroller. Serial interfaces, TCP/IP and other interfaces can be used [13]. The microcontroller can be eliminated altogether with a direct interface from the PC to the face or mask. There are numerous combinations of existing products that can be purchased to allow the PC to control the face or mask. The main advantage of using an Internet interface is that it introduces the students to embedded Internet and provides the opportunity for students to learn more about the Internet.

Student Outreach Program:

The SSU-1 robot offered an opportunity for students to work with others in their class whom they had never worked with. SSU-1 focused on important learning concepts such as Mechanics, Electronics, Programming, Teamwork, and cross disciplinary interaction.

Mechanics symbolize the interrelationship between various substructures of the robot. This includes an understanding of mechanical components and the manner in which all these components function together as a deterministic whole system. Basic mechanisms such as servos, motors, chassis and electronics which include microcontrollers, sensors and the vision system are the major components of the SSU-1. Integrating these components offered an opportunity for the students to understand the design/development of SSU-1.

Programming varied from secondary students to college students. The secondary level students were trained to program the SSU-1 from the user end point of view. At college level the students were introduced to program the microcontroller in assembly and C++ language. Also the concept of programming skills learned were extended to programming the animatronics puppet using the FreeStyler 512 at both secondary school and college level.

SSU-1 carried out the concept of teamwork in all phases of design and implementation. The goal of linking the students into a learning community is to give the student a peer group in which they feel comfortable. The team work prepares the students to solve technical problems in a group environment in addition to meet new challenges encountered in the work place. Students experience being on successful teams to understand and appreciate the values of good team work. SSU-1 emphasizes on the word team because team is not same a group. The term group implies a somewhat more than a collection of individuals but the team implies much more [14].

The curriculum in any specific area of study tends to narrowly focus students on that area, whereas real-world multifaceted systems tend to incorporate components from multiple disciplines. The development of such systems has shifted from designing individual components in segregation to working in cross-functional teams that include the variety of proficiencies needed to design an entire system [15]. SSU-1 provides an opportunity for students interested in art, music, robotics and entertainment to combine their interest in building an animatronics display.

The goal of this outreach program was to exemplify the impact of animatronics and emotional face display in learning Mathematics and Science at the secondary school level. Significant trends were measured from SSU-1 which included the mechanics, electronics, programming, teamwork, and cross disciplinary interaction. The results show that the students learned tangible lessons from each topic.

Conclusion

This paper described the design and implementation of SSU-1. This research has served as a reference for providing students in mathematics, science, and engineering technology with challenging and exciting learning experiences that involved various fields of mechanical, electrical, and artistic design concepts. SSU-1 provided an excellent opportunity for both the faculty and students to work in multi and cross disciplinary environment. From the findings of this project the relevance and application of robotics in the educational arena has implications for further research.

Future Directions

There are many different issues that must be addressed as a result of SSU-1 effort. At present SSU-1 is an output only device. Future improvements will include interfaces for human-robot interaction which is essential for upcoming generation of robots. The basic issue is to establish a natural interaction between the human and the machine. Plans include the integration of voice recognition and voice output capabilities provided by the Microsoft XP operating system. More requirements demand adding video (both visible and infrared) to design/develop anthropomorphic peripherals. In addition, building a system that human can interact with and train in a natural manner with the robot is necessary for successfully implementing the program. The eventual goal is to build an enhanced system that will reflect emotional communication in the classroom. From a broader perspective, this research aims at incorporating artificial muscles, hepatic actuators, tactile sensors, and biometric sensors into the anthropomorphic robots [16].

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Biographies

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