BearMax: Social Robot for Social Skills and Emotional Regulation Project

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Section 1: Executive Summary

BearMax is a robot designed to help people with Autism Spectrum Disorder to recognize and understand various social situations. There are many different types of robots designed to aid in various therapies for children and people of all ages with special needs. Additionally, this team is the second version of this project so inspiration can be taken from the first BearMax as well. The main goal is to build a robot that is able to make people feel comfortable and welcome, and help facilitate social-emotional learning.

The team's motivation mainly stemmed from the mission of this project. Robotics is also an interest to both the mechanical engineering students and computer engineering students on this team. Teamwork and ensuring everyone was willing to put in a great deal of effort and commit to performing quality work was also vital to all members. While being the Version 2 team of BearMax comes with its advantages and disadvantages, and while we are concerned about accomplishing as much as the Version 1 team, this team is ready to rise to the occasion.

Some improvements that needed to be made in the new version of BearMax. Although we have not entirely solved our proposed problems as of yet as we have not constructed different features for Bearmax 2.0, we have made some significant design changes. As of now we have worked to identify technical problems of Version 1 and our designed Version 2 and we have proposed solutions to mitigate our chances of setbacks. These problems include issues with tipping, adjusting for the new neck design, modifications for a track platform. A major generalized issue was how we'd acquire parts which were mitigated by connecting to an off campus machine shop. We approached the problems by dividing the robot into sections from a conceptual model. Each member of the mechanical engineering team was assigned different sections. We then further analyzed our sections with proposed ranges of motion, comparisons to last year's design and similar social emotional learning robots, and input from the previous team regarding struggles in their design process. It was with these insights that we moved forward with our solutions ideas which we will implement as we approach Senior Design 2. Similarly, another improvement was designing a better electrical system. Instead of using one breadboard, we decided to use a PCB setup. This was a challenging yet rewarding learning experience for the computer engineering team members. Ensuring that all components are securely connected and supplied a sufficient amount of power will increase the time that BearMax is able to run without being attached to a power source. This is vital especially for the mobile aspect of BearMax. There were several learning experiences with scheduling, working as an interdisciplinary team, and the designing process. While most of the conflicts that arose were conceptual, it is valuable to recognize and solve them prior to building.

We hope to continue learning more in Senior Design 2 and are looking forward to acting on the plan we have made in Senior Design 1.

Section 2: Project Description

Project Narrative

Robot Assisted Therapy is a growing field, especially for assisting those with Autism Spectrum Disorder. Those with Autism often struggle with recognizing facial expressions and understanding social cues. To help those with autism learn, different robots have been developed with varying degrees of success. One popular therapy robot is the NAO robot.[1] This small robot has been studied and has been proven to be quite effective at helping those with Autism, specifically young children with Autism, to learn and practice social skills. Another example is the BearMax robot, developed by a previous senior design team at the University of Central Florida.[2] Its robot was able to achieve a wide range of motion and was able to be integrated with a mobile application. However, these robots, along with others of its kind, are not without their problems. The NAO lacks the ability to perform facial expressions and has trouble with accurate voice recognition.[1] The BearMax Robot also lacks the ability to use facial expressions and has issues with its power. The developers also wanted to integrate a wearable stress detector bracelet, but were unable to complete it in time.[2] Other robots of its kind face similar issues; some of their major drawbacks include lack of facial expressions and lack of mobility.[1] Our project intends to improve upon these limitations. This group specifically wants to focus on making an improved version of the BearMax robot. We intend to create a version that has an improved stress detector system, more facial expressions, and better electronics.

Project Goals

The main goal of this project is to create an avenue for children with autism, through the medium of a robotic companion, in order to help deal with the challenges they may face, especially as it comes to learning emotions and dealing with sensory overload. Specifically, we shall be tackling issues that limited the previous iteration of the BearMax robot in its function and building upon the many areas in which the team was able to make massive developments.

One massive drawback of the first design was that only a single breadboard strip was used for all electronics, and as a result once the current exceeded 1 ampere, the electrical system would fail, causing a loss of functionality temporarily until rebooting. A big part of what we desire is improving that electrical structure, implementing a PCB for the components and redesigning the system in order to allow for a larger current limit. Another issue of the previous group was the components for the wearable stress detection device arrived late, meaning that the central function of stress detection was unable to be met. Our goal is to interface the wearable stress detecting device with the robot in order to actually detect stress and allow the robot to respond in an appropriate manner, whether that be the robot itself calming the user, or signaling a caretaker. We plan the robot to have the ability to “see” a potential user in a demo mode if the wearable stress detection device is not currently being worn, but the robot is powered on through the use of computer vision software.

Furthermore, our team's goal is to improve upon the successes of the previous robot. Firstly, the previous robot was semi-autonomous. It did not need an outside controller to move it, but it still needed a caretaker or adult present. Our team plans to implement this in our new design of the robot. A further goal we have is to implement treads or wheels to allow BearMax to move around and detect users. Moreover, it still needs to be able to detect faces and read their emotions. It especially needs to be trained to recognize emotions within autistic children, as their facial expressions may be different from how neurotypical children would express emotions. The previous project was successful in having it recognize emotions. Our team wants to continue training it. Finally, the robot must non-verbally be able to calm the users. Its exterior shape and mannerisms must have a welcoming and comforting appearance. We have noticed that other social robots animatronics have a tendency to become creepy, especially when they are designed to resemble humans. This team aims to avoid that scenario. We plan on making the design smaller, if possible, and to give the robot more spherical shapes in the torso and eyes. That way, the appearance of the robot will seem gentle and safe.

Table 1: Project Specifications

Cost	Less than 500 dollars to manufacture
Dimensions and Weight	The robot must be compact enough to fit within a home on a surface such as a table. The maximum weight should be around 20-30 pounds.
Power requirements:	Must be powered by a 12 volt battery
LCD screen eyes	Each LCD "eye" must have a minimum resolution of 320x240 pixels. Or, the size of the LCD could range from 4x4 inches to 6x6 inches.
Emotional detection accuracy	Must be able to detect emotions near instantaneously, if not instantaneously
Reactions	Must be able to react to emotions of user immediately after recognizing them

Stretch Goals

The stretch goals for this project mainly include things that would aid in the overall function of the robot and system. A main thing would be to reduce the size of the shells of the robot in order to minimize the footprint of the robot, as well as increase portability and allow for ease of mobility. Additionally, increasing the joints and dynamic range of mobility of the robot would allow for more fluid movement and flexibility. In order to give the robot the ability to feel more communicative, we also seek to add movable eyes that would track the user, increased verbal responses, and a softer/squishier exterior for the robot to allow for a more friendly tactile stimulation, as well as implement fully automated movement so that BearMax can track its user. Fully integrating the wearable device within the BearMax is also a stretch goal for us, as this would allow for real time feedback on the user, providing things such as heart-rate, and other biometric data we could use for monitoring the user's state while interacting with BearMax. Finally, we would create multiple different options for shells of the robot, perhaps not limited just to a bear design, allowing for user customizations options, as well as making all shells interchangeable with a robot, so a household would be able to swap the exterior in case of breakage, or a change of scenery. Although these goals would be nice to meet, and effective in the overall presentation, they may require more time and effort with the implementation of the various other technical features that are simply necessary.

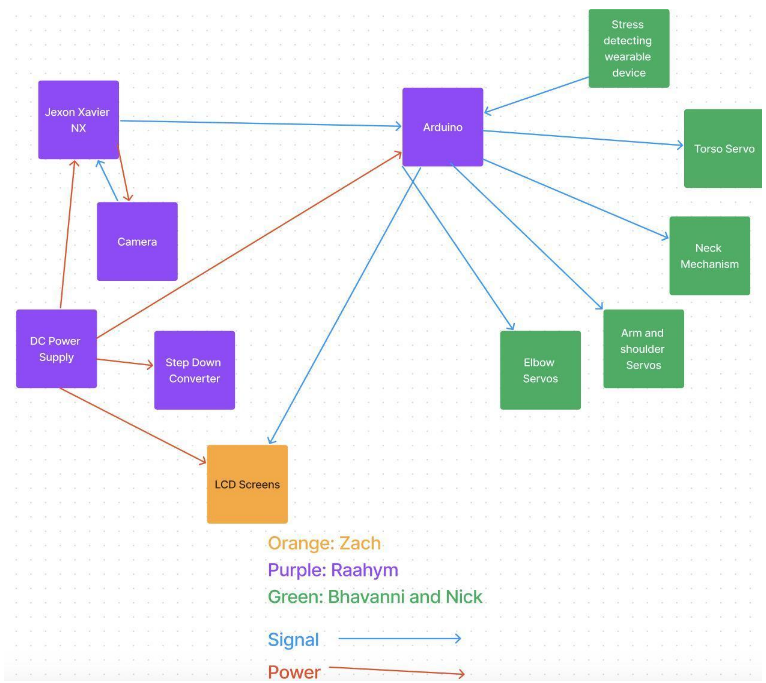


Figure 1: Hardware Block Diagram

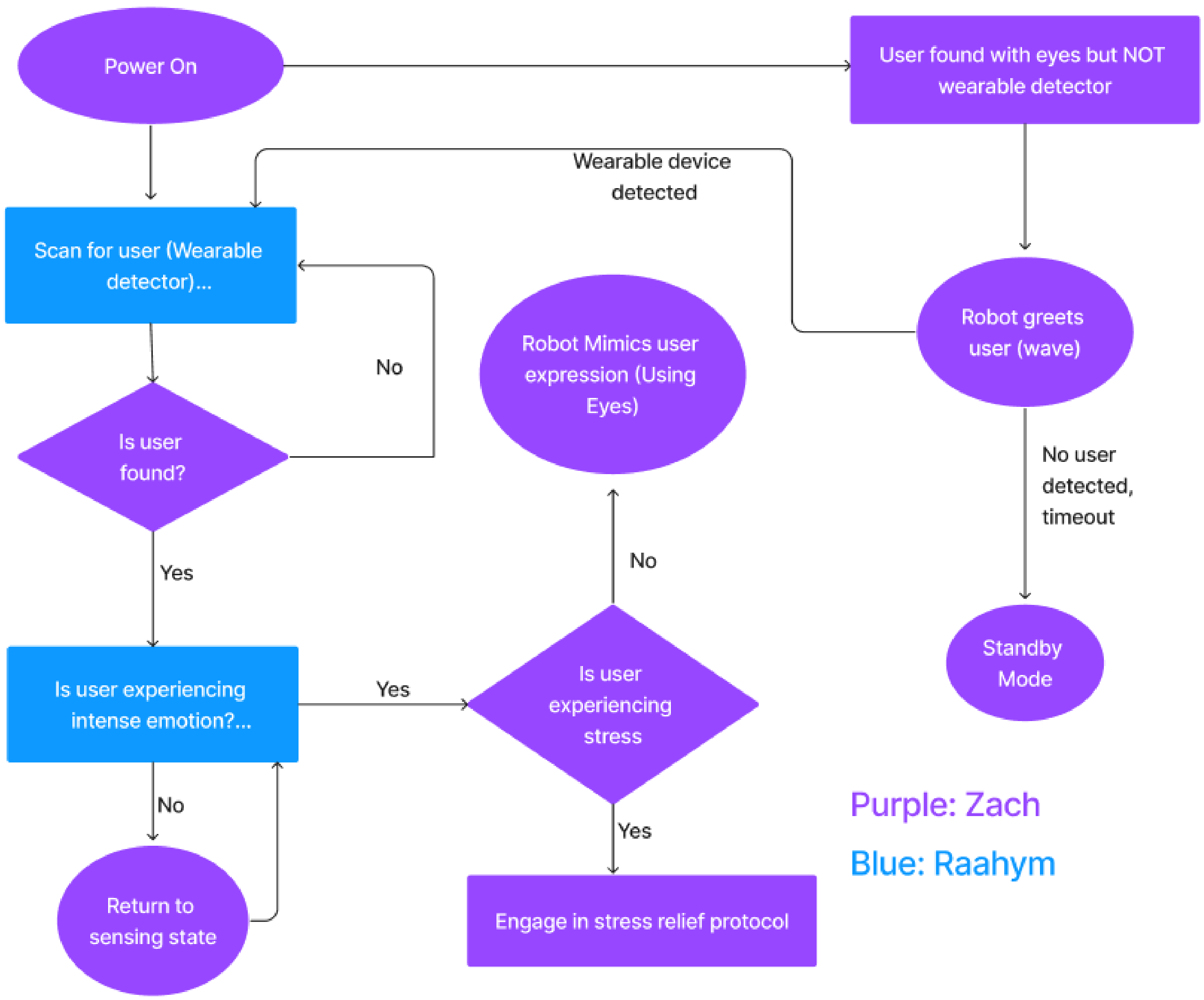


Figure 2: Software Block Diagram

Figure 3: Function Breakdown

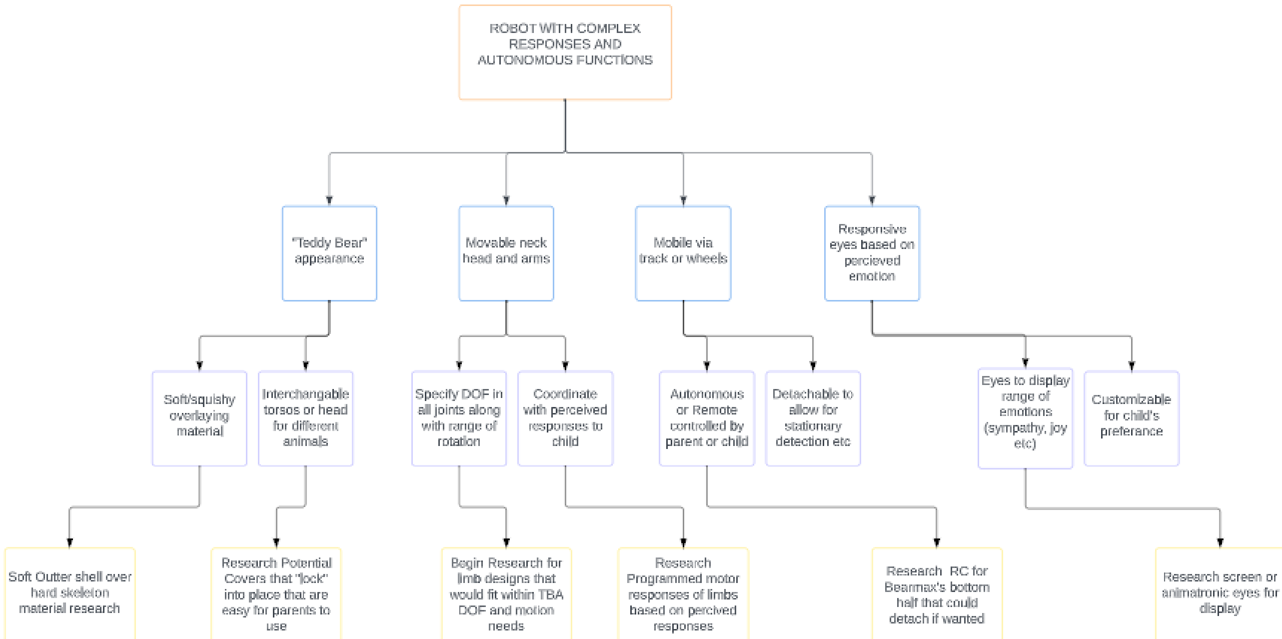


Figure 4: Initial Component Breakdown

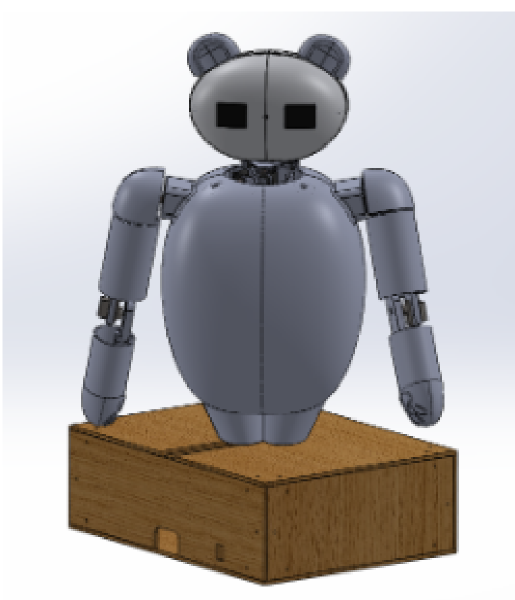


Figure 5: 3D Model of the BearMax Version 1 [27]

Figure 6: BearMax Version 1 Model [27]

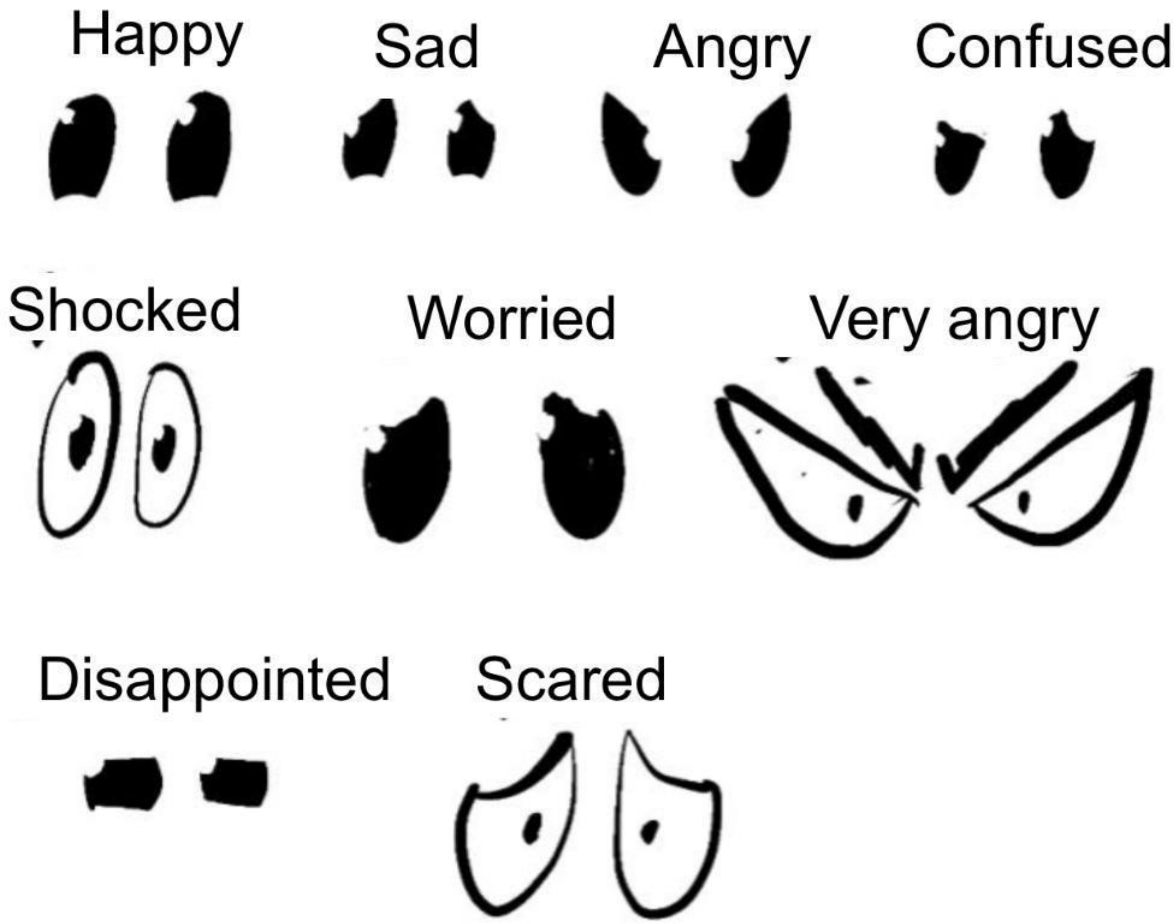


Figure 7: Initial Concept Sketch of the emotions the eyes of the robot should express

Preliminary Research

There are advantages and disadvantages to being a part of the second version of this project. An advantage is there is a lot of information and a Version 1 model to improve on, however there is also this pressure and expectation to at the minimum meet the previous version's standards and add onto the previous team's accomplishments. From discussion with a previous team member, the previous version's servo motors did not function to their full capabilities due to the large amount of torque pull being required of the motors. Another issue was the electrical system, specifically excessive current drawn from only using one breadboard which was a design choice due to not being able to enclose more components within the size parameters initially set. Finally, for the exterior design, the previous team member discussed that it can be improved, and different materials can also be used. This information provides direction and guidance in research and planning for this project and Version 2 of BearMax.

It is important to consider the target audience of this robot, which is children who are or are not on the spectrum. There are several robots that facilitate learning for children and the bond a child develops with their robot learning companion has positive impacts on their ability to bond with their human peers and teachers [11]. The first step to this is to develop a robotic companion that the child can easily bond with. BearMax Version 1 had a 3D printed hard, plastic exterior. Other robots that are designed for social-emotional learning or interaction, have an exterior similar to stuffed toys like “Mox” in Figure 8 [12]. While Mox still has some stiffer materials used, the robot’s surface is mainly soft because of the fabrics used. This robot could make a child feel more comfortable, welcome, and calm prior to and during the interaction. Most children may be used to seeing stuffed animals and toys and taking inspiration from models such as Mox, BearMax could also have a similar exterior that could help create a more familiar and safer environment. For the robot to create a welcoming atmosphere, in addition to the exterior, it is important to ensure the internal components all function as intended.

Figure 8: “Mox” a robot known as a Dragon Bot designed to play games with kids to help learning [12].

A well-designed mechanical and electrical system is required for proper function and for BearMax to be successful. Servo motors were largely used for the first version, and it is important to understand the reason. Servo motors are used commonly in robotics and are considered ideal in circumstances where position precision is a priority as opposed to speed [6]. High torque servo motors can be selected to assist with the robot’s motor control, though the issue with current draw still remains and overheating is something else that needs to be considered. While it is possible for a circuit design involving multiple breadboards and an Arduino to work, it should all fit within the BearMax model.

The BearMax model's body can be made larger, specifically wider, allowing for two breadboards and more powerful motors to be housed. For overheating, it is recommended to select a motor with lower current, however, it is known that torque is proportional to current; a lower current motor conflicts with the need for high torque [9]. To resolve this, motors can be selected with different torque capabilities and used for different sections. For example, for the head and arms, higher torque servo motors can be selected, whereas for the ears, hands, and other smaller parts, lower torque servo motors can be used. Version 1 only used one breadboard and due to the high number of motors and their current draw, there was overheating. By increasing the body size, this issue has high potential of being resolved by adding a second breadboard. To maximize size, the design can include using one motor driver for two or more servo motors. Depending on the purpose, the motors can be connected in series or parallel. In version 1, the ears were unable to move, and the arms were difficult to move with the motors. This can be addressed as we are aware beforehand of the potential complications, by selecting servo motors with different specifications.

