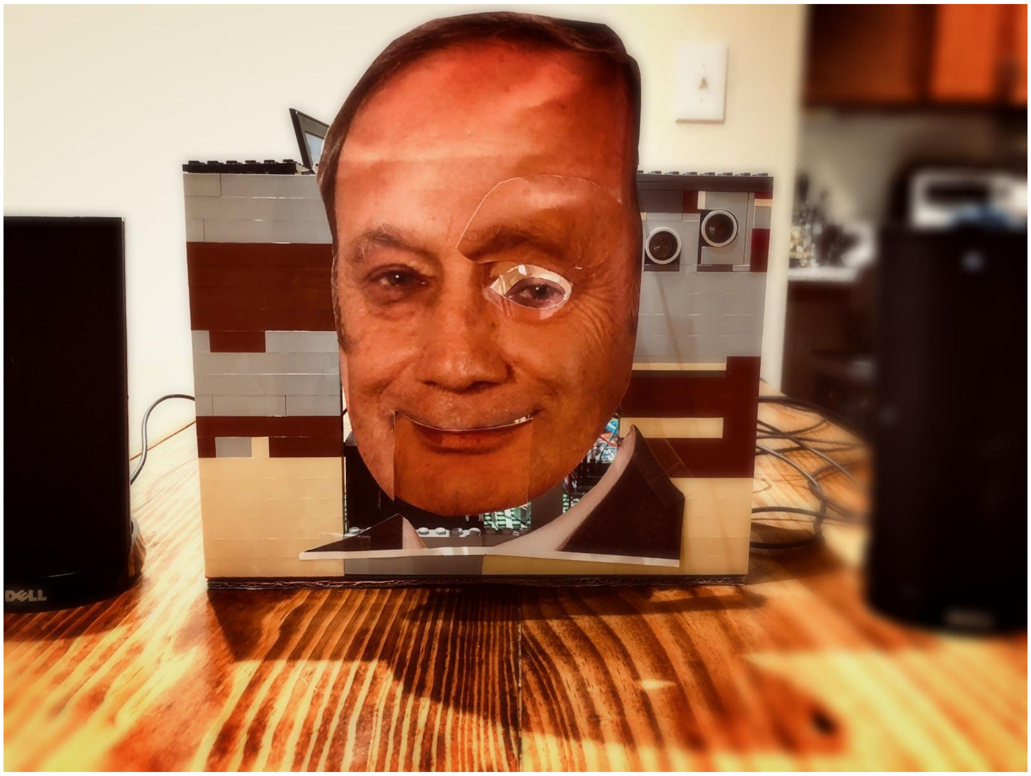
ANIMATRONICS FACE: AMIR KARIMI, PH.D.



https://www.youtube.com/watch?v=gcDggB1y1Tk

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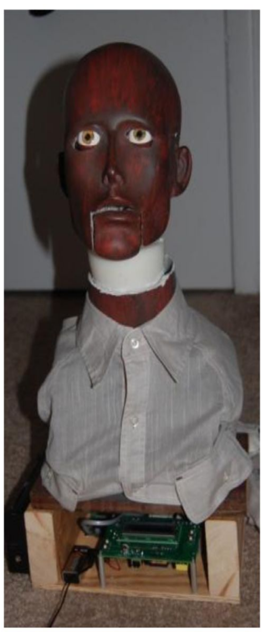
Abstract

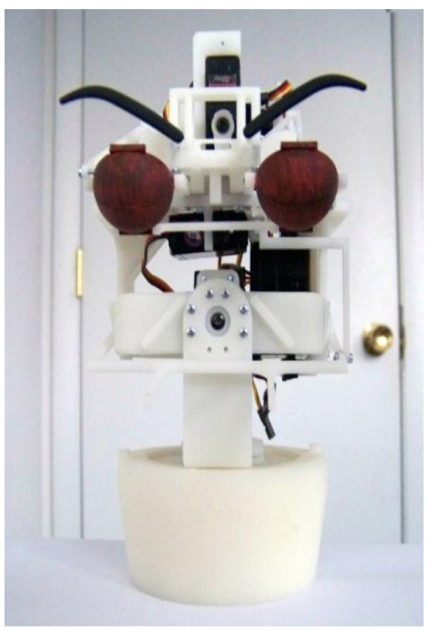
Purpose of this project is to provide a hands-on task allowing students to practice and demonstrate the theoretical and mathematical principles learned throughout the mechatronics class and in previous laboratories. The project is an animatronic face resembling a professor of the engineering department of the University of Texas at San Antonio. This animatronic face is designed to resemble Professor Dr. Amir Karimi. The face includes three moving parts. Their movement is initiated through two sensors. An ultrasonic sensor is used as a motion sensor to detect movement in front of the face. If movement is detected, a record of Karimi's voice is played and mouth movement is initiated, simulating a peaking motion. The second sensor is a touch sensor. It initiates a winking motion and eyebrow movement. The supporting structure is build using Legos. The sensors output is translated to the motors using MATLAB.

Overall, this project helped get practical experience in programming and in the design of mechatronic systems and helped students get practice in the development of real-life engineering projects.

Section 1: Literature review

Animatronic Face 1





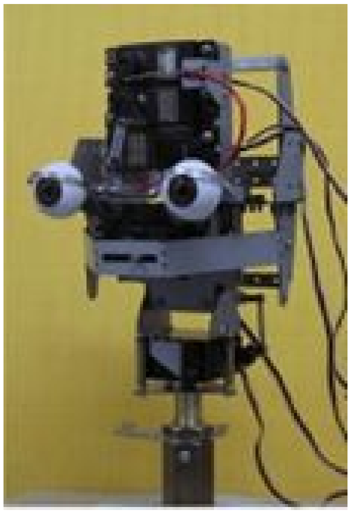
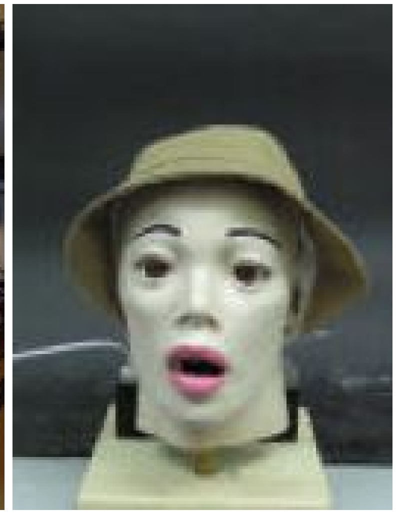
The first animatronic head design presented was manufactured by the graduate students of the Worcester Polytechnic Institute. The purpose of the project was a proof of concept for a humanoid animatronic head design. The character of the head is a form follows function approach with the face being designed for the purpose of highlighting the underlying mechanical processes implemented into the robot. The electronics for the robot are housed in a wooden box underneath the neck of the robot. The mechanical elements are attached to a fiberglass chassis. This fiberglass chassis serves as the spine of the robot. The key features of the robot are moving eyebrows, neck movement, eye and eyelid movements and jaw movements mimicking that of a human. For this purpose electric motors were used to adjust the neck roll, neck pitch, neck yaw, eyebrows, eye pitch, eye jaw, eyelids and jaw. To provide a realistic output a special focus was laid upon tuning the motors in order to not only match the directional movements of a human, but to also match the movement speeds in angular directions, resulting in a total of 8 degrees of freedom. The movements themselves were programmed using a variety of face-tracking software. The values gather through the software translated into MatLab code and then fed into Visual Show Automation. The electronic hardware used for this project was Mini SSCII motor controller from

Scott Edwards Electronics, a Brookshire Software LLC RAPU 5.0 single board computer. Power is supplied by a 9V battery and D cell batteries connected in parallel. The motor controller requires 9V input and motor controller board 6V input directly to the bank of leads that the servo motors connect to. The servo motors used are Hitec HS-7775MG motors [1].