To know the number of components required, the different aspects of the robot need to be considered. This version of BearMax has a focus to increase the degrees of freedom of different components in the system. There are many types of joints that provide the opportunity to have 2 or more degrees of freedom, as shown in Figure 9. A spherical joint has 3 degrees of freedom and is similar to a ball and socket joint, typically used for the eyes of a robot. This can perhaps also be used for the neck of the robot. The neck and head of the robot will be the main focus in version 2, to be able to depict and communicate a wider range of emotions and subtle changes in each emotion. For example, for sadness, the robot might tilt its head down paired with sad eyes, for expressing deeper sadness there could be a deeper head tilt and change in the eyes as well. If we want the robot to express that it is perplexed, we need the head to tilt sideways. This will require a three-axis rotation of pitch, roll, and yaw. We will most likely need to combine multiple types of joints into one system

Joint type	dof f	Constraints c between two planar rigid bodies	Constraints c between two spatial rigid bodies
Revolute (R)	1	2	5
Prismatic (P)	1	2	5
Helical (H)	1	N/A	5
Cylindrical (C)	2	N/A	4
Universal (U)	2	N/A	4
Spherical (S)	3	N/A	3

Figure 9: Table depicting different types of joints and the degrees of freedom it provides and constraints involved [10].

Furthermore, the hands and arms can also be paired/aligned with each emotion being depicted and provide a more expressive response from BearMax. Learning gestures has been found to be closely related to language development in some children with autism [13]. Body language is also difficult to understand for people with autism spectrum disorder (ASD) [7]. BearMax provides that extra step of gesturing with hand motions/movements in addition to head movements and emotions of the screens of the eyes is intended to aid in that gesture and language development, providing an additional factor to the social-emotional learning.

Table 2: Robot Comparison Chart

Robot	Target Demographic	Features
Mox [1]	Unspecified age group	Head exterior similar to stuffed animals, plays learning games with children, has touch sensors in place so can react if children pat the head or shake the hand
Moxie [2]	Children ages 5+	AI led chat feature, discuss interesting topics with user, tell jokes, tell stories, practice breathing exercises, help user draw picture. Durable yet soft to touch, huggable material, similar to silicone.
PEERbot: Migo [3]	0-6 years old	Customizable to child's needs; create age-appropriate lessons, read books with child/tell stories. Soft, huggable exterior material like plush toy.
QT robot [4]	8-14 years old	Visually expressive humanoid robots help express children's emotions better and be more expressive with feelings. Helps children with Autism Spectrum Disorder (ASD) to better recognize the emotions of others as well as communicate their own needs.
Mabu [5]	Elderly (ages 50+)	Humanoid robot provides reminders of daily tasks, to take medications, makes suggestions of diet options, recommend particles to call a doctor when needed, engages in conversation, has a touch screen tablet for patients to interact with.
Milo [5]	6-18 years old	Verbal lessons paired with various facial expressions, repetitive lessons without tiring the user. Acts as a tutor and encourages learning.

Pepper [6]	6-18 years old	Recognizes faces and basic human emotions, engages in communication through speech and via touch screen tablet on body of the robot (for nonverbal children with ASD), tell stories, play calming music/soothing songs, touch sensors on head and reacts positively when children pet the head.
Yale robot [7]	Unspecified age group	Lead interactive lessons, play games on a separate monitor, help improve and encourage eye contact, help initiate communication, help maintain focus and interest.

Pepper Robot from ELTL Review

When researching different social robots, our team discovered the Pepper Robot. It is a humanoid social robot that can detect faces and recognize emotions. It also has a tablet on its chest, which can be used for communication. While researching, we found a few studies from a research firm called the Equitable Learning Technologies lab concerning the use of the Pepper Robot in a school for autistic children[22]. In this study, the researchers introduced the Pepper Robot to students for three weeks to study how they would interact with the robot. Unlike other studies, however, the researchers did not define a clear schedule or agenda for how the robot should interact with the students. Rather, the researchers let the students interact with the robot however they wanted. This approach follows the researcher's belief that studies for those with autism should not simply be dictated by researchers. Rather, autistic people participating in these studies should collaborate and voice their own opinions about the research. As they say, "the robot interaction design is typically a top-down process: experts (typically SEN teachers or autism specialists) suggest age- and development-appropriate activities, implemented on the robots by engineers, and deployed in schools." This firm instead wanted to understand the perspective of the autistic children and how they felt about the social robot. After all, the "growth in autism research necessitates corresponding attention to autism research ethics, including ethical and meaningful inclusion of diverse participants." The study proved to be successful as teachers at the school commented that their autistic students became more social and talkative. One teacher even noted that some autistic children, who were previously averse to physical touch, were seen holding hands and hugging the robot. In another scenario, a student, who previously did not talk to people, was seen having conversations with the robot. From this study, our team learned several valuable lessons from these studies. These lessons include what ethical guidelines developers need to follow for developing robots for children, the capabilities of the Pepper Robot and how it helped the autistic children, ways in which social robots can be implemented in schools, and disadvantages of using the robot.

The United Nations Children's Fund, or UNICEF, has outlined several guidelines for developing robots for children. [23] These guidelines include ensuring the inclusion of and for children, protecting children's data and privacy, and supporting children's development and well being. During the research study, ELTL ensured that the use of the Pepper Robot followed these guidelines. Firstly, the study made sure to include children in the development of the robot, rather than having specialists dictate how the interaction with the robot should be. Additionally, the robot's facial recognition feature was not used during group settings. That way, the robot would not single out one student and all the other students could feel like they were participating. For our project, we are also looking into how the cameras in our robot can detect human faces. However, we learned that we ought to consider what to do in group settings. Secondly, the Pepper Robot was not connected to the Internet. That way, no hackers could remotely hijack the robot and steal data or otherwise do any sort of harm. Furthermore, any data that was collected on the children was modified to avoid recording personal information. This included removing the names of the children; they instead assigned letters to the children. For our project, since our robot will be connected to the internet to be connected to a mobile application, it will need to have a robust and secure connection, lest any hackers try to steal data or tamper with the robot. Another way the robot was able to conform to UNICEF guidelines was by providing different activities to support the well being of the participants. These activities included dances, music, and storytelling. Whenever a student felt a specific emotion, such as anger or happiness, the student would notify the robot by pressing one of the emoticon buttons indicating their mood. Then the robot would suggest activities to calm the child. In order to ensure the child did not just skip through the list of activities, and to make sure the child learned to listen when someone is speaking, the robot would verbally name the activities as they were being introduced. For our project, we intend to do the same, except that each emotion will have a specific activity designed to manage it. For example, if a child chooses anger, that child will be introduced mainly to calming music or other activities. Furthermore, there will be an option to go back after choosing an emotion. That way, if a child mistakenly chooses the wrong emotion, they can go back and choose the right one. This happened at least a couple of times with the Pepper robot, so we would like to avoid that. By using these guidelines and understanding how they can be implemented, we can create a safe, welcoming, and positive experience for autistic children using our robot.

Reading these studies also gave this team a thorough understanding of the Pepper robot's capabilities. The robot can converse with individuals, perform dances, recognize faces, and facilitate activities using the tablet on its chest. The robot is also not teleoperated. It can go wherever it is directed to go and operate in a semi-autonomous manner. It still required supervision from the staff, however. Even so, the robot's semi autonomous manner and activities provided students with a meaningful, and fun, experience. While the robot's physical capabilities were apparent, we also observed some unexpected yet unique capabilities of the robot. We observed that the robot has the capability to be a kind of friend to users. When surveyed, many of the children reported that they see the robot as a kind of friend. They certainly treated her like one too. Whenever students passed by the robot, they would say something like "Hi Pepper." Many of the children also enjoyed touching the robot like hugging it, cuddling it, or even placing their head on the head for head massages. Surprisingly, some of these children previously did not accept physical touch; it was like the Pepper robot had shown them how wonderful physical touch can be. Furthermore, the children loved to have conversations with the robot. Some students liked to talk about what they were feeling or how their day went. To them, it was their way of regulating their emotions. The robot, however, could not respond to their conversations, taking more of a listener role. In perhaps a tragic consequence of the experiment, one student was distraught that the robot was leaving towards the end of the study. These events seem to demonstrate that the robot was not only capable of conversing, albeit in a limited manner, and entertaining the children, it was also capable of showing the children how to be a friend. This resulted in the children becoming much more sociable and much better at handling their emotions (citation needed here). In studying this robot, we determined that we should integrate many of the abilities of the Pepper robot, such as the activities and the physical movements. However, we also wanted to add details that could improve the robot. For example, we would like to add eyes that can express emotion to the children. The Pepper robot only has unmoving camera eyes and a smiley face. Although appealing, some have remarked that the unblinking eyes seem rather creepy. It also does not display emotions such as happiness or sadness. Our robot will have eyes through an LCD that can display a range of emotions, from sadness to excitement. Doing this allows for the robot to, in a certain sense, empathize with the users as its emotions can be a response to the user's emotions. The team is also looking into adding large language modeling (LLM) so that it can talk back to users whenever a user says something. By implementing these features, we can ensure that users of this robot are provided with a fulfilling social experience.

While the Pepper robot proved to be promising for the development of autistic children, it also has some downsides. The most notable disadvantage we found was that a couple children hated the Pepper robot. One was afraid of it since they were afraid of technology breaking or malfunctioning. The other simply hated the sight of it. The other staff members had to make sure that this student could avoid the robot at all times. The researchers asked if it would be appropriate to end the study because of these incidents, but the staff insisted on continuing the study. After reading about this, we learned that we must ensure that our robot is functional enough to instill confidence in its users and must appear non-threatening. Moreover, we learned that not everyone will like our robot. As difficult as that is for us to accept, we learned to do so anyway. One other limitation of the Pepper robot is that it could not talk back or have a conversation with the students. A chat-bot-like feature was suggested; which is why our team wants to implement the large language model into our robot. Finally, the Pepper robot can also have some key issues that also prevent other social robots from being implemented. This includes cost, limited interactions on offer, and the inability to use different robots with the same software. The Pepper robot reportedly has a cost of one thousand five hundred dollars and can only be controlled through the tablet and by holding Pepper's hand and guiding it. Although, it does have a wide range of activities for users to explore. For these reasons, we intend to make our robot more affordable and have the ability to move around by itself. We intend for it to be able to see objects in front of it and avoid them. The software that connects to the robot will also be accessible by a mobile application.

The Pepper Robot, according to the study published by the Equitable Learning Technologies Lab, is an effective tool for aiding in the positive development of autistic children. It can play music, dance, read stories, and have conversations with users, all of which can be very beneficial for early childhood development. To better optimize the robot's capabilities, the robot was situated in a controlled environment, which was a school for children with special needs, where an adult supervisor was present and constantly watching the robot. Creating an environment like this allowed for the robot to be used properly according to UNICEF guidelines on AI development and use for children. Staff members reported that student social behaviors noticeably improved after this short study and reported that some of the students even missed the robot. The students themselves noted that they enjoyed their time with the robot and many saw it as a kind of friend. Although it has proven to be effective and provide substantial benefits, it is not perfect. For one, the cost of the robot is too great for many schools as it costs one thousand five hundred dollars. Additionally, the robot could have conversations with children, but they were quite limited. They could not, for example, respond back to a child if that child were expressing their emotions. Finally, it became apparent during the study that not everyone will like using the robot. At least two students in the study reportedly hated or feared the robot and actively avoided it. Our project will keep these findings in mind as we develop our version of a social robot. We will try to implement the best features of the Pepper Robot while also attempting to avoid implementing its drawbacks.

House of Quality

The purpose of a House of Quality is to consider customer requirements and the engineering specifications that are necessary to achieve the customer's needs. The House of Quality with the weights of customer requirements, engineering requirements and relationships between these are shown in the diagram below.

Relationships	
Strong	●
Moderate	○
Weak	▽

Row #	Weight Chart	Weight (%)	Customer Requirements (Explicit and Implicit) / Engineering Requirements	Flexible, soft outer covering	Durable material (for exoskeleton)	Weight (kg)	Cost ($)	Safe components, covered /padded sharp edges, multiple tests/trials prior to client/user interaction	Setup time (s)	Motor torque (N*m)	LCD eyes with programmed expressions	Motor speed (rpm)	Range of motion (degrees)	Remote controlled track system	User input options (touchscreen, microphone)	Speaker (dB)	Capable of expressing 10 different emotions	Programmed autonomous movements and responses	Camera, armband heart monitor and stress sensor
1		2%	Resembles a stuffed animal (bear), appealing appearance to children	●	○		○	▽			▽			○				○	
2		10%	Durable	○	●	○	○	●		○	○	○	○	▽	○				
3		2%	Lightweight	▽		●	▽	○		○			○	○		○			
4		3%	Low cost	○	○	○	●	●	○	○	○	●	○		○	○	○	●	●
5		10%	Safe	▽	○		○	●	●	○		○	○			▽		●	●
6		2%	Easy to setup		▽	▽		○	●										●
7		4%	Expressive body movements	▽						●		▽	○		▽		○	○	▽
8		4%	Expressive eye movements								●				▽		○	○	▽
9		4%	Capable of arm movement	○						○		●	○				○	○	▽
10		4%	Capable of head and neck movement		○	▽				○		▽	●				○	○	▽
11		5%	Capable of moving and walking with user		○	▽		○				○		●					
12		12%	Communicates with user in multiple ways (inclusive ie nonverbal users)						▽			▽	○		●			●	○
13		12%	Provides audio and visual feedback				○		▽	▽	●	○	▽	▽	○	●	●	○	○
14		12%	Helps children learn emotions	○							●	○	▽		○	○	●	○	○
15		7%	Keeps user(s) engaged	○						▽	○	○		○	●	▽	○	●	○
16		7%	Attentive to user specific needs/wants				○		▽									●	●
Total		100%																	

Figure 10: House of Quality

Section 3: Technology Comparison & Parts Selection

3.1.1 Microcontroller Unit Comparison

Embedded systems, as it comes to computers, are a field of engineering/programming in which we design a system with an integrated computer which controls the processes integral to the desired operation [1]. Essentially, this breaks down to a system which uses a computer, but is not a computer in its operation, and is used in many real world applications such as car systems, household appliances, and most relevant, robotics. In applications, we use a type of computer known as a microcontroller unit (MCU), which typically consists of a processor, memory, and I/O peripherals on board. MCUs come for many different types of systems, but in this section we will cover different types of MCUs that are commonly used in the field of robotics, and how we will consider the different specifications of each to use for the BearMax project.

As it comes to a full robot, the needs the MCU must support are very different compared to a regular embedded system, robots need things such as IP connectivity, security functions, and advanced algorithms controlling many aspects of the robot. This means the specs we need in an MCU must meet certain criteria in order to support the whole BearMax functionality, so running the emotional classification database, object and facial recognition, and sensors. Finally, the development board we choose to use shall act as a control hub for the components of the robot such as the power source, motors, distance sensor, camera, microphone, and speakers.

Many MCUs exist for robotics, however in order to determine the best one we will take into account the power consumption, size, cost, software supported, and the ability to run the emotional detection algorithm for the features of BearMax. The needs of the BEARMAX project also necessitate an additional board in order to ease the computing load.

Table 3: Summary of Development Board Technology Comparison

Development Board	Cost	Clock Speed	Power Consumption	Memory	Size
Arduino Mega Rev3	$40	16 MHz	1 - 5 Watts	8 KB SRAM, 256 KB FLASH	100 x 53 mm
Raspberry Pi 4	$30-$40	1.8 GHz	3 - 5 Watts	8 GB SDRAM	85 x 60 mm
NVIDIA Jetson Xavier NX	$500	1100 MHz	10 - 20 Watts	8 GB LDDR4	69.6 x 45 mm

Arduino

A popular choice in recent years for robotics and many other forms of beginner projects, the Arduino company stands as a prominent contender for an MCU our project could use. While there consist of many different Arduino boards to choose from, the main one we considered was the Arduino Mega Rev3 which boasts 54 digital I/O pins, 16 analog inputs, 4 serial hardware UART ports [2], and many more features that make it especially effective for a large-scale project.

One of the best advantages when it comes to this board is that it offers a great amount of these I/O pins, and since we will be using many separate small components to control the motors, sensors, cameras, and other peripherals, this huge number is definitely necessary. As it comes to things such as power this board is compatible with the overall parts we need as it accepts an input voltage from 3.9-16V [3]. The 8-bit processor and 256 KB of flash memory also are more than enough when it comes to development.

The biggest upside of any Arduino board is the ease of usability; The community online and many peers utilize this hardware for their projects, meaning many resources, libraries, and guides exist online in order to fully tackle most roadblocks and hardships that would arise in our project.

Raspberry Pi

The Raspberry Pi board is another popular choice in beginner projects, boasting many features such as greater processing power, memory, and connectivity options compared to most Arduino boards [4]. The specific Raspberry Pi board we will be looking at in this section is the Raspberry Pi 4, one of the more recent releases from the company, which has a 40 pin GPIO header, about 26 GPIO pins, 4-pole stereo audio and composite audio port, and 1 GB of memory, plenty for any project one would want to take on [5].

Similar to many other boards, the number of peripherals supported by the Raspberry Pi 4 is great, as this board is used to run projects with high demands when it comes to memory and processor power. This along with the fact that all Raspberry Pi boards come with support for the Linux operating system allows for much more versatility than other development boards such as Arduino's. By default the board supports the C and C++ language, but through installing other software it is possible to compile and run any number of programming languages. Another advantage of the Raspberry Pi hardware is similar to a previous point in a previous section, that the online community is quite large especially as it comes to large scale projects. There exist many tutorials online, libraries to access, and forums one may check in order to get a good idea for most issues.

In terms of technical specifications and support, the Raspberry Pi 4 board competes with many development boards on the market, but being a good development board is not the end all decision of how we can use the board for this project. One issue we run into is cost, as this board has a pretty steep price, especially if wanting better on-board hardware. Further on this point, due to scarcity of some parts, this board becomes unavailable for large periods of time, so if needed the board may arrive much later than is allowed for the project's time frame. Power consumption as it comes to this board is especially high since it has such a powerful processor and supports an entire operating system [4]. Our final issue with this development board comes from the difficulty of use. Although many beginners use this board for projects, it is by no means a beginner board, as installing the operating system, using libraries, and configuration takes more effort than other boards, so despite the benefits and upper-hand the Raspberry Pi 4 has over the Arduino Mega R3, the Arduino is simply an easier board to use. Overall, the Raspberry Pi 4 is powerful and complex, definitely a good choice in most projects, but for our purposes it may be more complex and technical than we need, and we may cut down costs and time by choosing a simpler piece of hardware.

Jetson Xavier NX

An important detail when it comes to the needs of the BearMax project is the ability to store and access the machine learning model associated with emotion detection. Most basic boards on the market do not support the capacity for a large scale AI model, and the ones that do although it is possible can run slow when they have many different sub-components to consider. However, the NVIDIA Jetson Xavier NX is a development board specifically designed for deep learning, large language models, and generally using real-time inferencing and processing of neural networks [6]. With AI performance rated at 21 TOPS (trillions of operations per second), a 384 core GPU, along with insanely fast processor speeds, the Jetson ends up blowing most of the competition out of the water. Finally, allowing for UART, I2C, and SPI I/Os allows for more peripherals to be used between components.

The Jetson's purpose is for AI development, meaning the board supports numerous machine learning libraries such as PyTorch, TensorFlow, along with many others. Due to this, the Jetson is well supported for projects involving image classification, object detection, and large language models, all of which are necessary aspects of the vision of the BearMax project. The emotional detection feature itself requires both image classification and computer vision. Further plans for the automated movement require object detection as well. One of the most important things is the capacity for the Jetson to process real-time requests with the model, known as edge AI computing, this means that the Jetson does not need to have a server along with it to process the requests and feedback response signals, it all happens on board [6].

Mentioning a downside is tough to find, but the biggest one is definitely the steep cost for the board, costing an average of $500 for the model we will need. However that being said, certain parts are available to our group for development already, including this board. Meaning that this is not a huge factor. Another downside is power consumption, since the board must run calculations, processes, and interface and communicate with many other separate components of the robot, this board has a power consumption even greater than the Raspberry Pi 4. However, the power consumption overall can be handled by our design as a whole, so even these disadvantages aren't enough to bring the Jetson down too much.

3.1.2 Development Board Selection

As stated prior the criteria we are most considering are power consumption, size, and the ability for an MCU to act as a hub for all of our electronics, meaning we needed ample GPIO ports available for use, additionally we must be able to house the machine learning models for emotional recognition for the user of BearMax. With this being said, we have decided that for our purposes, we would use both the Arduino and the Jetson boards for their own specific purposes within the robot. Our main reason for doing so is the availability of both boards, as the WEAR lab has the ability to provide us with these with no additional cost, meaning we are able to allocate our expenses to other components that may need it.

The Arduino Mega Rev3 will act as the hub for components such as motors, wires, the camera and other similar components due to the availability of many GPIO pins, ample memory, and fast processing capabilities. Arduino boards are compatible with many different libraries, languages, and support many different types of components that are directly made to be configured with Arduino, such as screens, cameras, speakers, motors, etc. Finally, the size of the Mega R3 board is not an issue, as the designs for the body will have to be specifically modeled to fit the internal components.

The NVIDIA Jetson Xavier NX board will also be used for this project due to its specific purpose being to support embedded edge computing with deep learning and machine learning models. Due to this, we will be using the Jetson in order to store the models created by the CS team for emotional recognition. Additionally, we will have this component linked directly to our power supply, then the Arduino will draw its power from the Jetson, and other components from the Arduino. Our camera will also be directly connected to the Jetson in order to properly implement computer vision capabilities easily, making our plan to have the Jetson communicate to the Arduino the correct movements to take place.

3.2.1 Camera Technology Comparison

The camera is one of the most crucial parts of the BearMax project, as it is what will be allowing for the robot to see and capture necessary data in order to properly detect the emotional state of the user. Our plan is to connect the camera unit to the Jetson as this is the unit hosting the computer vision capabilities. Furthermore, when choosing a camera for computer vision we have a number of different criteria to consider for the ease of capturing information. We will also be searching for a camera with a built-in microphone, as a microphone is also needed and if we can combine the components and find a microphone that meets our requirements Due to this, we will be considering factors such as camera resolution, size, power consumption, speed that objects can be detected at, serial communication standards used, framerate, and cost, as well as the effectiveness of the microphone [9]. In this section we will break down these factors and highlight why they are important to determine.

As stated prior, in order to have proper emotional detecting behavior, we must look at certain aspects of the camera for the use of computer vision. Since we plan on the robot being able to detect users and objects while it is mobile, the kind of camera used must be able to provide a "good enough" image for use in detection algorithms. This means we must consider resolution, framerate, shutter speed, low-light level functioning, along with other considerations.

Camera resolution is the ability for an image detecting device to resolve two points that are close together [8]. This essentially means that a camera with a high resolution has the ability to detect points that are very close together, or an object that is further away from itself. The resolution the camera itself has is further influenced by the exact dimensions and resolution of the lens on the camera [9]. Some lenses will expand the field of view (wide-angle lens), while some can add depth to the image (telephoto lens), but for our purposes a lens may not be needed to distort the image. Another consideration comes as the frame rate, which refers to the number of images captured and transmitted per second [9]. While this term is usually used when considering video capture footage and display, for static images and displays it can matter greatly. Having too low a frame rate will cause the system to overall be unresponsive, and after a certain frame rate going any higher will simply not make enough of a difference and may in fact consume too much power, memory, and time. As it comes to a robot, we would need a frame rate that is high enough to meet our minimum requirements and detect objects at a reasonable speed. Finally, when it comes to baseline consideration we must talk about monochromatic versus full color capture. Essentially, some applications of computer vision necessitate the use of color analysis, but unless we need said color captured, it is much easier and beneficial to the robot to contain a monochromatic capture, since a monochrome camera has less resources dedicated to color display, meaning that the images it can capture often contain more details than the alternative [9].

Additionally, the way our camera will scan the captured data is hugely important. The two ways a camera will scan in an image are line-scan and area-scan. A line scan camera will take a single line of pixels, sometimes more but typically will stay at a single line, and will build a final image line by line until there is nothing more to scan in [10]. This type of camera has many applications in computer vision, but typically is most effective when being used to observe something that is constantly in motion [10], such as conveyor belt surveillance in factories to find defects, imperfections, or general error when doing large-scale production. Since this type of camera uses pixel line by line capture they tend to be very high resolution. Conversely, an area scan camera will capture an image in a single frame which will have a one to one correlation with pixels on the sensor [10]. This allows for an in depth look at a specific frame, meaning this type of camera is most used in applications such as surveillance cameras outside buildings and in public, imaging, and most importantly robotics. This means that we will most certainly be using an area scan camera within our design of BearMax.

When it comes to image capture, the role of an image sensor is crucial, as this is what converts the actual photons into electrical signals that can be analyzed by other components [11]. Essentially, these break down light and convert it into digital signals, and there are two types of sensors: Complementary Metal-Oxide-Semiconductor (CMOS) and Charge-Coupled Device (CCD). The CMOS sensors are laid out with an array of pixel sensors which can each convert the light information they receive into a digital signal which can be interpreted by code. These pixel sensors are only active when the camera is reading or capturing an image, leading to less of a strain on the power-source and being power efficient [12]. CMOS sensors are widely used in many aspects of life and are the standard for cameras in smartphones, webcameras, and security cameras, as in these applications the goal is simply for information to be captured by the camera, and interpreted by another party or user. The CCD sensor functions slightly differently as compared to the CMOS sensor, as these work by accumulating charge from light information of a row of pixels and transferring this into an amplifier which will convert the data into a digital signal at the end of a row [13]. This design is perfect for capturing light information of dense clusters, as the pixels with more accumulated charge will have a different signal readout at the end which ends up in superior image quality, reduced noise, and exposure control over CMOS sensors [12], but this comes with the additional drawback of having to be drawing power constantly, making them less power efficient than most CMOS sensors. That being said, CCD sensors are hugely useful in many situations and are mainly used in scientific imaging such as spectroscopy, microscopy, as well as very high grade cameras. When comparing CMOS and CCD sensors directly, we can see that CMOS offers a low power consumption, fast image capture, and a low cost, where the CCD has the edge when we consider image resolution, low noise, and overall increased quality, at the cost of being more expensive. While both sensors have their applications, for our purposes and the goals of BearMax, we will most likely use a camera with CMOS image sensors, due to the low cost, high frame rate, and low power consumption meeting the goals necessary for the project.

3.2.2 Camera Comparison

In order to select a camera, the baseline we must search for is compatibility with the Jetson Xavier NX which will be used for computer vision functionality as a whole. Due to this, we have a limited type of camera available as there are only some specific models available for the Jetson. For our comparison, we will be looking at the Arducam 4K 8MP autofocus USB, the Waveshare HDMI 8MP, and the Sony 4K e-CAM80_CUNX cameras and see which one will fit our needs for BearMax.

Arducam

This camera is a Jetson compatible, 4K 8 megapixel camera that is natively compatible with Windows, MacOs, and Linux systems with an IMX219 sensor, allowing for sharp images and color contrast. The Arducam brand has many different types of cameras and lenses compatible with the Jetson, making any one of their choices a strong contender due to the availability and widespread use for many applications, the biggest of which being computer vision. The camera uses rolling shutter and can operate up to 30 frames per second (fps) at 1080 by 720 resolution, uses USB connection, has a 2.96 focal length with a 60 degree field of view, and most importantly contains a microphone able to be used to take in user audio. The camera also has a footprint of 44 by 44 millimeters, being slightly bulkier than most other cameras for its purpose, however we are able to remove the casing on the camera in order to integrate it within the head of the robot much easier. The camera costs more than most for its performance capabilities, but we are able to negate this cost as this specific unit was used in the prior year's BearMax version 1. Due to this, the ease of using this camera is much greater than the others as we are able to reference and use the last group's findings in order to implement its functionality better.

Waveshare

The Waveshare camera shares some of the benefits of the Arducam, being the same 8MP camera with an IMX219 sensor available leading to similar qualities for their picture output. Additional benefits come from this camera having a 160 degree field of view around the lens, and having a focal length of 3.15mm, and using a CMOS sensor. Additionally, the dimensions of this camera are 25 by 24 millimeters and only 0.01 oz, making it an acceptable size and weight to be integrated into the head of the robot. When comparing the Arducam with the Waveshare, they have similar uses as well, but the Waveshare comes a bit ahead as it is slightly cheaper as compared to the Arducam, but, as stated prior, the Arducam model is already available to our group. This camera also supports HDMI technology, and is even wireless through Bluetooth technology, but these factors are not needed for the purposes of BearMax. Finally, although this is marketed as a camera for the Jetson, some online reviews state their frustration with the use, connectivity, and general issues with being able to use it for computer vision purposes.

Sony

The Sony e-CAM80_CUNX is another 4K 8MP camera designed for the Jetson's use. This camera is more in depth than the other two cameras we have looked at, supporting much higher frame rates, speeds, and image processing capabilities. The biggest selling point for us is the capability of capturing 100 fps at HD resolutions on the Xavier NX, and 40 fps at 4K resolution, meaning the computer vision would have many samples and could update faster than if we used another option. This camera is 30 by 30 millimeters and weighs 0.7 oz, making it an acceptable size and weight to be placed within the head. This camera is also very well supported to low light level conditions due to it being able to automatically connect to the Jetson's exposure control and white-balance control. With these in mind, this camera is hugely useful for computer vision purposes, but the main limiting factor behind this camera is the steep price which would exceed the allowed budget for our project. Additionally, the applications of this are usually industrial applications such as quality inspection and factory automation. Finally, the overall complexity as it comes to this camera is high, which may cause issues when it comes to time management working with the camera in order to get it to work to our specifications.

3.2.3 Camera Selection

Considering the above specifications of each of the camera modules discussed, we decided that the overall needs of the project, balanced with the budget, and availability lead us to select the Arducam for BearMax. The main deciding factor was the availability of this camera from the WEAR lab, of which we have several parts provided, since this camera was used in the original BearMax design, we thought it best to build upon that previous framework and move forward with this part. The options provided are more than necessary, and the Arducam is an overall reliable choice.

Table 4: Summary of Camera Comparison

Camera	Fps at 1080p	Size	Weight	Cost
Arducam	30 fps	45 x 45 mm (with metal case)	3.2 Oz (with metal case)	$38
Waveshare	15 - 20 fps	25 x 24 mm	0.01 Oz	$20 - $28
Sony	70 fps	30 x 30 mm	0.71 Oz	$150 - $200

3.3.1 Range Sensor Comparison

For the goals of BearMax the proper sensor must be chosen that can give us an accurate measurement of distance from the robot to another object, for the purposes of object detection for autonomous movement. While autonomous movement is a stretch goal of ours, we found it reasonable to at least research the capacity and capabilities for this autonomous mode. The goal for this sensor would be to send the distance from the robot to another object so that while in motion the robot does not collide with any object, user, or other obstacle, and based on the distance read, move in a direction until the distance is within the threshold for a “collision”. For these purposes we will be comparing different technologies that are capable of rangefinding such as infrared sensors, ultrasonic sensors, and LiDAR sensors. In this section we will understand how each of these functions, how much distance they are able to sense, resolution, and power consumption in order to pick the correct sensor for our goals.

Ultrasonic Sensors

Ultrasonic sensors are one of the most utilized types of sensors in all applications, especially as it comes to range detection. These work like how the name suggests sound waves are emitted at a high frequency in a direction and are reflected if an object is in front of it [14], then distance is estimated using the speed of sound and the time interval that elapsed from emission to receiving the reflection of the waves. These kinds of sensors are used in a variety of different environments and offer many upsides to their use. One being that ultrasonic sensors are available at most sizes and price points, meaning their cost is usually no issue, and that since they usually are a smaller component they consume a low amount of power. Additionally, they are unaffected by some environmental conditions such as high levels of light and small particles through the air, and often feature a wide range of sensing depending on design, often going beyond 200 cm for even a small component [14]. The ability to also sense without making contact, or even being close, to an object is largely beneficial for most situations as well, and these sensors tend to have a high sensitivity as well, but there are definitely some downsides to consider for our design.

For one, ultrasonic sensors are very sensitive to many other environmental conditions, such as humidity, temperature, and atmospheric movements, such as loud sounds or liquid movements [14], this means that the situations that an ultrasonic sensor may be used in may should not involve big changes in these conditions for risk of inaccurate measurements. Ultrasonic sensors tend not to be accurate when they are close to an object, and do not offer too high a resolution leading to imprecise readings. Other disadvantages include: slow refresh rate, inaccurate data when changing surfaces, and narrow coverage [14]. This means that for our purposes an ultrasonic sensor may not be the best choice, as our needs require the sensor to be accurate in motion, on different surfaces, and with close-up objects.

Infrared Sensors

Another very popular type of sensor used in many types of projects and machines is the infrared (IR) sensor. These are aptly named, as they function by emitting infrared light from an LED, then this light travels and propagates until it hits an object, which is then reflected back towards a sensor, where the intensity of the light will determine the overall distance [15]. Typically these sensors come in two varieties, active and passive IR sensors. An active IR sensor will contain both an emitter and a receiver, and capture reflections as stated prior, where a passive IR sensor only includes a detector without a transmitter, meaning these require an infrared source in order to work [15].

The IR sensor shares some advantages with the ultrasonic sensor previously mentioned, being the wide range, low power consumption, and small form factor meaning it can be included with little design changes. IR sensors also have an additional use in that they are able to be operated in low light environments due to the fact that IR light operates in the non-visible frequency of light for humans. A final advantage this has over ultrasonic sensors is that they are unaffected by pressure, water, and some other surfaces and conditions that ultrasonic sensors struggle with, but this does not mean that IR sensors are perfect when it comes to sensing.

A major disadvantage comes from the reliability of reflection. As stated prior, the main way that IR sensors work is by emitting light, light reflecting off a survance, and then receiving the intensity of the reflected light, but that means that if the sensor encounters a highly reflective surface, it may give inaccuracy. Further, dark objects that may give off less IR light, we may have difficulty detecting an object. High temperature could also throw the sensor out of calibration, as IR light is often given off as heat, and in a robotic system with many components running at the same time for a long period of time, the temperature tends to increase the longer the machine is operated. Especially since the goal is to have BearMax used in a house, having something that could be hugely influenced by sunlight, humidity, and ambient temperature is less than ideal [15]. Finally, the biggest flaw with an infrared sensor is the limited range at which this can operate, often only being able to accurately detect an object at a maximum of a meter away from itself, and for our purposes we need this accuracy.

LiDAR Sensors

The final type of sensor we will be looking at in this section is the LiDAR sensor. Theoretically this sensor is very similar to the other two we've looked at. A LiDAR sensor will target an object and then emit a small laser towards it, then, the time that the laser takes to reflect off the object, and return are used to calculate the distance [16]. Essentially, where an ultrasonic sensor uses sound, and an IR sensor uses IR light, LiDAR uses laser technology which travels much faster and further than the other sensors due to these relying on the speed of light as opposed to sound or IR. LiDAR systems are not only used to simply detect range, as the precision of these sensors are so accurate and able to be fine tuned by many parameters, but also this same type of technology can be used to fully map out a 3D object through use of many small laser emissions. This precision is why most applications of LiDAR are for laser scanners able to map geography, architecture, measure distances for construction, as well as automotive and aerospace travel [16]. However, to see whether LiDAR would work for our purposes, we will see the advantages and disadvantages of this sensor and how it fares with distance, speed, and cost.

As to be expected by the above description, LiDAR is highly accurate. Lasers travel fast and can be used for a variety of applications requiring fast response time, as well as having a long range. Due to this, LiDAR sensors can detect at a range far beyond what is needed for this project, as well as being fast enough to be integrated into an autonomous robot. Furthermore, low light conditions have no effect on the overall accuracy, as well as having the ability to sense across different types of terrain, unlike the ultrasonic and IR sensors.

That being said, there are some disadvantages when it comes to LiDAR in a system. The main being the cost of integration, LiDAR sensors usually cost much more as compared to ultrasonic sensors of the same size. Furthermore, since these sensors operate fast they consume a lot of power compared to other sensors, and in a battery operated system like a robot this could lead to over drawing power and failure of the system to operate in an extreme circumstance. LiDAR is also prone to interference in systems with other sensors in use. Finally, similar to the IR sensor, when used on transparent or highly reflective surfaces, the laser may pass through, refract, and reflect away from the sensor, leading to struggles with detection. Despite these disadvantages, the high accuracy in measurement, fast performance, long range, and the ability to detect many small objects and different terrain, this sensor is the most optimal to use for our purposes in BearMax.

Table 5: Summary of Sensor Technology Comparison

Sensor Type	**Range**	**Operating Current**	**Possible Source of Error**	**Cost**
Ultrasonic	4 - 5 meters	2 - 20 mA	Humidity, temperature, sound, surface material	\$1 - \$30
Infrared	2 - 4 meters	2 - 10 mA	Reflective surfaces, high temperatures, dark lighting	\$10 - \$50
LiDAR	10 - 30 meters	100 - 500 mA	Reflective/	\$20 - \$500

			transparent surfaces, other sensors	

3.3.2 LiDAR Component Comparison

Now that we've chosen the type of distance sensor we will use for BearMax, we must compare different LiDAR modules in order to determine which works best for our budget and specifications. For our purposes, we only need the LiDAR to be able to measure distance from itself. Additionally this component's form factor is majorly important, as it must be placed somewhere it may have a good enough vantage point of objects that may obstruct the robot. Finally, since sampling the distance from the object is one of the only features needed from the laser, we can get away with not choosing an extremely expensive module in order to cut back on our budgeting. The LiDAR modules we will compare are the TFMini-S, SEN-14032, and Slamtec RPLiDAR modules.

TFMini-S

The TFMini-S is a time of flight (ToF) LiDAR module capable of sensing distances. This module has many advantages, the main one being its lower cost, the component itself being small enough to fit in a good area, as well as proper documentation for Arduino compatibility, requiring only 4 wires to be set up to the development board. This module also sports numerous test cases within its user manual in order to show that on dark, non-reflective surfaces and light, reflective surfaces the module will be able to detect objects with a good amount of certainty. The module operates with a detecting range of 12 meters, or about 40 feet, directly ahead, and some capabilities in detecting around the module. One main disadvantage when using this module is that there is extremely limited 360 degree distance sensing capabilities, only allowing for about 42 cm radius of vision at 12 meters. That being said, this module still is a good choice as it is simple to implement into a system where many parts will be interacting with one another.

Sparkfun SEN-14032

The SEN-14032 is another LiDAR module that is higher powered as compared to the TFMini-S, and offers some other benefits as compared to the previous component. For one, this module has a range of 40 meters, drastically outranging the previous module, and even giving it about 4 meters of 360 view at its maximum distance. This component has a stronger laser and reflectivity characteristic, but there are key downsides to using it. For one, the steep price that this module costs, being almost triple the TFMini-S, means that while definitely outperforming the Mini, it may not be worth the cost put into it. With this point, we also see that the footprint of this component is far too big to be conspicuous without serious design changes being necessary. Overall, this part may not be a great fit for our purposes.

Slamtec RPLiDAR
The Slamtec LiDAR module is unique compared to the previous components as it is a specific LiDAR sensor manufactured purely for 360 degrees of object detection at 12 meters diameter, with 1 degree angular resolution for 12 meter range. This means the Slamtec component is very skilled at detecting obstacles around itself, and especially mapping a 3D area in the space it operates. That being said, there are drastic downsides to this component being used. For one, like the previous part, this is extremely expensive of a module, which makes sense due to its astounding ability to map out an environment with its great sampling speed. Additionally, the module weighs 170 grams, which would make it one of the most massive parts in all of BearMax's designs.

3.3.3 LiDAR Component Selection

We have decided to move forward with the TFMini-S LiDAR module, as it was the cheapest option and still provided us with enough range to work with that it could feasibly be used for detecting objects within BearMax's vicinity at a reasonable rate. The in depth documentation of this component will allow us to integrate the range finding capabilities smoothly.

Table 6: Summary of LiDAR Component Selection

LiDAR Sensor	Power Usage	Range	Cost
TFMini-S	700 mW	12m	$40
Sparkfun	700 mW	40m	$130
Slamtec	1.5 W	12m (360 degrees)	$99

3.4.1 Image Display Comparison

In this section, we will cover different types of displays that are commonly used, and comprare the advantages and downsides to using each of them when it comes to the specifications of the BearMax project. For our goals, we need 2 types of displays and 3 in total, 2 to act as the "eyes" of the robot, and one display for the torso region to be used as our interactive device. The needs of these 2 displays differ in many ways, but in order to choose the displays we will be looking at similar criteria between the two. We will focus on many parameters including: quality, resolution, brightness and contrast, durability, and most importantly, how easy they can be integrated in combination with the other parts such as sensors. Now integration with such sensors should not be an issue, as we may simply find a display that is compatible with the Arduino used, and due to the popularity of this hardware the availability of compatible parts is not an issue. In the following parts we will be comparing LCD, LED and OLED, and e-paper technologies and will choose which type to use for our displays.

Liquid Crystal Display (LCD)
Liquid crystal displays, or LCDs, are extremely commonplace in our world today, and are a very useful choice when considering our uses. LCDs are a kind of flat panel display that uses light-modulations and polarization in order to function. This is possible due to the properties of liquid crystal, which is a way of referring to a specific state of matter in which a substance has the properties between that of a liquid and a crystal solid, which comprises the material of the monitor of the display [17]. This type of device by itself is passive, meaning that it is unable to produce light in order to display images, shapes, or movement in general, but it is extremely reliable in altering the light traveling through it. This means every LCD requires an internal or external component to produce or reflect the light, being a backlight or frontlight system. An LCD screen itself is made up of an array of small segments, known as pixels, that transmit red, blue, and green light, often thought of "sub-pixels" [17], which are then refracted through the layers of the screen in order to produce an image. Despite the wide-use of LCDs, we still have to consider the advantages and disadvantages of them for use in our project.

As stated prior, the wide-use of LCD technology means that they have a large variety of benefits over most other alternatives. One of the biggest advantages is the different sizes of screens available, and with this comes a large range of resolutions, meaning that the applied uses can be much greater as it may be used for many different projects and machines. LCDs are also capable of full-color display due to the use of the RGB pixel technology, as well as having good options for brightness control. These 3 things are the main reason LCDs are widely used, as with these we are able to have a reliable method of conveying information. In this same vein, the angles that LCDs are able to be viewed at are extremely wide, so in applications we can stay further back, or to the sides of the robot and the eyes should appear as normal [18]. Finally, due to the way that the pixels on this screen work, when rapidly changing between different images, LCDs are less likely to flicker out or malfunction. For these reasons, LCDs are considered viable in most projects, but they do not come without their downsides.

A big disadvantage when it comes to LCDs comes from the same properties that allow it to let light pass through itself. When in an environment where sunlight or other lights are bright, they can interfere with the readability and visibility of the display. Additionally, in high temperatures the internal components may malfunction and the display's contrast may suffer, which in a robot filled with multiple components running for a period of time runs a high risk. This hits another issue, LCDs are not as durable as other technologies, meaning that if the robot is to suffer some damage these components may get permanently changed. Finally, the backlight itself takes additional power to work, and since this is a necessary component this adds more power consumed by this part, and at times the backlight itself may appear uneven, and overuse may even begin to fade certain colors [18]. Overall, LCDs come with many benefits such as good display capabilities, however may suffer when it comes to durability and readability outdoors.

Light Emitting Diode & Organic Light Emitting Diode Display (LED & OLED)
An LED is a semiconductor device that gives off light once a current passes through it, and offers many reasons as to why they may be used for display technology. Similar to the LCD pixel displays, containing red, green, and blue sub-pixels, and LED display will have many small LEDs, also colored red, green, and blue, closely spaced out and have the ability to adjust the color and brightness of the overall image, allowing for the display of images and animations [19]. The way OLEDs differ from regular LEDs comes from the addition of an organic film within the electrodes of the diodes, which allow a much brighter light to emit once an electric current passes through the device [20]. Although we are including LEDs in this section, it is important to note that LEDs in displays are typically used with an LCD screen in front of it, meaning that this section will mostly focus on OLED screens, as this is what is typically used in digital screens in many different machines and systems. LED displays are typically used for simple segmented displays, such as the ones appearing on digital clocks and many small household appliances. Regardless, in this section we will discuss the advantages and disadvantages of an OLED display for the purposes of the BearMax project.

One of the biggest advantages of an OLED display comes from the fact that OLEDs emit their own light once current passes through, so unlike LCD displays a backlight or reflector is not required for these. OLEDs are also able to display very deep black colors, bright white light, and have an extremely high contrast ratio [20]. For the above reasons, OLEDS actually are considered to consume less power, as by removing the power to the device it is able to truly display black, and they generate their own light directly [21]. The layers of an OLED are extremely thin and offer a small form factor in most applications, meaning they are flexible and durable. Finally, OLEDs offer fast response time allowing for fast movement to be displayed with little to no screen flickering [20].

OLEDs do not come without their downsides, of which some are shared with LCDs as well. For one, the outdoor visibility of OLEDs is worse than LCDs, since LCDs may have reflectors in place for their light allowing for some visibility, OLEDs rely on its own ability to convert electricity into light, thereby making these unreadable outdoors [20]. Furthermore, the lifespan of these devices is hugely limited by the addition of these organic materials, which degrade much faster with use than inorganic layers, of which blue light given off degrades the fastest [20], which leads to color imbalance. Finally, it comes to cost, as OLEDs are relatively new technology, the cost of manufacturing is considerably high as compared to other options available. So overall, OLEDs come with the benefits of having better overall display capabilities, but risk chances of screen degradation, poor visibility in sunlight, and high manufacturing costs.

E-Paper

Electronic Paper, or e-paper, refers to a type of display technology that mimics the feel of paper, and is used in applications to mimic the effect of a “real book” with ink on paper, as well as being used for digital signs, billboards, and e--readers. Unlike other displays, e-paper functions not by emitting light but by reflecting ambient light [21], much like paper itself. E-paper is extremely energy efficient due to the fact that no internal light component must be used in order to allow the screen to work, and for the most part e-paper will only consume additional power when changing the image on the screen, if we persist on an image virtually no power is consumed [21]. That being said, most applications of e-paper stick to static, or mostly static, displays, which may not fully meet our purposes, among other disadvantages when it comes to the technology.