Animatronic Face 2

The second animatronic face researched was created by Samuel Seide.The initial purpose of building the animatronic was to create an autonomous halloween prop without spending an absurd amount of money. The materials used in the animatronic are a prop skull, a PIR motion sensor module, one small servo motor, 2 high lumen red LEDs, a Ladyada sound shield, and an Arduino Duemilanove. Most of the electronics and microcontroller are hidden within the skull, while the LEDs lay within the eye sockets. Each LED is powered by the Arduino microcontroller and are rated for 2.5 V each, making the 5V output of the Arduino well suited to the task.The servo motor is attached to the hinged jaw to allow the jaw to open and close in response to any motion sensed in front of the animatronic. Whenever the voltage of the audio output increases above a certain threshold, the jaw opens, and whenever the voltage drops, the servo closes the mouth. Both the LEDs and the servo motor were connected to separate analog pins on the Arduino and the motion detector was connected to a digital pin. This was done so that the digital reading from the sensor could then be converted to an analog output for the LEDs and the servo motor [2].

Animatronic Face 3

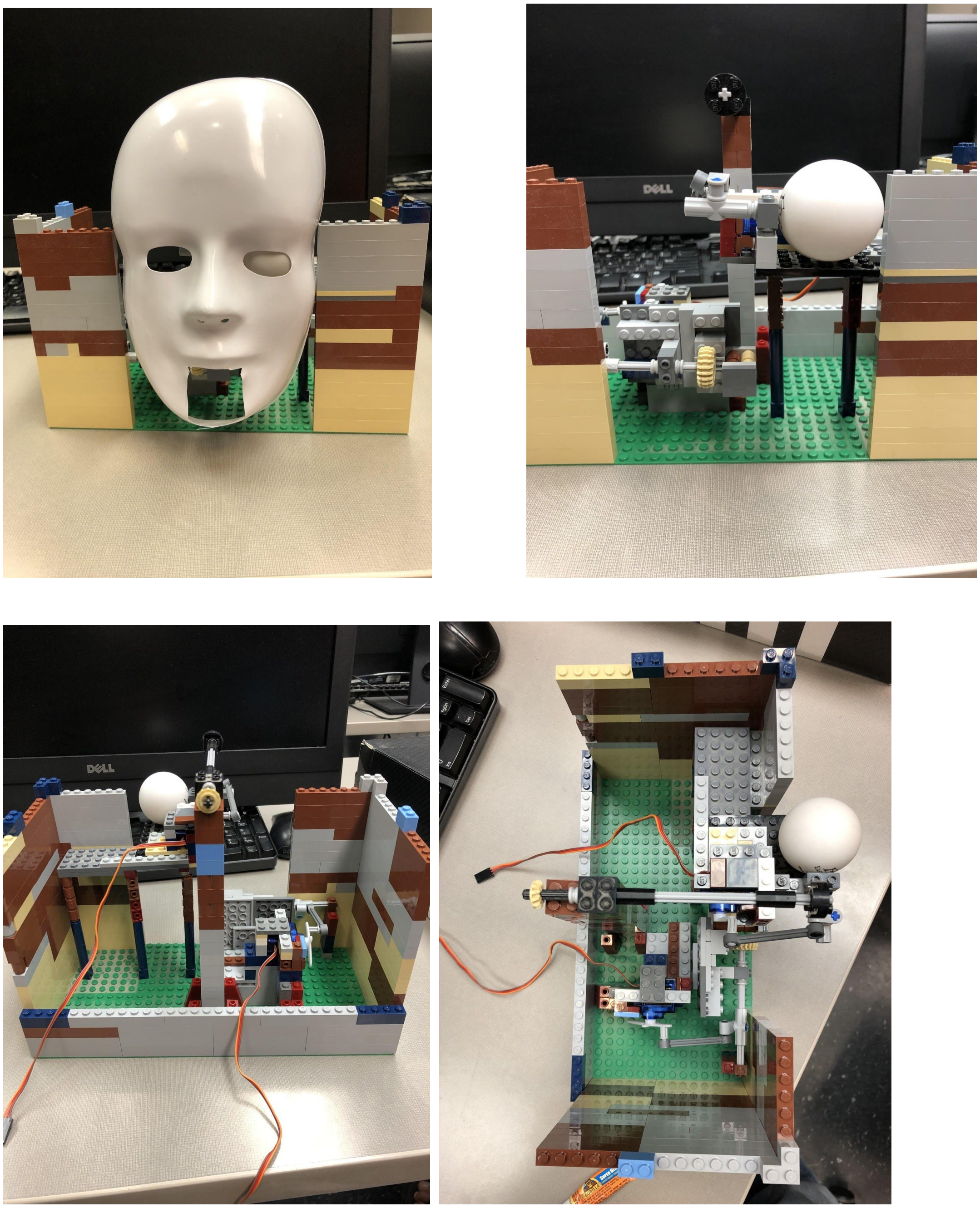
  

The last example of creating an animatronic face actually took on a larger project, making an entire animatronic head. This creation was designed by David Ng of Vancouver, BC, Canada and was made using sixteen servo motors, two mini-SSC controllers, an R/C unit, a Plexiglas skull, and some human impression pieces (wig, silicone skin, ect.). The abilities of this design include being able to rotate eyes, open and close jaw and eyelids, smile and frown, turn head and neck, and even make a kissing face. The programmability of David's animatronics allows for use in prop entertainment, live interaction, and being part of a larger more capable robot. Although the mechatronics aspect of the head was quite impressive, an improvement in the exterior of the head may be upgraded as to make a more visual pleasing and less robotic figure [3].

Section 2: Brainstorming