The biggest downside in most e-paper displays comes from the fact that most are monochromatic, which limits the amount of interactivity to a large degree when it comes to the BearMax’s displays [21], as the interactive display must be able to play certain animations and images, of which the message and interpretation from the robot may be ambiguous without color capabilities. As stated earlier, the main uses are for static displays, so the refresh rate when images are changed are highly limited and often have no smooth transition [21], meaning that for devices that need constant updates this will not satisfy. Additionally, high exposure to sunlight or constant updates may cause the screen to start to fade in quality anyways, so the added benefit of readability in ambient lighting can decay over time [21], and coupled with the fact that even some small e-paper displays can cost up to $80. So although e-paper technology is highly utilized and applicable in many different situations due to its low power consumption and ease to use, the drawbacks of having no color support, limited refresh rate, and a small life-span make it wholly unsuitable for the BearMax robot’s goals.

Table 7: Summary of Image Display Comparison

Display Type	Pros	Cons	Cost
LCD	High resolution, Cost effective, Low power consumption	Glare, Response time, Backlighting necessary	$8+
OLED	High contrast, Broad color range, Energy Efficient	Expensive, Complex electronics, Glare, Burn-in	$25+

E-Paper	Low power consumption, Image persistence	Monochrome, Slow refresh rate, Limited lifespan,	$15-$25

3.4.2 LCD Component Comparison

After comparing the types of display technology that would fulfill the base requirements of BearMax we have decided to move forward with the choosing of LCD displays for the eyes. This was primarily due to the low cost, low power consumption, and decent performance offered by the screens, balancing them against the LED and other options. In this section we will compare different LCD screens to consider for use as the eyes in the BearMax system.

DFRobot DFR0664 2" Screen

The DFR0664 LCD screen is a 2 inch, 320 by 240 pixel display, a type commonly used in smaller screens which need to display smaller less detailed images. This screen is Arduino compatible allowing for it to be well integrated into a system such as BearMax's.

One of the biggest advantages as it comes with the DFR0664 comes from its high resolution combined with a wide viewing angle, allowing for images to be displayed accurately no matter the position of the user, as well as accurately displayed. Additionally, it utilizes SPI to communicate with the controller, allowing for the screen to be interfaced within the Arduino code to other components, mainly movements from the main motors. Finally, the screens allow for MicroSD cards to be inserted, allowing for full image display capabilities.

The biggest disadvantage when it comes to the DFRobot screen comes from the additional features offered by the screen, most of which are unnecessary for our purposes, and raise the budget necessary for other components. Additionally, the specific screen dimensions are slightly misleading, as the screen itself is not perfectly the shape needed for the robot, meaning some math would have to be adjusted in order to properly get the display to show images in the manner in which they would be loaded. Overall, for the price point this screen is definitely useful, however may be too extensive for our purposes.

HiLetGo ST7735 1.4" Screen

The HiLetGo ST7735 screen is a very similar screen to the previous screen looked at, with some key differences that make it more viable. This screen utilizes SPI to interface with the Arduino code, and has a resolution of 128 by 128 pixels, with 16-bit color capabilities.

A big advantage when it comes to this screen is availability and price. Not only is this screen the cheapest option we are looking at, but the previous iteration of BearMax utilized these same screens, meaning the reuse of parts would make it cost no additional fees. Furthermore, as it comes to use within projects, we can see this company is reputable when it comes to the development of similar LCD screens of similar sizes. Most importantly, this screen is well suited to displaying moving images if needed with our designs for the eyes.

The disadvantages with this screen come from some user reviews specifically mentioning specific issues with extended use of the screen, mainly pertaining to the pixels on screen dying and interfering with the overall experience of using the screen. However with that being said, these screens still offer the best choice in overall performance for our purposes just simply due to availability of the part.

Adafruit 2478 2.4" Screen
The final LCD screen we will be discussing today is the Adafruit TFT display, a 2.4 inch 240 by 320 pixel display, supporting SPI as well as its own communication interface. This screen also supports full RGB color display and features touchscreen capabilities.

The biggest advantages with this screen come from the various supported graphics libraries allowing for complex shapes and images to be drawn onto the screens easily. Furthermore, the overall technology within this screen is more advanced than the other screens we have looked at, specifically due to the many features that allow the screen to be Python compatible, however there come many disadvantages with the screen.

A prominent downside to this screen is the steep price compared to the other options available, being almost $30 for a singular screen, meaning a net cost of $60 for our purposes. This is mainly due to the many advanced features that come with this screen, specifically the resistive touchscreen, which for this small screen for the eyes of BearMax are not needed to be included. The eyes should be kept simple, meaning these features may be unnecessary.

3.4.3 LCD Selection
When comparing the three screens, a clear choice for us is the HiLetGo ST7735 screen, mainly due to the availability, simplicity, and low cost compared to the other screens. Although there exist some problems with the screen, we have determined it to be the most feasible pick.

Table 8: Summary of LCD Screen Selection

LCD Screen	Resolution	Cost	Interfaces	Size

DFRobot	240 x 320 pixels	$18+	SPI	2 inches
HiLetGo	128 x 128 pixels	$8	SPI	1.44 inches
Adafruit	240 x 320 pixels	$30+	SPI, 8-bit	2.4 inches

3.4.4 Touch Screen Technology Comparison

In addition to the screen for the eyes of BearMax, our version 2 design plans to include a tablet within the body of the robot in order for user interaction capabilities. That being said, the technology to consider for a touch screen requires minor explanation in order to understand the choices and options necessary before part selection and inclusion within BearMax. The main goal behind touch screens is the same thing, to get user input from simply pressing upon a screen, but the manner in which to implement this is different depending on the technology behind it. Touch screens are mainly going to be either resistive or capacitive touch based, and in this section, we will break down the differences between the two and which we will be using for our touch screen on this project.

Resistive Touch Screens

The most commonly used type of touch screen which many see in their daily lives as a whole is the resistive touch screen. Similar to how these are named, when you touch this screen it “resists” the touch you give and allows feedback to be gained upon such an input, but the way these work are interesting. Resistive touch screens have multiple layers, a top most layer which can flex into the back layer and the back layer which is rigid. Then, these layers are separated by a gap of air, and once a user touches the screen the gap between the layers is closed, allowing for the flow of electricity to go through at the point of contact, and a function may be performed at this spot [23]. As it comes to the benefits of using such a screen, resistive screens tend to be more durable due to the addition of more layers, and most come scratch resistant from harder objects. Additionally, with resistive touch screens, since they operate through contact between layers, can be operated even without a finger, using styluses or while using gloves. That being said, there are some drawbacks and limitations when it comes to these, the main part being glare and readability due to the addition of multiple, we have multiple layers above the display that are able to reflect light, meaning more light gets reflecting and more problems we have with reading the screen under light. Furthermore, resistive screens are unable to support two-finger touch, common with screens that support zoom functionality. Overall, resistive touch screens are a good choice when wanting something cheap, durable, and especially when not wanting the touch screen to be the main feature of the robot, that being said the downsides of the screen are definitely to be considered, since these tend not to be extremely responsive and can limit the amount of functionality that may come from it.

Capacitive Touch Screens

The second type of touch screen technology used within most electronics is known as capacitive touch screens. Where resistive touchscreens use multiple layers are pressure based methods to get input, a capacitive touchscreen uses an electric field and the properties of human's electric charge in order to detect changes within the flow of electricity [23]. Instead of having a separate layer we touch, a capacitive touch screen either has a grid of extremely thin wires and sensors or sensors on the corners of the screen and a thin film over the screen, which are used to transmit the electric current across this screen. Upon a touch to the screen a small electrical charge gets transferred from the screen to the finger used to make contact, causing a voltage drop which can be sensed by the sensors under the film, and from there calculations can be made to react to the input at this point on the screen. Capacitive screens tend to be faster than resistive ones, due to the quick response time capable with electric fields as opposed to a membrane layer that must be fully pushed back into the back layer. With this same logic, we know that capacitive screens can also be more responsible than resistive ones, due to the thousands of tiny sensors that are able to detect differences in the field above them. Finally, capacitive touchscreens also support multi-touch features, as opposed to resistive screens which can only use one touch. However, there are downsides to the use of a capacitive screen. For one, these screens tend to be much more expensive than their resistive counterparts due to the need for many small components and sensors, whereas the resistive screen requires the layers and conductivity to work, allowing for it to be much cheaper. Secondly, these can only be operated with human skin, unless specifically designed with special gloves, or a film over the screen to allow for other objects, as the conductive material and surface is wholly needed for the operation of the screen. This adds some inconvenience, as we cannot always have our hands out, and may even lead to damaging the screen. Overall, the capacitive touch screen is a good choice when needing a screen that depends on precise readings and high accuracy, allowing for complex features to be used, such as multi-touch, and being simple to implement. That being said these screens tend to be more expensive, fragile, and cannot be used with hand coverings, which cause some issues when wanting to be implemented for BearMax's purposes, and especially after repeated long term use, the touchscreen may decay in overall performance

3.4.5 Resistive Touch Screen Comparison

After weighing the positives and negatives for each type of screen, we have decided to move forward with a resistive touch panel for the second LCD display in the body of the robot. The core reason we opted for resistive technology came from the fact that our secondary screen only needs to be used sparingly, and is not a main draw to BearMax, meaning that we can give up the cutting edge benefits from the capacitive screen and keep cheaper and more simple technology for this part, to aid in the overall development process. That being said, we must also compare the specific touchscreens we've looked at in order to find a good pick. We've opted for a 5 to 9 inch screen, as for readability's sake we want the screen to be "big enough", meaning bigger than the size of an average phone screen. The screens we will look at today will be from Elecrow, Adafruit, and EastRising, which we will be comparing to determine which fits for our project's criteria, considering size, weight, reviews, and cost.

Elecrow ESP01215E

The Elecrow ESP01215E is a 7 inch, 1024 by 600 pixel screen that supports HDMI and touch capabilities. To begin, this screen is the most advanced of the ones we will be looking at, having a higher resolution and speed than the rest, but with this benefit the cost is much higher than other options. The screen has full color capabilities, as well as a true white backlight with 18 white LEDs, allowing for bright displays mostly free of glare. That being said, this screen, although being very good in its own right, is not compatible with the Arduino hardware series, and rather uses Raspberry Pi to operate, meaning that for that reason alone we cannot consider the screen for BearMax.

Adafruit 2354 TFT Screen

Adafruit's TFT touch screen is another good option for a screen with touch capabilities, being the cheapest option for a screen we are looking at. This is a 7 inch, 800 by 480 pixel touch screen with a 24-bit parallel RGB interface and having 21 white LEDs. The screen offers some benefits, being simple to use and cheap for having a relatively big screen, and being from a reputable company for regular LCD screens as well. That being said, this screen does not have a lot of documentation, and has outdated datasheets which may prove difficult when having to integrate the screen within a whole system of many different parts as well. Furthermore, the availability of the screen is low, meaning even if ordered in advance delays due to material shortages is common. So even though this screen does fit the specifications and needs of BearMax, we may not be able to even access it.

EastRising ER-TFTM070-4

The EastRising TFTM070 is another 7 inch, 800 by 480 pixel touch screen that of all our options seems the most balanced. Having many different display formats, this screen has many different compatibility options, allowing for pinned connection or FFC (flat flexible cable) connection. Having the specs of the Adafruit screen, but with better compatibility and better documentation gives this screen the edge, as well as having high availability, meaning the part could be bought, inspected, and tested faster than others. With these benefits come some downsides, one main one being that this screen is slightly more massive compared to the other screens, meaning the strain it may bring upon the robot could be greater. Additionally, this screen comes from a slightly less reputable company, but with that come some positive user reviews. Overall, this screen offers the most benefits and positives compared to the other screens, but at the cost of being a bit more straining on the system.

3.4.6 Resistive Touch Screen Selection

We have elected to select the EastRising screen due to the reasons mentioned above. The core reason being the detailed datasheets, availability, and positive reviews for the part. Having a 7 inch touchscreen will allow for this component to act as an interactive console for the user to interact with BearMax through question and response could be done through this screen.

Table 9: Summary of Touch Screen Selection

Touch Screen	Resolution	Cost	Size Diagonal
Elecrow	1024 x 600 pixels	$55+	7 inches
Adafruit	800 x 480 pixels	$30	7 inches
EastRising	800 x 480 pixels	$45+	7 inches

3.5.1 Motor Technology Comparison

For the 2nd iteration of Bearmax to function as a social emotional learning tool, it's vital that the body language for each emotion is executed properly. This means that Bearmax requires a complex joint and motor system to emulate specific emotions such as excitement or fear.

These motors will be controlled by the arduino system. This will involve approximate calculations for necessary torque to move joints which will influence how we program the arduino.

We are planning to use more than one kind of motor for Bearmax depending on the needs of the section we are designing. For example motors in the track system will likely be different from those moving the neck.

In this section we will be covering the two different kinds of motors we will be using for movement in the joint system as well as the reasoning for why we avoided others.

DC Motors

Most commonly used in robotics, DC motors convert direct electrical energy into mechanical energy. DC motors work well for robots that must be battery operated such as mobile and collaborative robots. DC motors are advantageous in that you can vary the speed by adjusting the supply voltage, armature voltage drop, or flux due to the field findings. A downside to DC motors is that they will rotate continuously, this makes precise control difficult as they are not designed to be able to stop at a certain position. This ability to vary speed can give lots of options for the abilities of your robot.

We will likely be using DC motors for the track platform at the base which will allow the robot to be mobile via remote control.(1)

Stepper Motors

Stepper motors are made up of a rotor with permanent magnets and a stationary stator that carries the windings. Stepper motors work by moving in “steps”, there are so many of these steps that the motion looks continuous.

Due to the fact that they work in steps, there is a high degree of control around the position of the motor without the need of an encoder. A major downside is the decrease in torque as speed increases. Overall stepper motors tend to be more inexpensive compared to servos but are not as precise.

Servo Motors

A difference between servo motors and stepper motors is the amount of poles. Servos motors have less poles than stepper motors. Consequently, servos must be run as a closed loop system and have an encoder as opposed to stepper motors mentioned earlier. However, when used with a gearbox, this allows the servo motors to deliver much higher torque at higher speeds. It is for this increased precision and torque capabilities that servos will mainly be used for our joint system as opposed to stepper motors.(2)

3.6.1 Computer Aided Design (CAD) Software Comparison

AutoCAD is a Computer aided design package that has powerful 2D drafting capabilities. Its purpose initially was to replace drafting done by hand therefore reducing man hours and increasing efficiency. Since the initial intention was not for 3D modeling. AutoCAD is seen as rather limited for that purpose relative to other 3D modeling software. Bearmax will require hundreds of hours of modeling to finalize the design, it is therefore crucial to use the most effective 3D modeling software which will allow us to complete our design in the most effective manner.(3)

Solidworks is a parametric 3D modeling package. This allows for fast editing of object dimensions without having to redraw the entire design. It allows users to design and assemble individual parts in a 3D space. Furthermore there are packages which expand its versatility to things such as electrical components. Solidoworks includes analysis methods such as finite element analysis which will allow us to perform stress tests on different sections of Bearmax. Solidoworks also has CAM(Computer aided manufacturing) capabilities which will allow us to design how each part will be milled and constructed. A downside of Solidworks is its lack of 2D drafting however that is not essential for our goals in the Bearmax design.(4)

Onshape is also a parametric 3D modeling package, it has a lot of similar functionality to Solidworks. Aside from format changes, the biggest differences between the two software centers around how data is stored. Onshape uses the cloud which makes sharing data and editing with multiple users much easier. This requires internet connection whereas Solidworks could be used offline. We decided against using Onshape as our two mechanical engineers would be working on different sections independently so the benefit of working simultaneously on the same part wasn't seen as necessary.(5)

3.7.1 Speaker Technology Comparison

The speaker would be used to play music and say formal recorded greetings. The arduino community has several different speaker designs formatted for easy integration into the arduino system. That being said, we do not have a finite selection at this moment as we are waiting until more sections are designed before definite selection. We have broken down how we'd select our speaker based on research into speakers compatible with the arduino. Passive buzzers or speakers require an AC sound signal to produce a sound. [speaker section1]This is ideal for our project in contrast to active speakers which only require to be turned on as it generates the sound itself. Given that we intend to have a wide range of audio, a passive speaker is ideal.

Given that the speaker is not absolutely crucial to the function of Bearmax, we do not intend to invest lots of resources solely into the speaker.

Arduino speakers alone will likely not be powerful enough and will require a speaker amplifier.

So we will be investing in both a passive speaker and amplifier.

3.8.1 Robot Material Selection

Many factors dictate the material of a product, function, budget, machinability, durability, etc. and for BearMax, it's no different. BearMax has several components including the head, neck, body, shoulders, arms, digits, track system, and frame. For the shoulders, arms, and digits, the focus is on functionality, in this case movement. For the head and neck, movement is vital but as is weight. The neck and head joints will be supported by the body so they must be durable, yet still lightweight to ensure little load is being applied on the body. The appearance of BearMax is also very important as it can contribute to a child's ability to bond with BearMax and to feel comfortable. We also want to allow the child or user to physically interact with BearMax with hugs or high fives, similar to other robots facilitating social-emotional learning [2]. For this, safety is of utmost importance so materials there cannot be sharp edges or surfaces that are exposed. The material and texture of the frame or exoskeleton needs to be carefully selected as well as a lot of people with Autism Spectrum Disorder (ASD) experience sensory issues which need to be considered [9]. These sensory issues need to be accounted for so users can feel comfortable interacting with BearMax physically if they so choose and the exterior also needs to be appealing to make the user feel as comfortable as possible. The Robot Comparison chart discusses physical and functional differences of various industry/research robots. Several robots have hard exteriors and still are able to bond with users very easily and have touch sensors in place to record and respond to physical contact. Others have a hard exterior but have some components which are similar to stuffed animals or toys, such as Mox, a “dragon bot” that has a head surrounded by soft material similar to the mane of a stuffed lion toy [2]. Other robots are designed with a soft, huggable material completely. The goal for BearMax is to have an exterior that resembles a stuffed bear and be very soft and comfortable. While this is possible, the exoskeleton still needs to be sufficiently durable which cloth cannot accomplish alone. For this reason, the decision was made to have the exterior cloth purely for cosmetics and choose a frame that is durable and can protect all of the components of the robot.

The exoskeleton’s main purpose is to be the foundation, not only acting as the frame, but also housing several mechanical and electrical components. With a new neck design for Version 2 of BearMax, several existing structures need to be adjusted, mainly the PVC pipe for the torso. The height needs to be shortened and to implement the new neck design, the mounting for the neck and head needs to be changed to incorporate the PVC pipe or “spine” of the robot into the structure. Version 1 of BearMax also dealt with some issues regarding only using one breadboard. While we have found a solution to that initial problem, the challenge occurs when needing to incorporate several more components into the same size, if not slightly smaller torso. Additionally, we will also be having more motors and connections as we are adding degrees of freedom to the neck, head, shoulders, and fingers. An additional six motors will be necessary for the fingers and shoulders alone combined. To house these components, we decided to have 3D printed “shelves” made from PLA that can be attached directly to the PVC pipe and act as compartments to store several different components.

Version 1 of BearMax had several 3D printed components and we plan to continue with this approach as it contributes to the ease of manufacturing. The ease of customizability and reduced time in additive manufacturing greatly contributes to the reason we selected 3D print several components, such as the ears, shoulders, arms, etc. While acrylic was initially considered to replace and still might be used to substitute some components, additive manufacturing aids in reducing the weight, cost, and time of building. Resin was also considered to be used instead of PLA for the arms and ears, however, different types of resin pose different issues. Elastic resin would not be durable enough and epoxy resin might be too brittle and cannot handle the constant friction.

Though resin was not compatible with the structural components, it could serve as the soft, cushiony layer between the cloth and exoskeleton. Elastic 50 A resin which can be 3D printed using a Formlabs printer. Elastic 50 A resin is a material that not only has flexible properties, but can be adjusted in terms of durability with filament pattern and infill. This resin layer will cover individual components and also cover the entire exoskeleton and serve both as the protective padding and compressible soft texture, similar to a stuffed toy.

Revisiting the friction issue, it is not only of concern with epoxy resin, it is also a concern with PLA and any other material. To minimize the friction between components of the same material and the components attached to the motors (such as the joints of the arms) heat set inserts will be the best solution. Heat set inserts are metal thread fasteners that can be inserted into a designated joint which will reduce the friction between a rotating component such as a motor and a PLA joint, allowing us to still customize components while mitigating the damage to those joints.

3.9.1 Stress Detector Method for Wearable Device Technology Comparison

One of the main functions of BearMax as a whole is to detect stress and calm the user down if we detect that the stress levels exceed a certain threshold, and with this necessity there are many things to consider moving forward. There are many different methods of detecting stress, some more reliable than others, meaning that depending on the method used, we may have better stress detection overall. But the reliability must be balanced with the ease of implementation, with a project as big as BearMax we can afford to have features that are easier to implement, while being slightly less reliable to give us an overall picture of what can be done and what can be improved in the future. Furthermore, we must consider the integration of the method into a wearable device, as if the method of detecting stress is too bulky as a piece, the user may find it uncomfortable to wear for long periods of time. Finally, we must consider how much power is consumed by the use of the device under long periods of time, as the use cases for BearMax include being on while the user is at home, meaning that the wearable device must be able to last just as long on a charge as the robot, meaning the power consumption must stay lower. In this section, we will look at how the stress may be detected through heart rate, brainwaves, and sweat, and compare the three to consider which fits the criteria described above in what is needed from a stress detector integrated into a wearable device.

A final note, while we strive to find a way to detect stress, the concept of stress detection is inherently unreliable, as the human body is a complex, multi-layered structure with many processes running at the same time, many things to consider in a given moment. Due to this, any method chosen for detection will inherently be subject to outside interference as well as many inaccuracies, therefore we strive to find the most accurate way while considering the fact that none may be fully accurate. This is why we will include computer vision to detect expected emotional state as it may give a better idea of what the user is feeling at a given time, and why stress detection through the wearable device is a stretch goal.

Heart Rate Variability (HRV)

Heart rate is one of the most common ways to measure stress, and one of the most widely known in the general perception of the population, one of the most common things to be known is that when we are stressed our heart rate rises, and when we are calmer our heart rate slows. Stress detection through this method is specifically done through heart rate variability, meaning the variation in time between consecutive heartbeats [23]. What this means is that we not only look at individual speed of the heart pumping, but also that we would measure the time period between heartbeat changes in order to get a better picture of when one is truly stressed. Higher levels of HRV typically means a lower stress level and vice versa. This seems like a good way of detecting stress if not just due to the widespread use of heart rate monitoring, but we must still gauge the benefits and downsides as a whole in order to come to an accurate ruling.

One of the biggest benefits when it comes to measuring HRV is the non-invasiveness of measuring heart rate. Heart rate is a key part of medical examinations as a whole, so the manner in which detecting heart rate usually utilizes some small electrode placements and that's it. The widespread use of heart rate monitoring in even personal devices, such as smart watches, shows that it is quite simple to truly implement. Furthermore, heart rate is a very constant measurement within the human body, meaning it can be consistently monitored for a long period of time allowing for even the most acute detections of stress to be seen in measurements. Having a method of detecting stress over time would benefit wholly in data collection, and would give a measurement of how effective some methods of stress relief truly are for an individual. Having this would also help with overall stress detection, as even from person to person, baseline heart rate and stress resilience will vary hugely for a multitude of reasons, and having a trendline of the data over time would allow for many different users to have separate readings collected. While all of these are good to have in our detection hardware, we must consider the downsides to using HRV in its entirety.

As previously stated, the human body experiences many things at any given moment. In that same way, when our heart rate rises, it could mean many different things, such as whether we are currently exercising, outside, the temperature, and any other external stimuli that allows fluctuations within our body. Especially considering that different medications, caffeine intake, and general medical issues all lead to inaccuracies when we seek to detect stress especially through use of HRV. Additionally, our heart does not immediately respond to stress changes, causing a lag within the response system leading to some inaccuracy. Furthermore, there are a variety of sources that show that prolonged periods of stress, and chronic stress in general change the way our heart rate appears, making a reading less accurate to change as quickly as the stressor stimulus does.

Brainwave
Brainwave monitoring is another common way to detect stress in individuals used by medical professionals. Essentially, by using brainwave analysis, or electroencephalography (EEG), we are able to detect an imbalance of alpha brainwave activity on different sides of the brain, indicating a marker for stress [23]. EEG tests are usually used as a diagnostic tool to test for other disorders, such as epilepsy, dementia, and sleep disorders [24], showing that the information provided by EEGs are very detailed and give a whole picture of the user's brain activity at a given time. However, we must consider the benefits and downsides as it comes to BearMax.

A major benefit of monitoring brain activity as it comes to stress detection is the ability to see how specific stressors affect a user. Our major problem with stress detection as a concept is the unreliable nature of taking measurements and designating them as "stress indicative" due to the body reacting to many external stimuli. This full picture of brain activity allows us to see a user's cognitive process wholly, as well as giving further information about how much a stressor affects them and allows the development of a stress pattern for identification of stress from latent brain activity. This pattern benefits the user as it would allow for an earlier detection of stress even before any symptoms may physically manifest. Similar to heart rate, brainwave activity is unique to an individual, meaning that with all the information able to be collected, a good picture can be painted for a specific individual's needs and reactions to stimuli. Finally, and most importantly, we could specifically see how stress regulation techniques, such as the games BearMax can engage in, affect a user, and how effective they are.

The downsides of brainwave monitoring especially make it hard to integrate within the BearMax plan. For one, EEG machines and technology are extremely specialized, meaning specific training is needed to operate it, as well as an enormous budget to actually use the technology required, automatically making it unviable for integration within a small form factor. Furthermore, the monitoring of brainwaves requires the attachment of electrodes onto a participant's scalp/hair, meaning a more intrusive method of measurement. Additionally, the technology and expertise needed to analyze the data is completely separate from the ability of operating the machine and administering the tests required, meaning that more expenses are added. Overall, although brainwave technology could provide a good understanding of stress painted for the user, the additional cost, expertise, and invasiveness make it unviable for the purposes of BearMax.

Sweat
Of all the methods of stress detection, building a sweat sensor is the most simple to understand the methodology. The impedance across human skin is generally very high, due to skin not being a good conductor of electrical signals, whereas when we sweat, the resistance observed will drop, due to the chemical composition within our sweat

[25]. Therefore, if we simply had an impedance measurement device across the hand or wrist of the user, then we could monitor in real time the resistance on their skin and when the reading significantly drops, we are able to assume the user is experiencing stress of some variety.

A major benefit of using this method is the non-invasive integration of an impedance detector into a wearable device. Resistance sensors have existed for as long as electrical circuit design has, meaning that the size and form factor for these sensors has shrunk and improved over time, so developing a wearable device with this in mind is extremely simple. Furthermore, there are recent studies in which it was found possible to detect cortisol, the stress hormone, within sweat and test the levels of it, and showed a detection of cortisol at the same level as typical methods of cortisol detection [26]. While this is impressive, it should be known that this was done by researchers only, and it is not fully available to integrate within BearMax, as this idea is still relatively recent, but important to note how sweat detection could be as accurate as other methods of stress detection. Finally, a sweat based stress detection system could allow for the long term tracking of stress patterns like the other methods, and especially with other methods of tracking biodata, sweat detection can be significantly viable.

That being said, the same problem arises as with the other methods, sweating is not necessarily an indicator of stress but rather could be in response to environmental or physical conditions, such as the temperature where the device is being operated, or increased activity levels in the user. Furthermore, an individual who is undergoing a stressful situation may not even sweat as a response to it, and for that heart rate and brainwave detection seems more reliable. Overall, out of the options sweat detection seems the most simple to implement, cheapest option to design, and the least intrusive to implement, making it the one we will consider moving forward with in the design of the wearable device.

Section 4: Standards and Design Constraints

UNICEF Design Constraints

One of the primary guidelines we will be following is the UNICEF Guidelines on AI for children, known as the “Policy guidance on AI for children.”[20] This guideline will dictate how we will be approaching the development of the machine learning and programming of the robotic system. The report recognizes that there are potential uses of artificial intelligence for the positive development of children. It recognizes that artificial intelligence can aid in educating children by enabling adaptive learning platforms that can devise a curriculum for each student. The report also recognizes that AI can create educational opportunities through interactive games, chat bots, and robots. According to the report, AI-based interaction games run by social robots can help young children learn to read and tell stories, increase their vocabulary, and learn to draw images (citation needed). Furthermore, the report recognizes that AI has the potential to provide emotional support for children. It explains that, under the right supervision and in a controlled environment, AI-enabled products can be used to detect children's moods and help with behavioral regulation (citation needed here). Of course, the report clarifies that children should always be directed to online and offline human support for complex, sensitive scenarios like bullying. Even though it recognizes potential positive uses for AI, it also explains that AI can be used in harmful ways against children. One potential harm is that AI can be hindered by what is called algorithm bias. This is when datasets that inform the AI create negative biases within the AI, which translates to real harm in people. Algorithmic bias is often seen with surveillance AI, which has shown to profile ethnic minorities as dangerous because of biased data in its dataset. Another potential harm of AI is the privacy risks associated with it. Since this is an AI for children, it will rely on collecting data on children. If a hacker were to gain access to this data, it would create a dangerous situation. Finally, the development of AI could contribute to a kind of digital divide where only wealthy nations can access the benefits of this technology while developing nations will obtain modest gains at best (citation needed here). Understanding these guidelines will allow us to construct our robot in a safe, child friendly, and ethical manner. These guidelines include supporting children's development and well being, ensuring the safety for children, and to prioritize fairness and non-discrimination for children.

To support children's development and well being with our project, we will follow UNICEF's specific recommendations for their approaches in developing child-friendly AI. The primary recommendation is to develop it with a child-rights approach. This means recognizing a child's right to privacy, safety, and inclusion by design. To ensure that the data the robot collects is secure, we will be collaborating with a team of Computer Science students to develop secure systems. This is the team that will also be developing a companion mobile application along with the machine learning system that will enable the robot to recognize faces and emotions. They will implement fundamental security features, such as JSON Web Tokens. The next way is to integrate metrics and processes to support children's well being. Our approach for achieving this guideline is to include a device that detects stress, implement a set of activities known for mitigating stress, and program the robot to recognize emotions. The stress detecting device will be a wristband that detects the heartbeat of the user. If the user's heartbeat is elevated, the robot will recognize that and respond accordingly. It will first express concern for the user, then it will notify a nearby professional, and then it will offer a range of calming activities. These common activities will range from playing calming music to starting a storytelling activity. Furthermore, it will be able to see faces of children and recognize emotions. It will be trained on a large dataset of multiple faces expressing a range of different emotions, like sadness, stress, and excitement. Lastly, the report recommends that developers prioritize ways that AI systems can benefit children and to be aware of any risks. To achieve this, our team will do extensive research on the ways in which AI can be beneficial and we will search methods to prevent any risks, such as algorithmic bias. By researching the ways AI can be beneficial or harmful, developing systems for measuring the well being of users, and implementing security measures, we can develop a robot that ensures that the rights of children are respected and protected.

In order to ensure the safety of children, our team will follow UNICEF guidelines and create mechanisms for continually monitoring the impact of the Robot on children, continually assess its impact, and test the robot's safety features continuously. The mechanisms for monitoring the impact of children will be through its companion mobile application and through the required supervision of a mental health professional. The mobile application will be developed by the computer science team while our team will design the robot to send any relevant information to the application. Such information could be potential stressors of children, favorite activities of specific children, and emotional state of the children at different periods. This transmission of information will be secured to prevent malicious hackers from viewing or stealing it. Even with the security measures, however, it will still be accessible to mental health professionals and caregivers. In order to obtain a professional opinion on the impact of children, the robot will also require a mental health professional to be supervising the robot and its activities. Doing so allows for the professional to directly observe how the robot is helping or otherwise impacting the children. Moreover, the presence of a professional guarantees that the children using the robot will be completely safe. To continually assess its impact, the professional observing the robot working with the children will have to monitor the children long term to see how the robot affects their development. Our team also has researched, and will continue to research, how other types of social robots affect development of children in a positive way. We will take note of the methods by which these robots help the children and incorporate them into our robot. Finally, we will continually test the robot's features throughout the development process. We will converse with the robot's chatbot-like feature to ensure that the robot speaks in a polite, kind, and unproblematic manner. Furthermore, we will be testing and evaluating the data collection and transfer features of the robot to ensure that these features are as secure as possible. Finally, we will design the robot in a way that it cannot physically harm a child in a significant way. For instance, we will make the robot small so that it will not tip over and fall on a child, hurting them significantly. We will also incorporate rounded corners on the robot so no child will be in pain if it bumps into the robot. Furthermore, we will make the robot light enough so that if it falls on a child or rolls over a child's foot, it will not significantly harm the child. By incorporating child-friendly design features, enabling the robot to share information through a secure mobile application, and requiring the presence of a supervisor to observe the robot, we can ensure that the robot will not endanger children in any way.

Our goal with this social robot is for it to be accessible to as many children as possible, if not to all children. In order to accomplish this, we must develop the robot to be fair and non-discriminatory. The UNICEF guidelines recommend developing datasets that represent a diversity of children's data and actively support marginalized children so they too may benefit from this system. To diversify the dataset, we will collaborate with the computer science team to ensure that we have a dataset that fairly represents children of all ethnicities, social statuses, and backgrounds. Additionally, since our project focuses on autistic children, we will use datasets that provide essential information for children with autism. Furthermore, we will research each dataset we use and be mindful of any drawbacks or weaknesses of each one. That way, we can avoid instilling any kind of algorithmic bias into the robot. In order to support marginalized children, we will be researching numerous ways that our robot can assist children of more marginalized backgrounds. One method we have considered is making the robot as affordable as possible. That way, schools can afford to purchase these robots and incorporate them into their curriculum, thus allowing for widespread use. In addition to schools, therapy organizations, especially those that aid in the development of autistic children, should be able to afford these robots and use them. Additionally, one of our team members has also been in contact with an organization dedicated to researching how to help autistic individuals using science and technology. The organization in question is the Equitable Learning Technologies Lab, a firm affiliated with the University of Florida. This firm has experience researching how the Pepper Robot can be used to assist in the positive development of autistic children. It has shared its findings with our team and we have been learning how to implement the helpful features of the Pepper Robot while also being mindful of its drawbacks. Furthermore, members of our team are well acquainted with disabilities. For example, one of our team members is autistic and has been in behavioral therapy for much of his childhood. In addition, he has experience volunteering for an autism therapy organization and is currently a part time employee of the Equitable Learning Technologies Lab mentioned before. He has been reflecting on his own experiences with autism therapy and has been using them to guide us in the development of the robot. By including our autistic teammate in our discussions of the robot, relying on the advice from organizations whose aim is to help autistic individuals, and doing extensive research on accessibility and fairness practices, our organization can design a robot that is accessible and respects the diversity of children that will likely use it.

The goal of our social robot is to develop it to support children's development, ensure their safety, and ensure that it is fair and non-discriminatory. To support their development, we plan to implement privacy features into the robot, allow the robot to measure the emotional state of children, and to provide a variety of activities which can help users manage their emotional states. To ensure their safety, we will allow for the robot to monitor the emotional state of the user, enable the robot to provide data to caregivers for continuous assessments of its impact, and test its safety features throughout the project. To ensure the robot is fair and non-discriminatory, we will select datasets which include a diverse portrayal of children, research ways in which this robot can be accessible to marginalized children, and will listen to the guidance from autistic individuals and autism-related organizations. Developing the robot with these guidelines in mind will allow us to conform to UNICEF recommendations for developing AI for children.

Other design constraints UNICEF recommends are ensuring the inclusion of and for children, protecting children's data and privacy, providing transparency, empowering governments and businesses with knowledge of AI and children's rights, preparing children for present and future developments in AI, and creating an enabling environment. Including children in our project development will be difficult as it requires a completed prototype. This team will need to complete a working prototype of the robot and thoroughly test its features before testing this robot with children. If we were to test the robot with children, however, we would schedule a time for the child to interact with the robot. We would have an adult supervisor or a mental health professional be present in the room to evaluate how effective our system is. After fulfilling those requirements, we will then let the child interact with the robot without us interfering. We will be taking extensive notes on which features the child paid more attention to and take note of any errors that occur during our program. If we have the opportunity to do a test with multiple children, we will go through the same procedure. This is a goal we hope to achieve in the future. We have considered ways the robot and companion mobile application can protect the children's data. We have discussed JSON web tokens and other secure programming practices with the Computer Science team. We will keep this constraint in mind as we develop the robot's features. To provide transparency to users and caregivers, we will think of ways we can explain how the technology works in a non-technical and simple manner. Additionally, the robot will clearly remind users that it is an AI, not a human. This is to avoid a potentially problematic situation of a child becoming too attached to the robot and seeing it as if it were a human. The robot will not be able to help children as much as a professional adult can; it is only designed to help educate children in a more personalized manner. We have no plans to design the robot in such a way that it can replace human therapists. As for empowering businesses and governments with the knowledge of AI and child rights, we will fulfill this requirement by speaking about children's rights and the potential of AI to our review committees. During our presentations, we will discuss the ways in which children's rights must be protected throughout the development process of AI, how the robot fulfills these requirements, and ways in which future versions could continue to respect children's rights. As for preparing future children for present and future developments in AI, we hope that our project can be a shining example to professors, engineers, and future students of how technology can be used to help not only autistic children, but children in general. Admittedly, this approach is indirect, but unless we will be presenting our project to schools or therapy organizations, we will not have many opportunities to directly interact with children until our project is complete. Finally, for creating enabling environments, we hope our project can be an example of how technology can be used to help children. We also hope that our project is affordable enough so that it can be used in rural and underprivileged areas. Furthermore, we hope that our presentation can inspire observers and future students to keep working to reduce the current “digital divide.” This digital divide is where the majority of the benefits of technology can only be enjoyed by the wealthy and powerful, while people of developing nations and underprivileged areas struggle to receive the benefits. By following these UNICEF guidelines, we hope that our project helps discover new ways artificial intelligence can be optimized to help children and to make the project as accessible as possible in order to reduce, or even end, the digital divide.

IEEE Robot Standards

The Institute of Electrical and Electronics Engineers, or IEEE, has numerous standards for the development of robots. For our project, this team will focus on the standards IEEE 1872, which is the Standard Ontologies for Robotics and Automation; IEEE 7007, which is the Ontological Standard for Ethically Driven Robotics and Automation Systems; and IEEE 7008, the Standard for Ethically Driven Nudging for Robotics, Intelligent and Autonomous Systems. After all, these standards are the most relevant to our project. IEEE 1872 is a standard that focuses on core design patterns in robotics, general use cases for robotics, and general ontological concepts to consider. IEEE 7007 defines concepts, definitions, and use cases for ethically driven robot development without considering practical applications. It is a kind of general guide for robotics engineers. IEEE 7008 defines how “nudges,” or overt or hidden suggestions meant to implement the behavior or emotions of a user, should be developed. All these standards define potential ethical issues with robotics, who will be affected by this issue, how to address these issues, and who will be responsible for the robot’s failures.

For our team to follow IEEE 1872, we need to follow the Core Ontology for Robotics and Automation, or CORA, it defines. This ontology guides all different kinds of robots, from autonomous robots to industrial and medical robots. The main element of this ontology is that we must organize the robot’s tasks, jobs, and resources into a coherent diagram. This diagram must explain all the ways each part relates to each other, whether they contain the functions of another part or operating simultaneously with another part. For our purposes, our diagram will have groups for each part of our robot, including the camera, the track system, and the robot limbs. We will use phrases like prompts or activates since each sensor in the robot prompts another part or activates a function. For example, the camera detecting the face prompts the neck mechanism to move to follow the face. Similarly, input from the separate stress detecting wearable device prompts the robot to adopt a calming demeanor, ask what the user is feeling, and notify the caretaker supervising the robot. Finally, buttons pressed on the touchscreen on its chest prompts it to perform certain actions, like dancing or telling stories or displaying particular emotions. By forming a coherent diagram explaining the robot’s behaviors, functions, and working process, our team will be able to present how the robot functions and thinks. This standard also requires us to consider common definitions used for ontologies, such as this one. For example, when the standard refers to the environment, like a physical environment, it refers to the region where an object of interest is located. This is known as an Object-centered environment. It considers all entities that the robot can encounter. For our project, the object would be the child user whom the robot recognizes. If it is a group of children, the group is the object in the environment. When all the objects are considered, it affects the robot's interaction with the objects. Being able to understand and model these relations will aid us in both communicating our vision and will provide an outline for us when designing and building the robot.

As this team designs and builds our social robot, we will need to consider the proper format to outline the process by which it functions. To suit this purpose, we will be following the IEEE 1872 standard. This standard defines terminology and formats for developing an ontology, or ethical guideline, for robots, especially autonomous robots. We will follow this standard by creating a flowchart depicting what each component does and how they relate to each other. Next, we will consider how the robot interacts with the environment and any objects of interest. In this case, the environment will be a school or therapy organization where the robot will be situated. The object in this case will be the child or children that the robot interacts with. Following this format will not only allow us to have a coherent guideline to developing our robot, but also an excellent way of communicating our ideas and plans. Furthermore, it will allow us to follow IEEE's ethical guidelines for developing robots, whether they be autonomous or controlled. Some of these guidelines include IEEE 7007 and IEEE 7008 standards. IEEE 7007 defines more ontologies for developing ethically driven robots and automation systems [15]. IEEE 7008 offers guidance for developers of intelligent systems that seek to "nudge" humans [24]. To nudge a human in this context means to subtly influence its behavior. In the case of our robot, our robot intends to nudge autistic children into learning how to communicate, manage their emotions, and understand social interactions. By following these standards, this team can ensure that our robot follows IEEE standards and respects the rights of humans. Such rights include the right to privacy and the right to human dignity.

Designing the Mind of a Social Robot Requirements:

To familiarize ourselves with the process of designing a social robot, we read the paper "Designing the Mind of a Social Robot," From MDPI Open Access Journals [17]. This paper provides specific guidelines for designing the robot and provides an example of how those guidelines can be implemented. The primary guidelines provided by the paper include designing a sensing and thinking framework, implementing a low-level control architecture, and implementing a high-level pattern recognition and reasoning architecture. The sensing and thinking frameworks in this paper include three models: the hierarchical paradigm, the reactive paradigm, and the hybrid deliberative/reactive paradigm. The hierarchical paradigm dictates that the robot gathers data from its sensors, devises a plan on how to react to those standards, then acts according to that plan. While this process allows for the robot to be meticulous and well mannered, it could become too slow and complex to use. The reactive paradigm seeks to overcome this issue by only including the sensing part and the reacting part. That way, when a robot senses something, it immediately acts on how it was programmed to do so. This allows the robot to be fast, but this framework does not allow for any careful planning or consideration before any action. In social situations, this can prove to be costly as the robot could act inappropriately in a situation based on its sensor data. In such a situation, the data from its sensors could be wrong. They could also be correct, but since the robot does not think through its actions beforehand based on its sensor data, it could act too quickly and inappropriately. The paper recommends using the hybrid deliberative/reactive paradigm. This paradigm includes the sense and act cycle that the reactive paradigm uses, but also includes a planning capability that can interfere and assist when needed. Using this paradigm, the robot can act quickly when needed, but if it is in a complicated social situation, it can stop and plan its next action. In addition to the basic paradigms, the paper also recommends having a working low-level architecture to control the robot. This means that developers need to design architecture that allows robots to sense and perceive the world around it along with controlling its movements. For our project, this low level architecture would require using operating systems specifically designed for robotics and to incorporate embedded systems such as microcontrollers and sensors into the functions of the robot. Finally, the robot recommends implementing a certain high level architecture that allows the robot to recognize human emotions, recognize faces, and have a framework for understanding how to respond in social situations. For our project, this will involve working with a Computer Science Team to develop a way for the robot to see and recognize human faces along with their emotions. By choosing to use and outline a hybrid deliberative/reactive paradigm, a working low-level control architecture, and a multifaceted higher level architecture into the robot, we can ensure that our social robot matches the kind of quality the paper expects.

For our project's purposes, we will develop a hybrid deliberative/reactive paradigm framework that will dictate how the robot will act. In some circumstances, whenever its sensors detect something, it will immediately act according to its programming. For example, the team has discussed what it would do if it bumped into a wall, object, or any other obstacle. One team member proposed that the robot can have buttons on its front to detect collisions, much like a Roomba. When that happens, the robot will yelp in pain. If it bumps into objects too many times, it will then adopt a sad demeanor and refuse any inputs from its controller. The user must tell the robot they are sorry if they want the robot to be controlled again. Another idea that has been proposed is to have the robot use ultrasonic sensors to detect objects close to it. If it senses one, it will stop or purposely redirect itself to avoid the obstacle. In both of these scenarios, the robot senses an object, such as a wall, it will then have an immediate reaction. No planning is required in these scenarios. However, other scenarios require that the robot has a more planned and cautious action. In these scenarios, the robot needs to consider its protocols in order to plan for the correct response. For example, if the robot notices that the child is sad or stressed, it will enact specific protocols such as offering comforting activities like telling stories or playing music. The robot will detect stress using a wearable device the user wears, which we plan to detect the user's heartbeat. If the heartbeat is elevated, the robot will then notify the supervisor nearby. Next, it will offer the stressed child a range of activities meant to calm and manage stress. Such activities include calming music, games, or dances. In this case, the sensing was the robot detecting an elevated heart rate, the planning was asking the child what would calm them down and initiating an action based on that input, and the action would be notifying a supervisor and acting upon its previously formed plan. By using this framework of sensing and acting in certain scenarios, but utilizing planning when in more complex situations, the robot can engage with users in a way that is socially appropriate. Whenever the robot faces a more immediate situation, such as bumping into a wall, it has an immediate reaction, which in this case would be yelping in pain. No planning is required. However, when the robot faces a more delicate situation, such as a child expressing sadness, the robot will need to consider its protocols and determine the best action to undertake, thus including the planning aspect.