For the animatronics project, Group 2's assigned professor is Dr. Karimi. The team intends to have 3 moving joints in the animatronics face. The bottom jaw of the mouth will move up and down to simulate speaking, one eye will rotate forward to simulate winking at the audience, and finally the eyebrows will move up and down to simulate anger or surprise. All the moving components will be done by using a combination of servo and stepper motors. Two servo motors for the eyebrows, one stepper motor for the rotating eye, and one servo motor for the lower jaw. One sensor will be a motion sensor that triggers the audio response from the animatronic. The other sensor will be a touch sensor that triggers the second animatronic reaction of winking and raising the eyebrows in surprise. The chassis will be manufactured from common household items, specifically LEGOs, cardboard and Styrofoam. For the mouth, a hard-plastic mask will be overlaid with a rubber mask that the professor's picture will be attached to. The eyes will be ping pong balls that are painted accordingly to allow for rotation. The eyebrows will be made from cloth and either painted wood or cardboard. The audio file will be recorded with a team members phone and the audio file will be extracted. Both the Arduino and the stepper motors will be powered either with the Arduino power adapter or with multiple batteries connected to the Arduino. Lastly, the script for the specific audio that will be collected from the professor is as follows: “Conversions: you cannot add apples and donkeys together!”, a phrase frequently used by the professor in various lectures.

Section 3: Supporting Structure



Supporting Structure Including First Generation Joint Designs

For the supporting structure Legos were used, as mentioned in the planning section. One gear type device was created for vertical movement of the mouth which will be translated from a horizontal movement supplied by a stepper motor. A second device that translates horizontal movement to a rotation aids in moving the eye from open to close for a winking gesture, also supplied by a stepper motor. If time allows another supporting structure will be added to accommodate the motor used to rotate the eyebrows. Finally, the face is held to the structure using a rod that is superglued to a touch sensor which will provide interaction to users on the forehead area. The adhesive will be applied throughout the design to promote stability and allow multiple uses overtime without failure.

Both sensors, the ultrasonic sensor and touch sensor will be implemented into the Lego chassis and if necessary glued to the frame to prevent failure.