Properly controlling the robot will require a sophisticated, yet well designed low-level computer architecture. It will consist of sensors, motors, and robot-specific programming. The paper cited here also requires that the hardware platform used should be easily adapted to various robotics platforms to be used in future research. To program this, this team will be implementing an Arduino Microcontroller into the robot for the main control of its limbs, for controlling the eye expressions, and for connecting to the wearable stress-detecting device. Additionally, the robot's movements will be programmed using Robotic Operating Systems 2, or ROS 2. Collecting data from the camera and connecting with the machine learning aspects of the robot will be handled by the Jetson computer embedded in the robot. When it comes to controlling the robot, the paper requires that the movements and behavior of the robot are easy to read. Doing so allows for neuroscientists and behavioral psychologists to incorporate their theoretical models into the robot to see if they work. Of course, these theoretical models will need to be formatted into executable scripts for the robot to follow. If these scripts were to be uploaded to the robot, they would first be uploaded to the Jetson. Next, that Jetson will send its data to the Arduino to mandate the robot's behavior. Thus, the requirement for a deliberative reasoning high-level architecture for implementing behavioral and emotional models is fulfilled. The current plans for the robot include programming the robot to be able to express a wide range of emotions, from happiness to sadness. To do so, it will utilize body language and eye expressions. It's body will adopt specific demeanors to appear happy. For example, if it is sad, it's head will look down, its body will slump forward, and its hands will reach its face and make a crying motion. Additionally, its LCD eyes will portray sad-looking cartoon eyes. Similarly, if the robot is happy, it will raise its arms in the air and tilt its head to portray a happy demeanor. Its eyes will display happy-looking cartoon eyes. Doing so allows for child users to practice recognizing emotions. The robot will even include a game where it acts out an emotion and the students will have to guess what the emotion is. Giving the robot the ability to express itself also allows for users to form a kind of connection to the robot. Users will be able to recognize these emotions, carry conversations with the robot, and see it as a kind of friend or even a pet. Furthermore, these emotional models can be used for future research purposes. Another element of its low level architecture is the way it reacts to receiving headpats. The robot will have a touch or light sensor on the top of its head to detect when a person is giving the robot a head pat. It will be programmed to accept headpats happily if the user asks for permission using the mobile application. If the user does not ask for permission and reaches for a headpats, the robot will become scared and shy away at first. If the user continues to reach for the head, the robot will become angry and tell the user not to touch it. If the user wants the robot to exit this state, they must apologize to the robot. Doing this will teach users a valuable lesson about respecting other people's boundaries. The last form of the low-level control architecture will be the motors and track system implemented into the robot. The robot will move using a track system and this system will be controlled by a separate remote controller. The robot will also have a LiDAR system on its face that allows it to detect objects in front of it. It will be programmed to yell in fright if it starts driving too close to an object. Additionally, the robot will have buttons at the front or the back that will detect when a robot hits an object, much like a Roomba detects objects. If it gets hit, it will yelp in pain. If it bumps into an object too many times, it will adopt a sad demeanor, communicating that it is in pain. When in this state, the users will need to apologize to the robot if they want the remote controller to work again. By implementing this control architecture at the low level, future researchers will be able to study their behavioral models and users will be able to connect to the robot like a kind of friend, which thus fulfills the low level hardware requirements of this paper.

In addition to a well designed low-level control architecture, the paper also requires a high-level architecture that manages the social perception system, the reasoning, the storage and communication, and a method for implementing any behavioral or emotional models. This architecture level will be handled by the computer science team, but we will be collaborating with them to make sure the robot fulfills all its requirements. For our robot, the social perception system will consist of a camera in the robot's head that can detect faces and their emotions. This camera will be connected to the Jetson and the robot will undergo machine learning to be able to recognize faces and their emotions. After recognizing their emotions, the robot will be able to respond in an appropriate and caring manner. For example, if a child is sad, the robot will recognize that emotion, adopt a caring demeanor, notify a supervisor, and ask the child what would make them feel better. The reasoning part of the robot will be developed in the Jetson as well and will consist of different greetings and mannerisms for interacting with the child along with logic frameworks for maintaining the child's attention long-term. For example, when the child greets the robot, the robot will then allow the child to choose from a range of activities, from music to dancing to games. After choosing an option, the robot will initiate that chosen activity until finished. For the communication and storage element, the robot will be storing the data into an online mobile application. Such data will be made secure so malicious hackers cannot access it. Finally, the implementation of the behavioral and emotional models will be handled by this team since we will be directly concerned with programming the robot's movements, mannerisms, and expressions. By implementing a logic framework, a method of implementing behavioral and emotional models, a communication and data storage method, and a social perception system, we can develop a social robot that can recognize and understand emotions, manage itself in social situations, and provide necessary activities for helping autistic children.

By developing a hybrid deliberative/reactive framework, implementing a sophisticated control architecture, and a high level pattern recognition and reasoning architecture, we will be able to develop a robot that can fulfill its purpose of helping autistic children. Moreover, future researchers will be able to modify it to experiment with new behavioral or emotional models. Thus, our project will be fulfilling the requirements of the paper "Designing the Mind of a Social Robot." The paper itself acknowledges that social robots have the potential for being useful machines for the treatment of those with Autism Spectrum Disorders, or ASD. The paper reviews a certain social robot called FACE, which stands for Facial Automation for Conveying Emotions. This robot was designed to resemble a human and convey facial expressions like a human does. It could perceive its environment and recognize human faces, demonstrate the necessary social awareness to conduct itself in social situations, and could convey emotions using complex algorithms and motors. When tested with participants with ASD, it was proven to be effective. Our project is similar in that it will be able to conduct itself in social situations, recognize human faces, and express emotions. However, there are significant differences between FACE and our project. While FACE is designed to resemble a human, our robot resembles a teddy bear. Also, while FACE is designed to emulate human emotions, our project will only use LCD eyes and body language to convey emotions. The LCD eyes will also resemble cartoon eyes. Finally, our project's facial and emotional recognition capabilities may not be as complex as FACE's capabilities.

Indoor and Outdoor ASHRAE Standards:

Bearmax 2.0 will likely be operating inside schools and homes but could be stored in unconditioned indoor environments such as attics. It was therefore crucial to make note of the kind of temperature conditions that would be affecting the internal components, especially the more delicate controllers.

ASHRAE (American society of heating, refrigerating and air conditions engineers) have released the 9th edition of “Principles of Heating, ventilation, and air conditioning” in which they detail the methods surrounding the parameters for both indoor and outdoor design conditions.It is based on these guidelines that we will make assumptions about the climate influences on our design. Bearmax will be functioning in comfortable indoor conditions where the dry bulb temperature does not break from an average of 75 degrees. Dry bulb temperature refers to the temperature at which it is not affected by humidity. As for the relative humidity of indoor design conditions that would be within the range of 30-60% These would be under the ASHRAE Standard 62.1-2016. Specific standards supporting the full range of design conditions can be found in the ASHRAE standard 55.

Being a social emotional learning tool, unless Bearmax is in storage it will be indoors under the specified design conditions however, the clinician or child may want to go outside and expose Bearmex to central Florida outdoor conditions. Florida has a dry bulb temperature of 99.6 degrees corresponding to 99% frequency per the 2021 ASHRAE design conditions for the Orlando executive airport. For our design, it’s imperative to consider how such high temperatures could affect Bearmax’s performance and ensure that it can operate under such conditions through extensive testing.[26]

Section 5: Comparison of Chat GPT and Other Platforms

Relying on ChatGPT, although tempting, is problematic. Some of our members have experience using it and are well aware of not only its positives, but also its downfalls. While it can write sections of code and paragraphs for us, it lacks the contextual knowledge required for the writing to be effective. When asked to write text according to a specific prompt, it will give generic answers based on the text it has been trained on. When asking it to write code for a program, it can certainly provide some code to use, but there is no guarantee that the code will be useful. Finally, ChatGPT has been known for giving false information at times. OpenAI even has a disclaimer saying “ChatGPT may give out false information about people, places, or facts.” To illustrate these shortcomings, we will provide three examples.

For the first example, one of our members asked ChatGPT, “Please tell me how the Pepper Robot can be helpful for the positive development for children with autism.” It listed various ways it can be helpful, such as emotional recognition, social interaction, and reducing anxiety. With each point listed, it elaborated with long explanations of what each point meant and how the robot provides that. For example, it listed customized learning as something the Pepper robot can provide. It explained that, “Pepper can be programmed to cater to the specific needs and interests of individual children, providing a customized learning experience that is tailored to their requirements.” While true, these are explanations given without examples. It does not cite studies, articles, or stories of the Pepper robot helping autistic children. In fact, when asked to provide an example, ChatGPT provided a hypothetical scenario where the Pepper robot helps an autistic child. It told the story of Alex, a nine year old autistic boy who found social interaction, communication, and expressing emotions challenging. In this story, Alex’s therapist suggests using the Pepper robot to teach them how to effectively communicate and participate in social activities. This robot was able to incorporate Alex’s interests, like drawing or playing games, into the activities. With time, Alex’s confidence improved and he was able to participate in social situations. While this scenario is plausible, it is merely a hypothetical scenario. ChatGPT did not cite any studies or articles, so whether or not ChatGPT really knows what it is talking about is still unknown. Meanwhile, our team has read studies on the Pepper Robot and learned how effective it is at helping children with autism. Not only have we read and understood it, but we also have observed some unexpected actions that ChatGPT probably would not have considered. One of these actions was when a child tried to give the Pepper Robot hair using a rubber snake. It was an act of playfulness that neither we, nor ChatGPT would have thought of. While ChatGPT can certainly write, and admittedly write well, it lacks the knowledge one needs to actually write effective essays. It cannot read or cite sources unless prompted to. Even if our team did give the studies to ChatGPT and told it to write our paper for us, it would likely regurgitate what the studies said without offering its own thoughts or opinions.

The second example of the limitations of ChatGPT is evidenced by an experience one of our members had when trying to code using ChatGPT. Our member, Zachary Larson, had a programming assignment for his Operating Systems class. This programming assignment required that he try to get ChatGPT to create a round robin scheduler in Python. Zach decided that for this assignment, he would approach the topic step by step. He would first ask ChatGPT if it knew what a Round Robin Scheduler was. If it did, he would ask it to write a basic version of the scheduler, then add on more features to fit the assignments requirements. It took him three attempts to get a functioning code whose output was at least close to being correct. The first time he tried, the scheduler kept giving the wrong outputs. No matter how many prompts he gave, no matter how many times he pointed out the mistakes in its code, ChatGPT would not fix the code. In the second attempt he tried again. In this attempt, he first asked ChatGPT to write a basic program in Python that would print the phrase “Hello World.” The purpose of this was to guide ChatGPT to first understand what Python is, then try building the Round Robin Scheduler. After proving that it understands the basics of Python, he then asked ChatGPT what a Round Robin Scheduler is. ChatGPT answered correctly. After that, he tried to get ChatGPT to write another round robin program, but much like before, it failed to give the correct outputs. Frustrated, he tried a third time. This time he wanted to build the round robin scheduler, but use ChatGPT as a helper. Although he did rely on ChatGPT for drafting the initial part of the code, he modified the program so that it could work correctly according to the assignment requirements. However, there was one flaw in the code that he could not figure out. He knew what the flaw was and how it was affecting the output, but he did not know how to fix it. He tried asking ChatGPT multiple times to fix the error, but it did not produce a solution even when it said it found a solution. Ultimately, Zach concluded that ChatGPT was no replacement for real coders. While it can be useful for creating initial code and can make coding faster, an experienced and knowledgeable programmer is still required to make the code the best it can be.

The third example of ChatGPT's limitations is the number of times ChatGPT has written wrong information as outputs. ChatGPT itself even refuses to answer questions about public figures in the current year because its training data includes written text written up to 2021. OpenAI's disclaimers clearly state that ChatGPT can often get information wrong on multiple topics. OpenAPI has also described its dissemination of false information as "hallucinating" and "making up facts."[16] For example, a Purdue University study explained that out of five hundred and seventeen software engineering questions, ChatGPT got fifty two percent of the questions wrong and seventy two percent of the questions verbose [21]. Ironically, ChatGPT is often used to help people write code and understand Computer Science Concepts. Zach Larson, a computer engineering major, admits that he has used ChatGPT a few times to help with programming assignments. However, he has also noted that ChatGPT is not always correct. The same Purdue study also states that at least thirty nine percent of people rely on ChatGPT for software-related inquiries. In another incident, a journalist for Insider, named Samantha Delouya, asked ChatGPT to write a news article [18]. The article was about a Jeep factory in Illinois whose production was struggling due to the cost of producing electric vehicles. Despite being written quickly and seeming convincing, it contained fake quotes from the CEO. Vincent Conitzer, a Carnegie Mellon professor of computer science remarked that "These models are trying to come up with text that is plausible according to their model. Something that seems like that kind of thing that would be written. They're not necessarily trying to be truthful."[18] Thus, our team feels that we cannot fully entrust ChatGPT with writing our paper for us, since it regularly writes wrongful information.

After reading about incidents of ChatGPT failing and experiencing its shortcomings ourselves, we conclude that ChatGPT cannot be totally relied on to write our paper or our code for us. While we may use it to draft initial versions of our paper and write initial drafts of our code, we still need to extensively edit the outputs to ensure that they meet our expectations. The problem with relying on ChatGPT extensively is that it produces well written but uninformed opinions of topics, produces code that only functions after careful editing, and often produces misinformation. These shortcomings seem to be a key design flaw that results from its original purpose: to be an artificial intelligence that successfully mimics human language. It can certainly mimic human language in an incredibly convincing fashion, but only because it considers which words and which phrases are most likely to be used after certain words or according to a prompt. As stated before, its goal is not to be correct or knowledgeable, its goal is to write text that can pass as human. Therefore, we conclude that the best use of ChatGPT for our purposes is to prompt it to write initial drafts of code and papers for us, and then help us edit them after we have modified them to suit our purposes. By employing ChatGPT in this manner, we can ensure that our work is honest, informative, and well written while also allowing us to be more efficient and work faster.

In addition to using ChatGPT, we have been using Google to research our project. Google has been an excellent platform for finding researching materials that can aid in our project. It has an incredibly large variety of resources and is excellent at choosing the most relevant resources first. It has provided us with studies to demonstrate that our project has potential. When we were first researching our project idea, we needed to find studies of similar projects to see if the idea had any merit. We asked Google to find us articles or research on social robots and it gave us several that were exactly what we needed. These studies discussed multiple social robots, affirmed that their use in therapy was effective, and provided examples of downsides of each robot. After finalizing our project idea and finishing our preliminary research, we needed examples of other social robots to understand their strengths and weaknesses. So, we searched on Google for other related robots and found numerous examples. One of the robots we found was called Moxie, a small, cute robot that can have conversations with children and recognize faces. It is designed to be a friend to young children and can teach them important social skills. We used this robot as one of our inspirations as we learned what it is capable of, how exactly it helps its users, and what downsides it has run into. We hope to create a social robot that not only has the same advantages, but also improves upon its disadvantages. However, Google has not always been able to provide direct answers to all our questions. For example, one of our members wanted to look for robots that can teach young children consent and boundaries. He knew that, if implemented, such a feature can make our robot unique among many of the other social robots. However, he wanted to research to see if other robots implemented this feature and, if so, how it was implemented. Unfortunately, Google's results did not include articles or studies of robots teaching users consent. It instead linked to more articles about the previously mentioned Moxie robot. Ultimately, while Google can provide sources and can better understand search queries, unlike ChatGPT, it cannot always provide direct answers to questions. Nonetheless, this team will research what it can and learn all that it can in order to design the best possible social robot.

Section 6: Hardware Design

Table 10: Summary of Requirements

MULTIPLE REQUIREMENTS		
Emotions with 5 - 10 programmed emotions with expressive visuals and body language.	BearMax as an SEL tool will be able to execute stated emotions for help in teaching how to perceive emotions.	Test runs of each emotion movement program, then a test runs to see if BearMax responds with correct movement.
Move well with a track system easily navigable with remote controls.	Speed = TBD Able to move forward backward and change directions.	A test course involving carpet and wood flooring to test the track system for BearMax.
Must be able to detect stress in persons with camera	CS team details, outside of ME/CE scope	Verify that BearMax is identifying stressed people correctly.

Table 11: Engineering Specifications

PERFORMANCE/MAIN DETAILS		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Weight of Body and Frame	Maximum 20-30 pounds	Weight scale measurement
Height of Robot	Maximum 3 feet	Inspection (use measuring tape)
Width of Robot	Maximum 2 feet	Inspection (use measuring tape)
Material of Frame	Composed of PVC, 3D printed PLA parts for the rigid structures, Elastic 50A resin shell, and a cloth covering	Inspection each material satisfies each purpose

Number and List of Components	Head, neck, body shaft, 2 hands with digits, 2 lower arms, 2 elbows, 2 upper arms, 2 shoulders, torso, base, tracks	Inspection
Manipulators	Electrical motors	Inspection
Type of Manipulators	Servo Motors Designate torque and power for each motor	Inspection and testing each movement to ensure load requirements are met by motors
Head and Neck Motion System	Neck is capable of bending forward, backward, and side to side to express emotions. Neck is also capable of 180 degree yaw rotation. Ears are capable of rotating forward and backward to help with emotional expression.	Verify neck and ears move through proposed range of motion, evaluate by inspection.
Shoulder and arm motion system	Shoulder joint is capable of rotating forward 180 degrees and sideways rotating 90 degrees. Inward rotation of 90 degrees. Arm limb will be connecting to the elbow joint	Verify shoulders move through proposed range of motion, evaluate by inspection.
Elbow joint and forearm	Elbow joints will be capable of 90 degree rotation toward the body.Elbow joint will be connected to the forearm which will be connected to digits.	Verify elbows move through proposed range of motion, evaluate by inspection.

Torso	Inner torso will be a rotational rod able to support the upper structure that connects into the track platform. Rod will be able to yaw 180 degrees. Outer shell will then cover the rod to retain the goal of teddy bear appearance. BearMax 2.0 will have a screen on the torso to display emotion for the game. Design will be likely be similar to BearMax 1.0	
Digits	Our hand design will consist of 2 large fingers and a thumb. Each finger will be capable of 90 degree inward rotation at 2 different points, while the thumb will be capable of 90 degree downward rotation.	Verify digits move through proposed range of motion, evaluate by inspection
Platform/Track	BearMax will have a track system for movement which is adjustable with the app. The track system was decided because of the prevalence of carpet in living rooms which BearMax would likely be positioned in. The carpet surface would make tracks more suitable because it is a softer surface.	Test track system on course similar to family home and or classroom which would include carpet and tile flooring.

BearMax is able to play two distinct games (stretch goal have more) and greet the person interacting(“Hello”, with wave) 1.Rock Paper Scissors 2. How is BearMax feeling today? Identify the right emotion.	BearMax waves and greets correctly. BearMax is able to correctly be prompted into either game and identify when it has lost or won. BearMax will display different emotion options on the torso screen and the child will select the perceived emotion BearMax is making.	Testing each game and greeting to confirm BearMax is operating properly.

Table 12: Robot Operating Environment

OPERATING ENVIRONMENT		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Temperature Requirement Must withstand indoor/outdoor temperature range.	Per ASHRAE Orlando design conditions 2021 concerning dry bulb temperatures, temperature does not normally exceed 99.6 degrees fahrenheit and does not drop below 32.2 degrees fahrenheit.[25] Comfortable indoor range per ASHRAE is listed as roughly 75 degrees averaging both winter and summer conditions.[26] BearMax will almost always be operating indoors but we can confirm	Full test including emotion movements/displays and linear movement on track system.

	it will still function under these conditions.	
Humidity Requirement	Comfortable relative humidity of indoor conditions per ASHRAE range from 30% to 60%. Outdoor Orlando humidity can approach 100% on extremes. BearMax will likely only be outside if children/clinician find it comfortable that day so these extreme conditions are not restricting so we should assume mainly indoor conditions.	Full test including emotion movements/displays and linear movement on track system.
Pressure Requirement.	Standard atmospheric pressure.	Full test including emotion movements/displays and linear movement on track system.

Table 13: Emotions Specifications

EMOTIONAL BODY LANGUAGE		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Emotion: happy/excited	BearMax displays a happy face and eyes on screen in addition to raising arms/shoulders/elbows and thumbs up. Torso screen displays emotion.	Visual inspection

Emotion: sad	BearMax displays a sad face and eyes on screen in addition to slumped shoulders/tilting head down. Torso screen displays emotion.	Visual inspection
Emotion: angry	BearMax displays an angry face and eyes on screen in addition to balling up hands, straightening arms and nodding forward. Torso screen displays emotion.	Visual inspection
Emotion: confused	BearMax displays a confused face and eyes on screen in addition to tilting head to side. Torso screen displays emotion.	Visual inspection
Emotion: shock	BearMax displays a shocked face/eyes in addition to raising hands to face and bending elbows. Torso screen displays emotion.	Visual inspection
Emotion: fear	BearMax displays a frightened face/eyes in addition to covering head with hands and looking down. Torso screen displays emotion.	Visual inspection

Emotion: tired	BearMax displays a tired face/eyes in addition to tilting head to side. Torso screen displays emotion.	Visual inspection

Table 14: Measurement specifications

GEOMETRY/PHYSICAL		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Specific length/width/height of Torso skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length length/width/height of Neck/head skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of track system/platform	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of shoulders, elbows, hands skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of outer plastic shell covering skeleton	TBD	Measurement via CAD software and confirmation with measuring tape

Table 15: Product summary/details

COMMERCIAL/SAFETY		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Cost	<500$ to manufacture	Sum of cost related to parts

Tip risk and countermeasures if needed	Identify risks of tipping over and insert counterweights/redesign if needed.	TBD
Appeals to market(clinicians/parents)	Using benchmarked traits from competitors, ensure BearMax has major abilities that meet industry standards.	Confirm feature in relationship matrix
Ensure low risk of laceration	Avoid exposed sharp corners or edges	Visual inspection

Table 16: Electrical/Computer System Summary

ELECTRICAL/COMPUTER SYSTEM		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Battery voltage power supply	Maximum of 12 volts, step down converter will be used to lower to 6 volts	Confirm via multimeter
Battery current	TBD	Confirm via multimeter
System resistance	TBD	Confirm via multimeter
System operating power requirements	TBD	Confirm via multimeter
Computer/head operating system power requirements	TBD	Confirm via multimeter
Run time	When plugged in, as long as they want. When not plugged in, a goal of 20 minutes to an hour.	Confirm with stopwatch
Speaker System	Must be loud enough to say simple greetings.	Confirm with volume measuring app

ELECTRICAL/COMPUTER SYSTEM		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Battery voltage power supply	Maximum of 12 volts, step down converter will be used to lower to 6 volts	Confirm via multimeter
	Estimated around 50-60 decibels based on CDC guidelines for conversation volume measurements	
Microphone System	Able to detect spikes in volume, range from 50-80 debels to determine a “normal range” and a “loud range”.	Ensure it could pick up volume from these ranges with testing verification of normal and yelling conversations.
Camera system	Each LCD eye will have minimum resolution of 320x240 pixels, size of LCD could range from 4x4 inches to 6x6 inches	Quality ver

Table 17: Actuator System

ACTUATOR SYSTEM		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Actuation	Electrical	Servos motors, possibly DC motors
Motor size	TBD but must fit within size parameters	Measurement verification
Motor Power	Can operate within 1-6V range	Measurement verification

Motor RPM	Must be able to turn joints as specified	Measurement verification

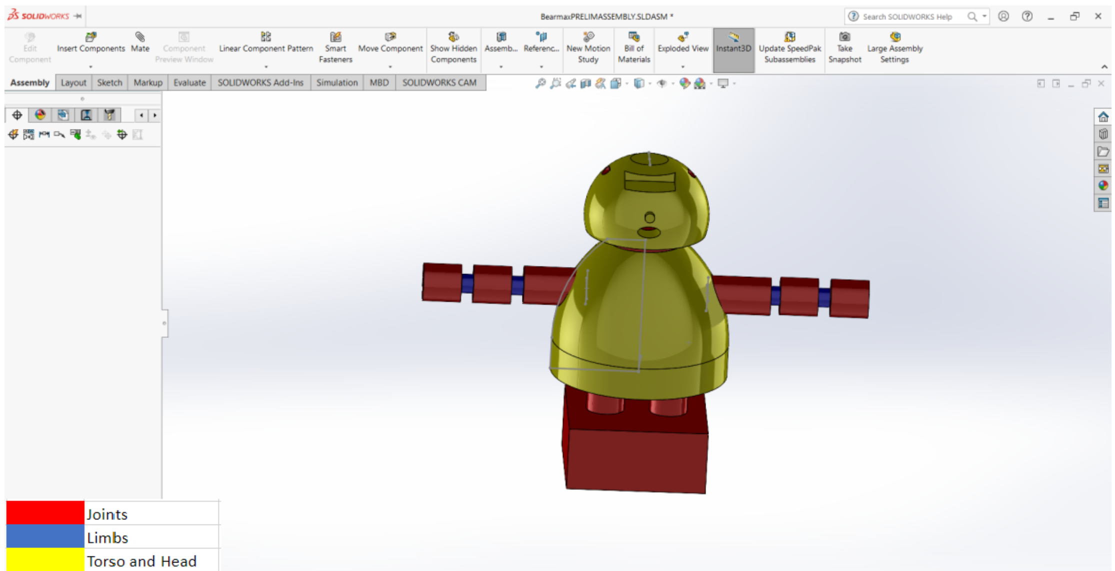


Figure 11: Initial conceptual CAD model of Version 2 BearMax

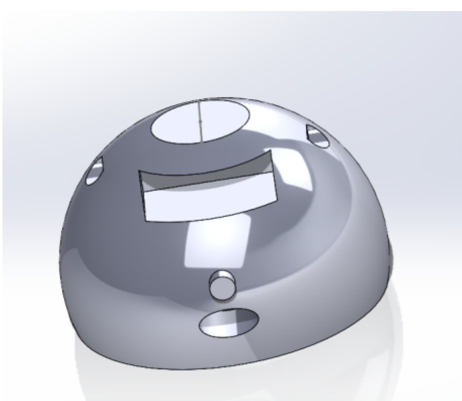


Figure 12: Initial CAD close up of conceptual head of Version 2 BearMax

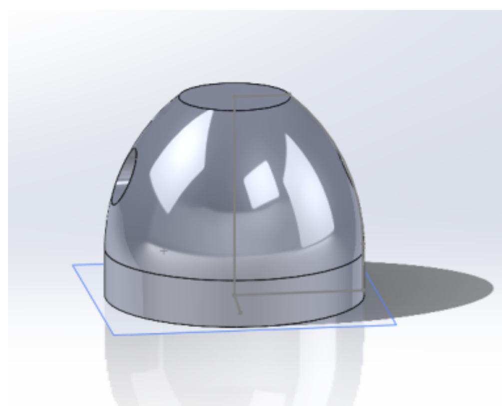


Figure 13: Initial CAD close up of conceptual torso of Version 2 BearMax

To design the overall frame and joint system of Bearmax, it was decided to break the robot into individual sections based around each joint system. Each Mechanical engineer then assigned themselves their systems to design. Bearmax was broken into the following areas.

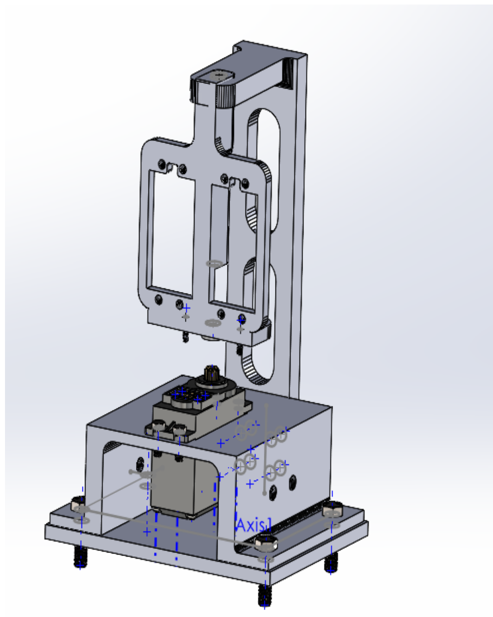


Figure 14: Initial CAD of further specified Neck Design

Table 18: Summary of Version 2 Topics

Bearmax 2.0
Head
Neck
Shoulders
Elbows
Hands
Torso
Track Platform

In our overall design process, it became helpful to subdivide possible building challenges by each section. The purpose of this was to compare our changed systems with last year's design to avoid setbacks for the construction/testing phase of senior design. The following charts and descriptions relate to our expected design process and subsequent challenges.

Head

The head of Bearmax will have to contain two ear joint systems, a camera, sensors, LCD display, wiring, speakers and possibly more. Due to this complexity, it was suggested to build the robot starting from the neck/head region as this area is undoubtedly the most important section of the robot.

Our biggest suspected challenges all relate to sizing. The head must have adequate space for all the components so accurately estimating the needed area of components from both the computer engineering team and computer science time is vital before starting construction.

We plan on using the "Y" shaped design from last year's team to hold the LCD screen display but the location may not be directly about the torso due to the change in neck design.

Table 19: Version 2 Head Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Head	Sizing the head to mount on the neck base	Our neck platform must be able to support the head, ear mechanism along with the components for the LCD eyes.This is a lot components for such a small area	Assigning components to a lower stairwell like base in the torso to save space on the neck platform and possible head platform
	Adequately sizing the space for the proposed ear mechanism	The joints and motors need a mount/securing assembly in the head or adjacent platforms for their location and the small sizing could complicate that	Tape, securing platforms on the exterior, extensions to the "Y" frame for the LCD eye display.
	Adequately sizing the space for the proposed Camera/LCD/Eye setup	The LCD display will likely have the "Y" frame to support it coming from the center of the neck platform or torso	Reusing the "Y" display design from last year and possibly modifying it to account for the change in neck design.

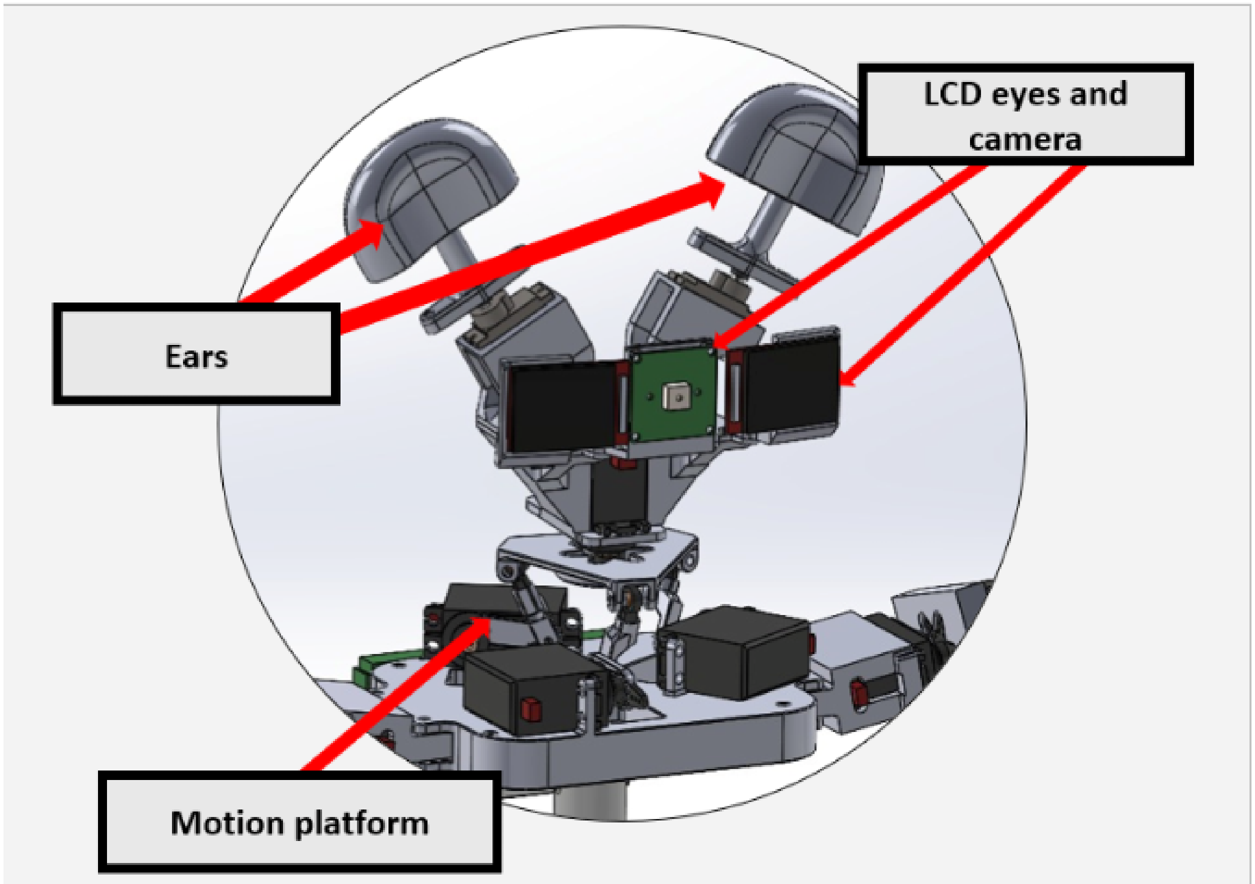


Figure 15: Version 1 Eye mount [27]

The motion platform from last year was positioned directly over the torso pipe opening, ours may be shifted forward or backward as the large platform supporting all the components will have to be adjusted for our changed assemblies. A similar design to the "Y" apparatus to hold the ears and LCD will likely be used for our proposed head design.

Neck

Last year's neck design used a 4 DOF platform. The heave DOF added no value of emotional expression but was already designed and constructed by a member of the mechanical engineering team. So it made logical sense to use it to save time. That is not the case for the current Bearmax team.

The options for a new neck design were narrowed down to a traditional six degree of freedom stewart platform, a similar animatronic neck design and our selected animatronic design.

Utilizing a new design with emphasis on three DOF was decided. The neck design selected is for mostly animatronic applications, so its ability to aid expression has already been tested in similar projects. Using a pugh matrix allowed us to focus on our main design concerns which were building complexity, DOF requirements, and length of construction.

Pugh Matrix					
		Solution Alternatives			
Key Criteria	*Importance Rating*	Existing 4 DOF with Servo	Animatronic Neck 3 DOF	Traditional Stewart Platfrom 6 DOF	Humanoid Robot 3 DOF Neck
Cost	3		S	-	S
Length of construction	7		S	-	S
Added changes to existing design	4		-	-	-
Build complexity	8		+	-	+
Weight	4		S	S	-
Meets needed DOF	8		S	+	S
Sum of Positives			1	1	1
Sum of Negatives			1	4	2
Sum of Sames			4	1	3
Weighted Sum of Positives			8	8	8
Weighted Sum of Negatives			4	-22	-8
TOTALS			**4**	**-14**	**0**

Figure 16: Pugh Matrix

Our selected design provided the largest benefit per our criteria relative to last year's neck design.

Building complexity involved things such as amount of components, variety and obtainability of components. Once we obtain the components, they could require complex processes to fit our design idea, adding to the likelihood of a setback. The second main concern was related to our range of motion. Ensuring that our neck could meet our three DOF requirements is absolutely imperative to the success of the project. Our last major concern was the length of construction. Due to our strict deadlines, lengthy manufacturing designs should be avoided unless absolutely necessary.

Table 20: Version 2 Neck Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Neck	Securing the Neck to the Torso spine	The neck is much taller than the previous year's neck design. This will require adjustments to the adjacent parts to allow the robot to perform movements	Shortening the torso to maintain the neck design
	Selecting Motors that can bear the load	The design we're using was originally used for animatronics with little weight in the head. Bearmax 2.0 will have lots of components and a head shell bearing down on the neck platform. The motors may have to be adjusted	Using different motors if needed, or moving weight OFF the head
	Calibrating the motors	The yaw ability of this neck is a full rotation. This could create problematic collisions with lots of other components	The movement of the neck will need to be restricted to less than 180 degrees to avoid these possible collisions

We have a largely developed preliminary CAD model of our proposed neck design. That being said, we are still investigating our manufacturing capabilities so this design is not finalized.

Furthermore, it is necessary to expand on solutions to the torso/neck/head connections.

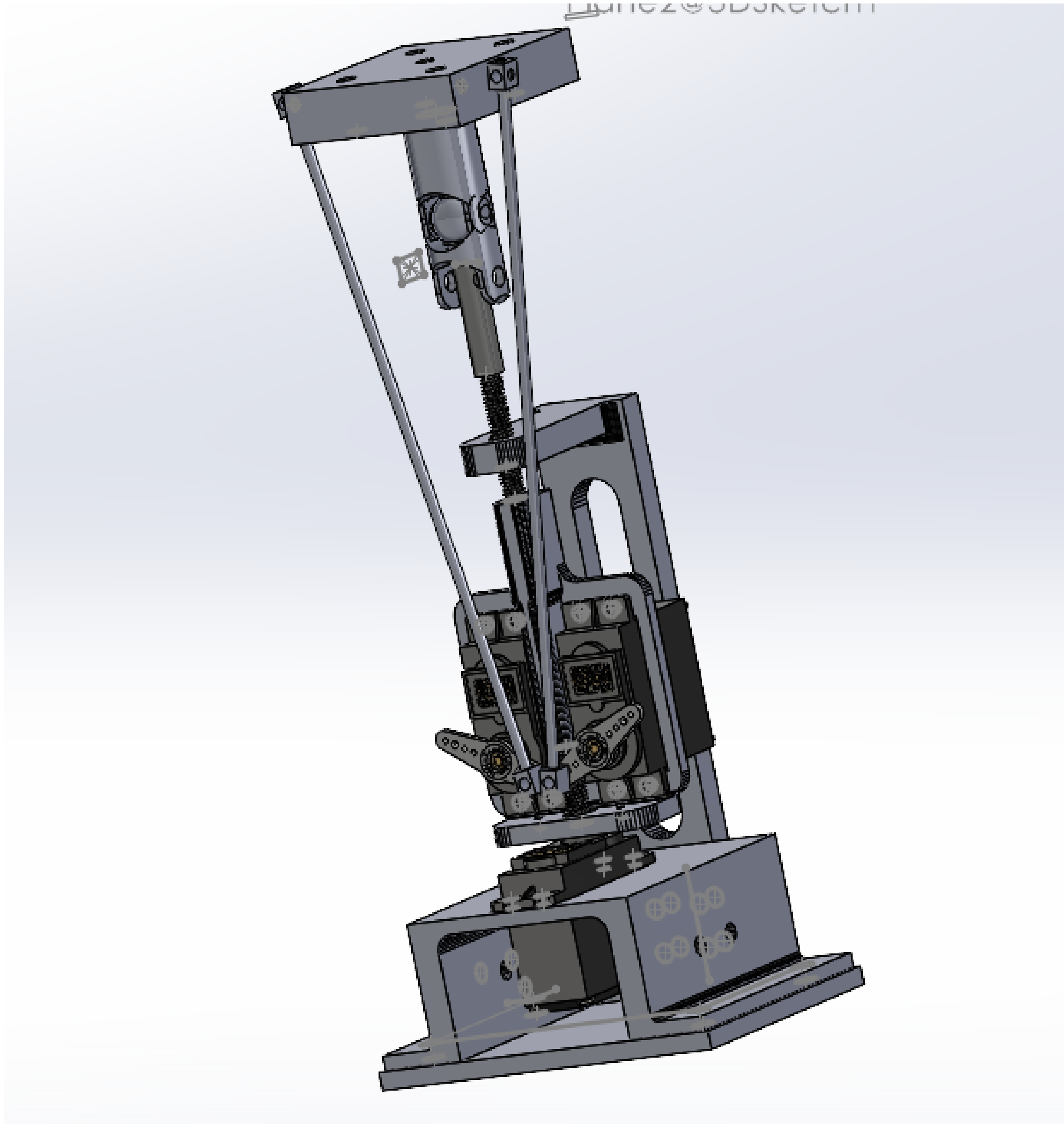


Figure 17: CAD model of near finished neck

Torso

The neck is significantly taller than last year's design. This will require changes to the adjacent components such as shortening the torso.

Table 21: Version 2 Torso Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Torso	Motors selection	Due to the different design and change in major joint systems, the motor may have to be adjusted for the difference in weight and moment	Using a different motor or adjusting the settings
	Torso sizing	The adjustment needed for the increased neck height will make the torso shorter, this will need to be accounted for when determining sizes	Torso and Neck CAD modeling to highlight any needed changes in dimensions
	Analyzing weight distribution	The risk of tipping is much more important as the robot is completely mobile now.	Installing counter weights at the bottom to keep most of the mass at the base or putting as much equipment as possible towards the bottom
	Securing the tablet	The tablet must be secured to the outside of the shell for the child to be able to see its display. This will require a design to mount the tablet.	Indenting the outer shell to shape to the tablet could simiplify the mount assembly. CAD perspective will be helpful in determining the most effecient design to secure the tablet

Our torso must be able to yaw between 120 to 180 degrees for emotional expression. On top of that, the robot is now mobile, making weight distribution much more important than last year. This is because of the increase in risk of tipping. Our proposed solution is a series of platforms to hold on to more components with less length as well as counter weights at the bottom if needed.

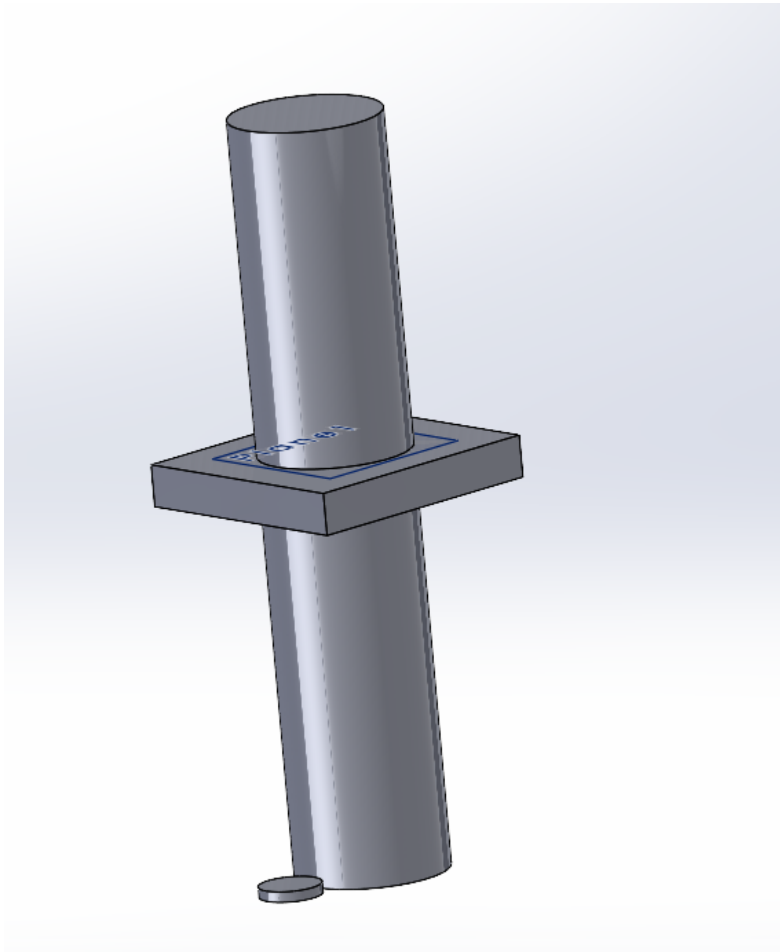


Figure 18: CAD model of platform

Multiple platforms similar to the one depicted above were proposed as a solution to contain additional components. As for the motor assembly to rotate the spine of the torso, we will be using a similar design as last year's team unless load requirements change and it must be significantly edited.

Shoulders

At this point in time we do not have a finalized shoulder design. We have established ranges of motion and subsequent degrees of freedom but not specific assemblies.

The biggest change in our arm mechanism is the addition of the fingers and connection to the torso. The load the shoulders will bear will be different because of the increased complexity of the hand so this could result in increased weight the motors must overcome. A design with torso connection must be determined before a more in depth analysis can be done.

Table 22: Version 2 Shoulders Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Shoulders	Sizing connections	The shoulders must lock into the torso, but the torso is shortened due to the neck design so this could complicate how we do our shoulder	Moving the neck to not be directly above the torso, this will require a CAD perspective to fully understand the possible shoudler sizing complications
	Analyzing weight distribution	Bearmax 2.0 will have a more complex arm system than previous years. This means more weight on the shoulders joints due to the increased moment from the entire arm	Idenifying powerful motors that can support the proposed load could mitigate the increased strain the joint will have

Our theorized issues stem mainly from sizing the connections to the torso and the new weight distribution of the arm. This will require CAD modeling if we are to move forward before building.

<u>Elbows</u>

We are still developing our arm mechanism so the elbow design is not well defined at this time.

Due to the complexity of the adjacent hand assembly, the elbow may have to house components related to the finger movement in the hand as the hand may not be large enough to conceal everything.

Table 23: Version 2 Elbows Details

Elbows	process step	What/how can it go wrong?	Possible Solutions/Mitigations
	Motor selection	The elbows will be redesigned as part of the entire arm mechanism which will overall be more complicated than last years. This makes increased load a possibility which could affect motor selection	Estimating the possible moment, weights and relevant stresses to aid motor selection

The added components could require changes in the motor loads but this remains to be seen.

Hands

One of the biggest changes relative to the previous iteration of Bearmax is the addition of fingers. One of our stretch goals is for Bearmax to be able to play rock paper scissors with children and providers. This led to a new hand design of at least three digits. The hand is small relative to the motors being used so other parts of the arm may have to be used to conceal components for the hand. As of right now, we have conceptual CAD models for the hand that will be further built on as we get closer to senior design 2.

Table 24: Version 2 Hands Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Hands	Component Placement	Bearmax is relatively small and the appearance of a teddy bear is crucial to its function. Therefore concealing the robotic looking components for a complex system like the hand will be difficult given the small surface area and volume of the hand	Placing hand components in the more concealed wrist and elbows if needed.
	Shell sizing	Sizing the hands will be difficult for the outer shell because of the small finger size.	Adjusting our material selection to adapt to a possible complication such as the lack of size

So far we developed a conceptual hand model to be mounted at the end of the arms. However, we are still researching our capabilities for manufacturing and working to ensure functional connections to the limbs. This leaves this concept very open to change.