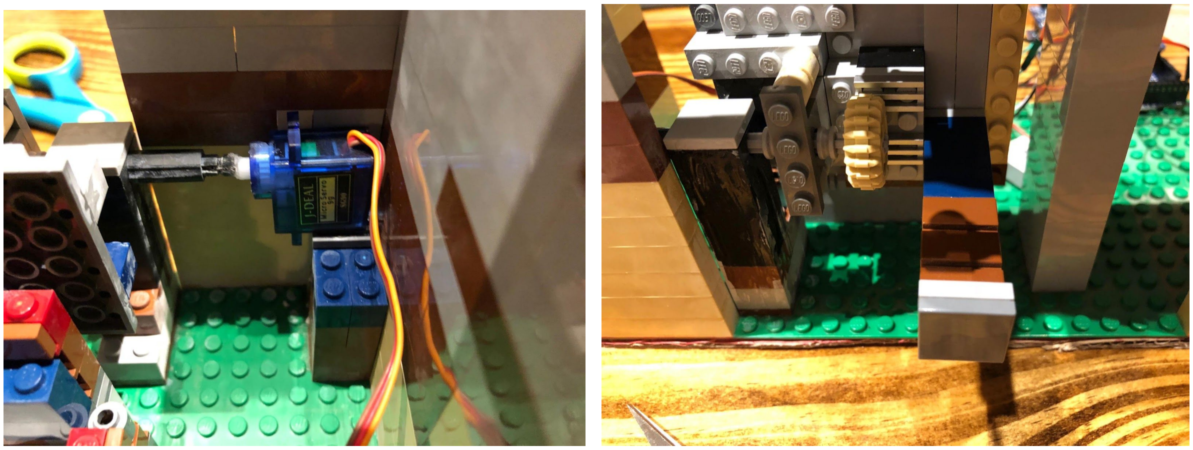
Section 4: Joints and Motors

For the eye a winking motion is imitated. This is achieved by rotating a ping pong ball forwards (towards the spectator). The ping pong ball represents an eyeball. The top half of the ball is painted to represent the eyelid. Therefore, when the ball is rotated forward it’s in its closed state, imitating a winking motion. The joint is actuated using a servo motor. The servo motor was chosen, because there are only two states, open and closed. Consequently, a servo motor is the best choice for this type of motion as no high precision movement is needed and a servo motor is easier to implement and interface than a stepper motor. The movement is activated by a touch sensor. The used code first defines the motors as servo motors and defines the connection pins.

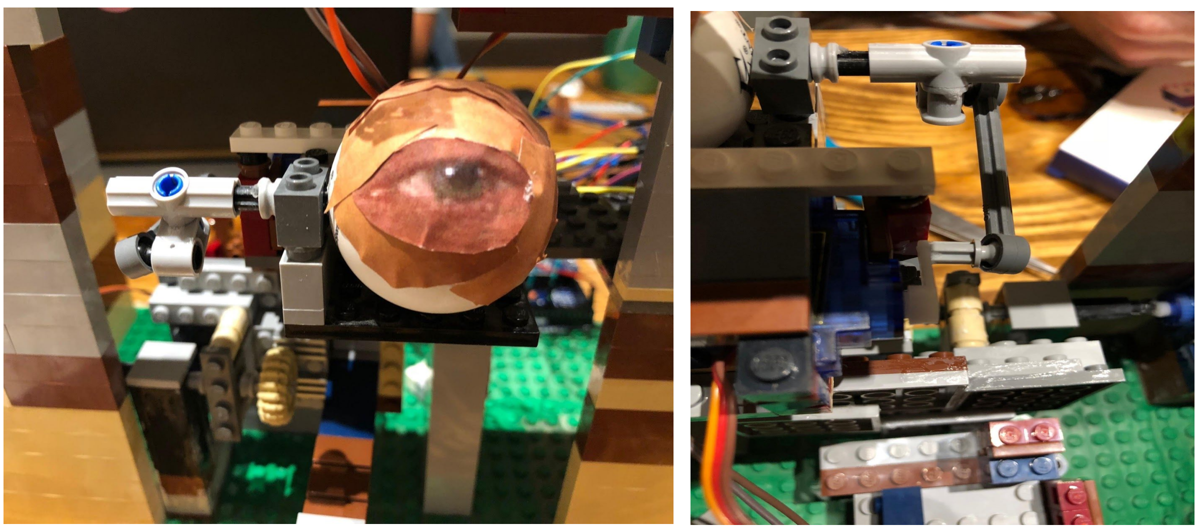
The second joint implemented is used to imitate mouth movement and a speaking motion. Again, a servo motor is used as it’s easier to implement and interface. For simplicity, the mouth is designed to have two states, open and closed. The accuracy of the motion is achieved by adding delays according to the words spoken by the animatronic face. One challenge regarding the joint is that the mouth movement isn’t a rotating movement. Accordingly, the rotating output movement of the motor is translated into linear movement using a gear wheel and a geared pin. The movement is activated by an ultrasonic sensor.

A third joint was implemented to allow for eyebrow movement. Rotating movement is translated to the eyebrow using a wire structure glued to the motor. The eyebrow movement correlates directly with the winking motion. This simplifies the wiring necessary and allows for both motions to run at the same time using similar code.

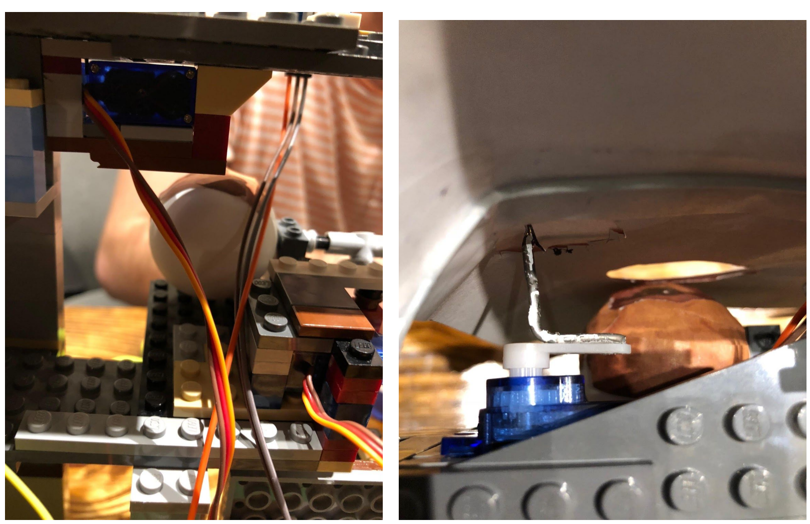
The code first defines the motors as servo motors and pins used. Next, the serial communication is implemented and the talking and winking motions described in a loop. The talking and winking were defined as separate functions, so they could run in the same loop. For increased accuracy a delay is added to stop flickering motions, this behavior was frequently observed for the ultrasound sensor if the source of motion was close to the sensors limit. Lastly, an If statement is used to correlate sensor input and motion. The motion is applied using the write command.



Mouth Joints



Eye Joints



Eyebrow Joints

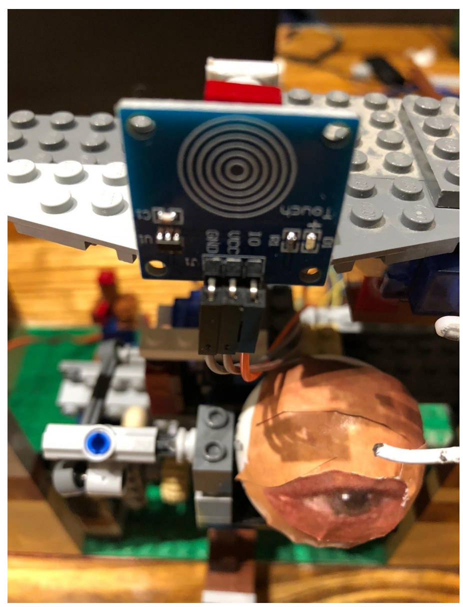
Section 5: Sensors

For the purpose of activating the loops controlling the animatronics face movements two types of sensors are installed:

1. An Ultrasonic Sensors is used to activate the mouth movement. It was chosen as to attract people towards the animatronic face and initiate the professor's voice recording. The ultrasonic outputs need to be exposed in order to allow the sensors to detect movements. Accordingly, two holes where built into the chassis to fit the sensor. (The sensor works by sending out ultrasonic waves and measuring interferences in the signal)
2. A Touch Sensor was chosen to activate the eye/eyelid movement and initiate the winking motion and also to activate eyebrow movement. The sensor needs to be firmly mounted to evade false input signals while also being uncovered to allow interaction. To allow for easy access a hole is cut into the mask, in front of the sensor module. The sensor is mounted in the center of the face behind the faces forehead. (The sensor works by measuring changes/increases in the output capacitance - it increases if a conductive object touches/approaches the sensors electrode)

As mentioned previously, both sensors are implemented into the supporting structure and superglued to the Lego chassis to prevent failure.

Ultrasound/Motion Sensor



Touch Sensor

Section 6: Programing for Interaction

The first step in the Arduino code was to initiate the Servo library so that the Arduino could use the multiple servo functions. The next several lines of code are dedicated to initiating several variables as servos, and to initiate the multiple pins of the sensor on the Arduino. In the void setup section, the declared servo motors were attached to two seperate digital pins and the value from the touch sensor is stored as an input for both the eyebrow and eye motors. Next, in the void loop section, we defined two of our own loops to occur, simultaneously inside the overall loop. This was done because the Arduino can not run multiple functions in the same loop simultaneously, hence multiple loops are required. The first loop called is for the mouth motor and the ultrasonic sensor. Multiple lines are dedicated to controlling the sensor and its output signal used to measure distance, and that signal returning determines how much time is used in the conversion to distance. It is then shown that when the sensor reads below 30cm, the first 3rd servo(used to press the spacebar for sound) is activated, followed swiftly by over twenty lines of code for controlling the motion of the mouth motor. Several delays were used to synchronise the motors movement with the audio. The values inside the parentheses of the myservo.write() function determine what angle the servo motor will turn to. After this, the second loop is called forward. The first few lines are dedicated to reading the values coming from the touch sensor. Because the sensor only reads two values, i.e. 1 equals high, and 0 equals low, those values are used to determine the reaction of the motor. If the value is high, the eyebrow and eye motor rotate from 90 to 30 degrees in increments of 2, and when the value is low, the motors rotate from 30 to 90 degrees in increments of 2. Lastly, the sensor input is printed in the serial monitor.

Section 7: Lessons Learnt and Suggestions

1. The project helped in learning to be flexible with design choices:

   Various issues or potential sources of failure were only identified at a late design stage. Accordingly, the design had to be adapted to provide a reliable final product. Some of the major changes made include rebuilding the chassis to increase sturdiness and make sure the Lego structure supports the weight of the wiring and motors, another design change made at a relatively late stage is the use of wire instead of a plastic mask to support a print of the professor's face. This change was made to improve the overall appearance of the animatronic face. After trying to glue the print to the mask is became obvious that the print dimensions don't match the mask dimensions. Using a wire structure solved that issue, as the wire frame could be easily adjusted/bent to accommodate the print.

2. The advantages of simplicity:

   As sensors, supporting structures, motors and wires were added during the building process, it became obvious that the simplest solution was mostly the best and especially the most reliable solution. Initially, we designed a more complex joint system to simulate mouth movement. This design was quickly scrapped and replaced by a design where the gear causing the mouth to move up and down is directly glued to the rotating part of the motor. This reduced the amount of moving parts, reduced the risk of failure, reduced the overall weight supported by the Lego chassis and most importantly it condensed the joint structure, creating space necessary to accommodate wiring.

3. Using online code libraries:

   Originally, we tried to develop the majority of the code necessary to initiate and control the motor movements ourselves. However, this process showed itself to be very tedious and time consuming. The solution were online code libraries. While animatronic faces aren't a particularly common project, many sections of code from other projects could be implemented and adjusted according to our criteria.

4. Plan ahead of time:

    While we tried our best to keep ahead of schedule and ordered all materials necessary in advance, we falsely assumed that the final assembly and especially the implementation of the voice recording would be a relatively simple task. For future projects it would be highly recommended to plan on having the project finalized ahead of time in order to have a reasonable buffer to solve unforeseen complications.

Suggestions for Improvement:

1. Better time management:

    Focusing more on the grading scheme provided by the professor to focus our effort and spend our time more efficiently.

2. Choice of base material:

    Using a base other than LEGOs in order to increase stability and minimize the use of other items like super glue and tape. While using LEGOs allowed us to build the faces chassis relatively quickly and also allowed for short-term adjustments, parts that weren't glued together had to be repaired frequently.

Section 8: Personnel and Bill of Materials

(a) Personnel

Task	Main Personnel	Secondary personnel
Structure/Chassis design	Jan Boeck Jusbasche	Vincent Perez
Face implementation	Ryan Hadley	Vincent Perez
Joint implementation	Jan Boeck Jusbasche	Ryan Hadley
Motor integration and interfacing	Ryan Hadley	Jan Boeck Jusbasche
Sensor integration and interfacing	Vincent Perez	Jan Boeck Jusbasche
Programming and Code assembly	Vincent Perez	Ryan Hadley

(b) Bill of Materials

No.	Description	Website/comment	Qty.	Unit $	Total $
1	Arduino MEGA 2560	Provided	1	n/a	n/a
2	Micro Servo Motor	Amazon.com, 5pc	3	2.35	11.78
3	LEGO's	Already Owned	n/a	n/a	n/a
4	Touch Sensor	Amazon.com, 5pc	1	1.40	6.99
5	Face Mask	Amazon .com, 12pc	1	.65	7.76
6	Computer Speakers	Already Owned	1	n/a	n/a

The total price for this project excluding the Arduino MEGA was **$26.53.**

amazon.com

Final Details for Order #113-5521064-3245057

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Order Placed: October 26, 2018
Amazon.com order number: 113-5521064-3245057
Order Total: $21.53

Shipped on October 27, 2018

Items Ordered	**Price**
1 of: *WINGONEER DIY 5PCS TTP223B Digital Touch Capacitive Sensor Switch Module for Arduino* Sold by: 3C4U@US (seller profile) Condition: New	$6.99
1 of: *Design Your Own White Face Masks Pack of 12* Sold by: WBO (seller profile) Condition: New	$7.76
1 of: *J-Deal 5x Pcs SG90 Micro Servo Motor 9G RC Robot Helicopter Airplane Boat Controls* Sold by: J-DeaL (seller profile) Condition: New	$11.78

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2010 CHITTIM TRAIL DR
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United States

Shipping Speed:
Two-Day Shipping

Item(s) Subtotal:	$26.53
Shipping & Handling:	$0.00

Total before tax:	$26.53
Sales Tax:	$0.00
Gift Card Amount:	-$5.00

Total for This Shipment:	**$21.53**
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Gift Card

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Total before tax:	$26.53
Estimated tax to be collected:	$0.00
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Grand Total:	**$21.53**

Credit Card transactions — Visa ending in 5144: October 27, 2018: $21.53

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Acknowledgements

Dr. Amir Karimi

References:

[1] Worcester Polytechnic Institute, Animatronic Face
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[2] Samuel Seide, Halloween Animatronic Face
https://www.instructables.com/id/Talking-Arduino-Halloween-Skeleton/

[3] Animatronic Face by David Ng, http://www.androidworld.com/prod66.html