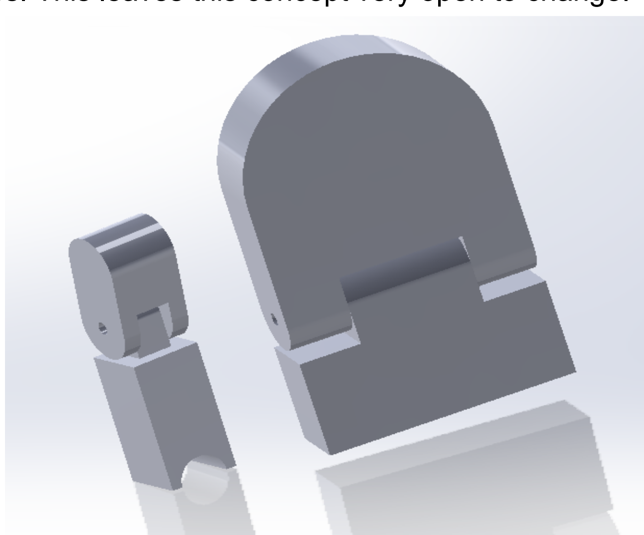


Figure 19: CAD model of initial digits

Track Platform

One of the most noticeable changes in Bearmax 2.0 is the mobility. Bearmax 2.0 will be moveable via remote control. We decided that a tanklike track system would be most adequate for the mobility needs of Bearmax. Refer to the pugh matrix below for the logic behind our decision making.

Table 25: Track Platform Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
Track Platform	Designing the surface area conncetion	There is a large amount of weight in the upper section of bearmax relative to the lower half. Last year's project used a large wooden box as the base but the RC track platform poses a lot of new challenges related to balancing the robot	The top platform of the RC tank base could have a small box to hold the torso apparatus but this will still require a larger base for the robot. It will definitely complicated the track platform base
	Motor selection	The Tank RC platform for which we are basing our design off of is not made to have lots of weight on the surface. The additional weight could overstress the motors.	Using more powerful motors or testing similar models to determine load requirements.

The increased movement forces us to strongly consider the overall moment of the robot as the risk of tipping over will be increased. This leads us to focus on two different components of the track platform; the torso connection and the overall area. Existing reference models for our track design such as the YAHBOOM G1 Smart-Robot Car will likely be too small to support Bearmax.

Figure 20: Depiction of pre-built robot car [28]

Between our movement options, the realistic choice was between a wheel system or a track system. The advantage of a track system over soft surfaces such as carpet led to the overall selection.
We also briefly considered other movement options such as flying or walking but due to the increased complexity associated relative to our movement needs, the track system became the obvious choice. It’s important to note that last year’s project was completely immobile in terms of translation, it was therefore important to note that any change involving a movement system would create increased construction times and complications.

This will likely call for substantial adjustments and modifications to make the track system functional for Bearmax. Our expected challenges revolve mainly around balancing the moment of Bearmax to avoid tipping and creating a platform that can adequately support the entire robot.

General

After working through each section, it became apparent that we would have recurring or overarching design concerns for the collective robot which were summarized below.

Table 26: Version 2 General Component Details

	process step	What/how can it go wrong?	Possible Solutions/Mitigations
General	Shell Design	We don't have a concrete idea of our skeleton so planning out the shell design this early could prove complicated	Finishing the skeleton early so that we have time to manufacture the shell components
	Power supply	Until we have a concrete design for our components, knowing our exact power requirements will be difficult	Finish joint designs early to allow for accurate accounts of energy requirements
	Part machining	We will likely be using an off campus machine shop one of our members has access to. There are benefits like speed of building but they likely don't have the resources that the IDEAlab at UCF does.	Get an early baseline for what parts will be too complicated for our manufacturer and order parts from UCF long before issues with deadlines

Until the skeleton is finished, it will be difficult to design an adequate shell. This creates an incentive to finish the skeleton quickly so that we do not experience a setback for the outer shell. Another concern was the power supply. Until we have a definite load from all our electronic components, it is impossible to estimate our power needs.

One of our mechanical engineering members has connections to an off campus machine shop that has agreed to assist in machining parts. This is convenient as we are not limited to the UCF lab but the full capabilities of this shop are not fully understood.

To mitigate this it is early to communicate with their machinist on their ability to create our parts. Our design selection process for the track concept is summarized in the pugh matrix below.

Pugh Matrix					
	Solution Alternatives				
Key Criteria	***Importance Rating***	Wheel Platform System	Flying/Helicopter Syetem	Track Platform System	Functional Legs
Cost	2		-	S	-
Length of construction	9		-	S	-
Added Risk (Tipping)	5		-	S	-
Build complexity	9		-	S	-
Weight	2		+	S	-
Allows for wide range of environments	6		+	+	+
Sum of Positives			2	1	1
Sum of Negatives			4	0	5
Sum of Sames			0	5	0
Weighted Sum of Positives			8	6	6
Weighted Sum of Negatives			-25	0	-27
TOTALS			**-17**	**6**	**-21**

Figure 21: Pugh Matrix summary

We have also attempted to consider the design and construction complications associated with such a large change.

Table 27: Failure Modes and Effects Analysis Chart

What is the component, process, or step that can go wrong?	How can it go wrong?	L	SC	C	D	SHs	Hs	RPN	Prevention
1. Eyes and body reflect	Incorrect coding inputs; incorrect	3	5	1	2	15	3	6	Proper and sufficient trials and test runs; double checking the

different emotions than intended	motor labeling and placement; communication error between ME and CE team								code; communicating well and restating information to ensure all parties are clear on the goals and information to carry out a task/specific emotion
2. Robot falls / pushed on ground	Sensor issue, not properly detecting obstacle; robot offends user/user chooses to push robot for unknown reason	5	4	3	3	20	15	45	Inspection of sensors and testing the robot multiple times in before official user interactions; ensuring sensors for collision avoidance are functioning properly and appropriately placed for best outcome
3. Robot falls / pushed off elevated surface	Sensor issue, not properly detecting obstacle or edge of elevated surface; robot offends user / user chooses to push robot for unknown reason	4	5	4	3	20	16	48	Inspection of sensors and testing the robot multiple times both in regards to the autonomous portions and human controller (remote controller track); ensuring sensors for collision avoidance are functioning properly and appropriately placed for best outcome
4. Robot falls on / pushes user	Hardware and coding issue, incorrect motor labeling and miscommunication between ME and CE team; Sensor issue, not detecting obstacle properly	2	9	6	3	18	12	36	Inspection of movements of hands, arms, torso, head, tracks, etc. (all components) of robot and recording movements or adjusting hardware; ensuring LiDAR sensor and other sensors for collision avoidance are functioning properly and appropriately placed for best outcome
5. Robot moves over / on top of hands / legs of user	Sensor issue, not properly detecting obstacle, coding issue; hardware issue	3	10	7	2	30	21	42	Inspection and testing of sensors for collision avoidance; ensure that sensors and collision avoidance features are functioning properly and

	with motors, not stopping fast enough								sensors are appropriately placed for the best outcome and to cause as little harm as possible both to the user and robot if issues do occur
6. Battery failure	Not charging correctly; power/battery insufficient; insufficient power/not correct routing of power source to all the motors and other components	2	6	1	4	12	2	8	Ensure the battery is charged before a testing session or session with the user. Inspect multiple times
7. LCD eyes failure	Part malfunction, disconnected from main system	3	5	1	1	15	3	3	Secure connection and wire routing using wire sleeves, 3D printed clips, velcro straps, or similar items to ensure wires stay in place and are secure
8. Motor failure	Part malfunction, improper routing of cables and excessive / insufficient routing of voltage	2	5	2	2	10	4	8	Utilize wire sleeves, velcro, 3D printed parts, etc. to organize and keep all wires routed properly and from entangling within the torso/shell of the robot; In case of part malfunction, troubleshoot, repair, and replace if necessary; Inspect, turn to mentors if unsure about proper power source, etc. Select different parts if of great concern, consult the help of voltage converters when needed
9. Camera failure	Part malfunction, disconnected from main system	1	4	2	5	4	2	10	Secure connection and wire routing using wire sleeves, 3D printed clips, velcro straps, or similar items to ensure wires stay in place and are secure; In case of part failure, troubleshoot, in case of unable to repair/solve issue, if within the budget and timeframe of project, replace part

10. Speaker failure	Part malfunction, disconnected from main system	2	2	1	1	4	2	2	Ensure wires are secure; In case of part failure, troubleshoot, repair; if repair is not possible, replace if possible
11. Tracks / Treads failure	System malfunction, sensor failure, motor failure, controller error / failure / disconnection, human error	4	1	3	2	4	12	24	Ensure wires are secure; In case of part failure, troubleshoot, repair; if repair is not possible, replace if possible
12. Sensor failure	Parts malfunction, disconnected from main system, excessive / insufficient power provided, incorrect routing / labeling and wiring / coding	3	4	4	3	12	12	36	Ensure wires are secure; In case of part failure, troubleshoot, repair; if repair is not possible, replace if possible; communicate properly amongst team and restate ideas/actions to ensure all are working towards common goal
13. Touch screen failure	Part is disconnected or damaged	2	2	1	1	4	2	2	Ensure wires are secure; In case of part failure, troubleshoot, repair; if repair is not possible, replace if possible
14. Exterior damaged	Material properties insufficient to handle pressure, temperature, force / load, etc. Physical trauma to robot, mishandling components	4	6	5	2	24	20	40	Proper material research, analysis, and selection; combination of materials compatibility and understanding effects of having different materials proximal in different environments; Sufficient padding and durability along with the flexible texture
15. Exoskeleton damaged	Insufficient padding / protection, user squeezing robot	6	7	3	3	42	18	54	Securing internal components properly, increasing layers between outermost layer and exoskeleton

	too hard, robot falling, etc.								

Failure Modes and Effects Analysis

The purpose of the Failure Modes and Effects Analysis is to recognize potential failures in the design and final product and effects of these failures, and recognize ways to prevent these problems from occurring. The first column represents what can occur, the second column is the cause of that failure.

The third, fourth, fifth, and sixth columns each represent a criteria that is being ranked from one to ten (1-10). The third column is the Likelihood (L) that a failure might occur with 1 representing the situation to not likely occur, and 10 representing that the situation is most likely going to occur. The fourth column is the Social Consequence (SC) of the failure, meaning how will the customer, user, or users feel if BearMax does this action or if something is problematic with BearMax. Will that user no longer feel like they will want to interact with BearMax? Will they quickly focus on the session again? Is it even possible to focus on the session or resume the learning session or learning exercise if this particular failure occurs? How long will BearMax take to repair? Will this time greatly affect a participants time and learning or only have a minor consequence? All of these questions need to carefully be considered in this analysis, among others. The fifth column is the Severity of the Consequence or Physical Consequence (C) is also very important to consider. It is also rated on a scale of 1 to 10 with 1 representing very minimal or not serious, and 10 representing life threatening. 10 should not occur under any circumstances at any point in this project. Safety is of an utmost importance to the BearMax team. While initially only viewing from the perspective of an adult size or the consequences that some actions might have on an adult, it is important to consider the potential future user. Users of BearMax can be anywhere from six years old to thirteen years old, or older. And it is important to consider how a small child will be affected by some failures and actions and the severity of that consequence (physically and emotionally) on that individual. Once again, emphasizing safety of our users is the highest priority, which is why rating this particular criteria was very important. The sixth column is Detection (D) which is how likely we are to know before the problem occurs. 1 is when a failure is easy to detect and 10 is when it is not possible to detect or near impossible to know before it occurs. Detection is also a very important criteria. If the problem is not able to be exposed prior to occurring or the cause of the problem is not able to be found and therefore not able to be repaired. Replacing a component can also be expensive and time consuming, adding to the budget and timeline of the project, which is why the failure modes and effects analysis is so vital, as it will limit or prevent the team from extending deadlines and pushing building sessions or testing.

The seventh, eighth, and ninth columns are crucial to understanding which issues are critical and need to be handled immediately and which ones are not of great concern. All of these values are calculated as well based on Likelihood, Social Consequence, Consequence, and Detection values. The seventh column is the Social Hazard Score (SHs) which is calculated by multiplying the Likelihood and the Social Consequence values (L * SC = SHs). The eighth column is the Hazard Score (Hs) determined by multiplying the Likelihood and Physical Consequence values (L * C = Hs). The ninth column is the Risk Priority Number (RPN) determined by multiplying all three criteria, the probability, the severity, and recognition ability for that particular failure values all determine this (L * C * D = RPN). The risk priority number was only evaluated for the physical consequence (C) in this case as that is of most concern. The Social Hazard Score is sufficient to understand how damaging emotionally it might be for the individual user or customer. However, physical safety needed to be evaluated further than just the Hazard Score. The Hazard Scores, and RPN columns are highlighted with different colors. The green background represents that it is not of great concern, yellow means that it needs to be monitored closely, orange is quite concerning, and red means that urgent attention is needed. Finally, the tenth column is Prevention, methods to prevent this failure from occurring.

Firstly to begin analysis, the hazard scores can be studied. Both hazard scores are shown in two separate scatter plots below with the x-axis being the respective consequences and the y-axis being the likelihood.

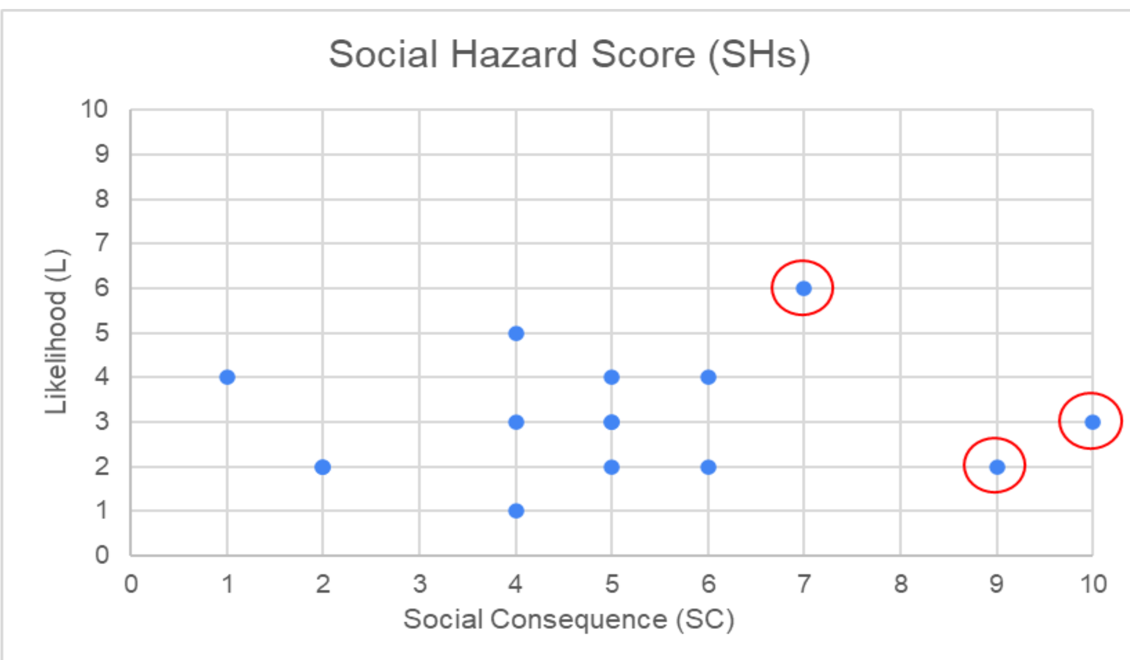


Figure 22: Social Hazard Score

For the Social Hazard score chart, the data is mainly in the center which would be categorized as more needing to be monitored, and even two points to the left of the graph which will be in the green category, which are both not as much likely to occur and have low social consequence. The three dots that are circled red are of high priority and high concern. Though two of these three points have a lower likelihood, they have a high social consequence so need to be addressed. For the point that is of high likelihood (6) and of high social consequence (7), this needs to be urgently addressed.

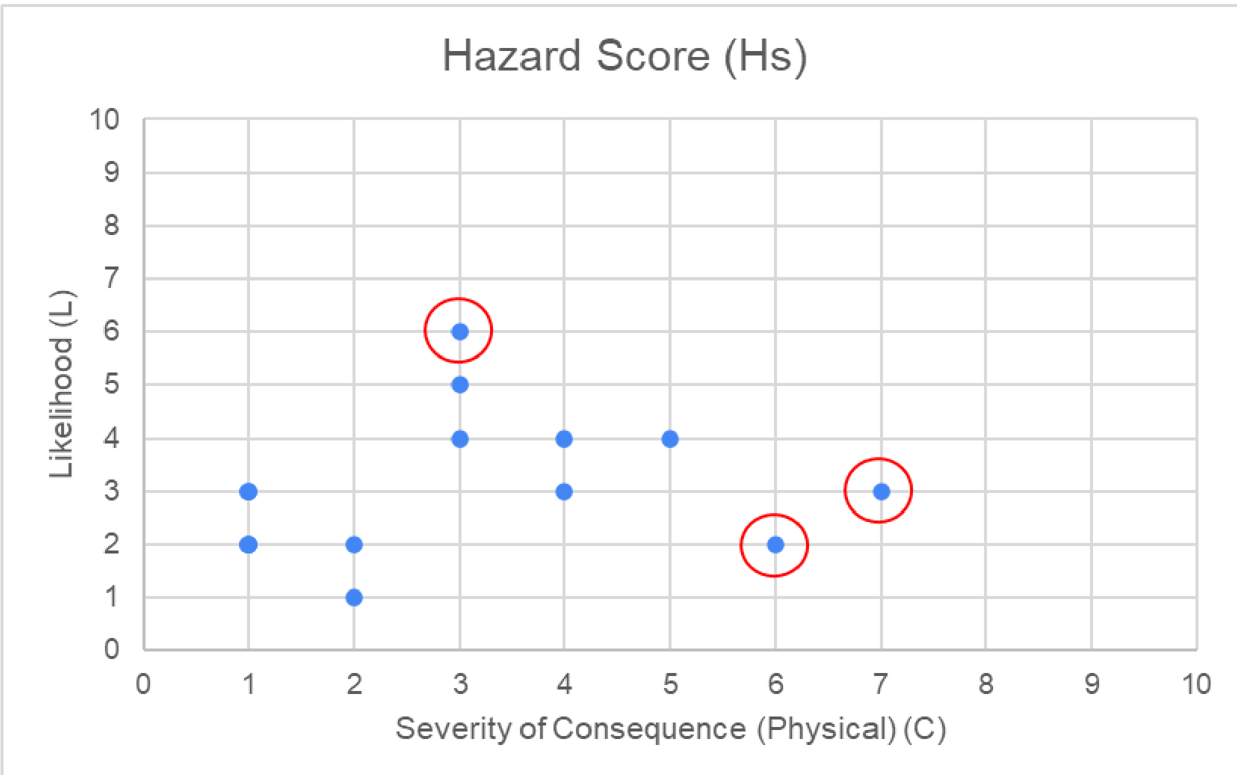


Figure 23: Hazard Score

The Hazard Score diagram shown is very similar to the social hazard score chart, but takes into consideration the physical consequence. In this chart, four points to the left have low likelihood and low severity of consequence, five points are more centered, and three points that are circled in red are of more concern. The two rightmost points are distressing as though they have a low likelihood, they have the highest potential for physical consequences. The point circled in red that has a consequence of 3 and likelihood of 6 is also bothersome as it is more probable to occur.

Analyzing the three points respectively from both hazard score graphs, they surprisingly correspond to the same three failures. The failure numbers that are of highest concern are 4, 5, and 15 in the Failure Modes and Effects Analysis Table. These are if the robot falls on or pushes the user (4), if the robot moves over or on top of the hands or legs of the user (5), and damage to the robot's exoskeleton which could cause injury to the user if not detected early as there might be sharp edges or other mechanical failure that can cause harm (15). These however, are not the only failures that urgently need to be accounted for.

Observing each of these three cases individually, beginning with 4, if the robot falls on or pushes the user is more likely to be strictly a mechanical issue. A coding issue is easier to detect as if a collision is detected by the LiDAR and the robot does not stop, then the code can be changed easily after testing. However, mechanically, if the sensor malfunctions or disconnects during a session, it is harder to detect. Also, it could be a motor issue and the speed the motor stops may not be able to be predicted as easily after only one test run. Multiple trials will need to be conducted on different elevations to ensure quality of the coding and mechanical design. Regarding 5, BearMax potentially moving on top of someone's hands or legs can be either a mechanical, software, or human error issue. In the case that the track movement is autonomous, if the motors do not stop quickly or if it is not coded to stop quickly after an obstacle is detected, it can pose issues. In the case the track is not autonomous and remote controlled, it is vital the team member controlling that movement has large amounts of practice and if controlling from a separate room, it is vital the camera provides a clear, unobstructed view. Ideally, the person controlling BearMax's movements via remote control will be in the room during a session, however it is important to take into account multiple scenarios. Next, is 15, injury to the robot's exoskeleton. While it is predicted that the padding provided by elastic resin will be sufficient, it possibly can get damaged as well. Either by the robot falling, bumping into objects, or injury caused by the user or by the team while making changes to the robot, damage to the robot's exoskeleton is distressing. It may not be as easy to detect because of the layers between the main layer and the exoskeleton. Additionally, it would be a large setback, several components and systems may need to be repaired or replaced, adding time to the project. To prevent this from occurring, it is important to inspect BearMax before and after each learning session with a user or before a trial run. It is also vital to ensure all electrical and mechanical components are secured within the frame and dangling wires and other parts are minimized as much as possible to prevent entanglement and disconnections from occurring.

The most concerning failures are not only indicated by the hazard scores but also indicated by the higher risk priority numbers (highlighted in red). This is where the mitigation methods will be highly necessary and urgently need to be implemented. The failures with the highest risk priority numbers are concerning potential injury to the user and robot. Injury or failure to the robot might cause injury to the user which is unacceptable. The primary prevention method is to conduct extensive testing and inspections prior to even introducing a user to a learning session with BearMax. Trial runs are also vital to assess the potential issues that may arise and develop prevention and solution strategies. Failuress 2, 3, 14, and 15 may potentially occur where the child user physically causes harm to the robot for unknown reasons such as by pushing the robot from an elevated surface. We hope to have BearMax itself give warning signs such as if an unknown physical contact is initiated, BearMax expresses that it does not like that and to please be respectful. Additionally, a team member and parent or guardian of the child user will be present to prevent further harm/injury being caused to the child or BearMax. While BearMax will have sufficient padding, it is not guaranteed to not harm the child because of either the robot falling on one of the user's arms or legs, or because the padding may be insufficient. In case the padding is insufficient, this will closely be tested and monitored prior to a session to ensure injury will not occur to the user in the case they do decide to strike BearMax. Also, the damage to BearMax will also be assessed from testing to see if there is need to increase the padding or potentially change the material of the padding altogether. While this may require sacrificing the texture and possibly appearance of a stuffed-animal, the safety of both the user and BearMax are of utmost importance.

Section 7: Software Design

Since our project has a separate Computer Science team that will be handling the mobile application and the machine learning, this section will focus on the embedded system software. This includes the software controlling the motors, eyes, and the mobile platform. Figure 14 is a figure describing the overall functions of the robot. These functions include playing the emotion game, receiving head pats, and playing a game of rock, paper, scissors.

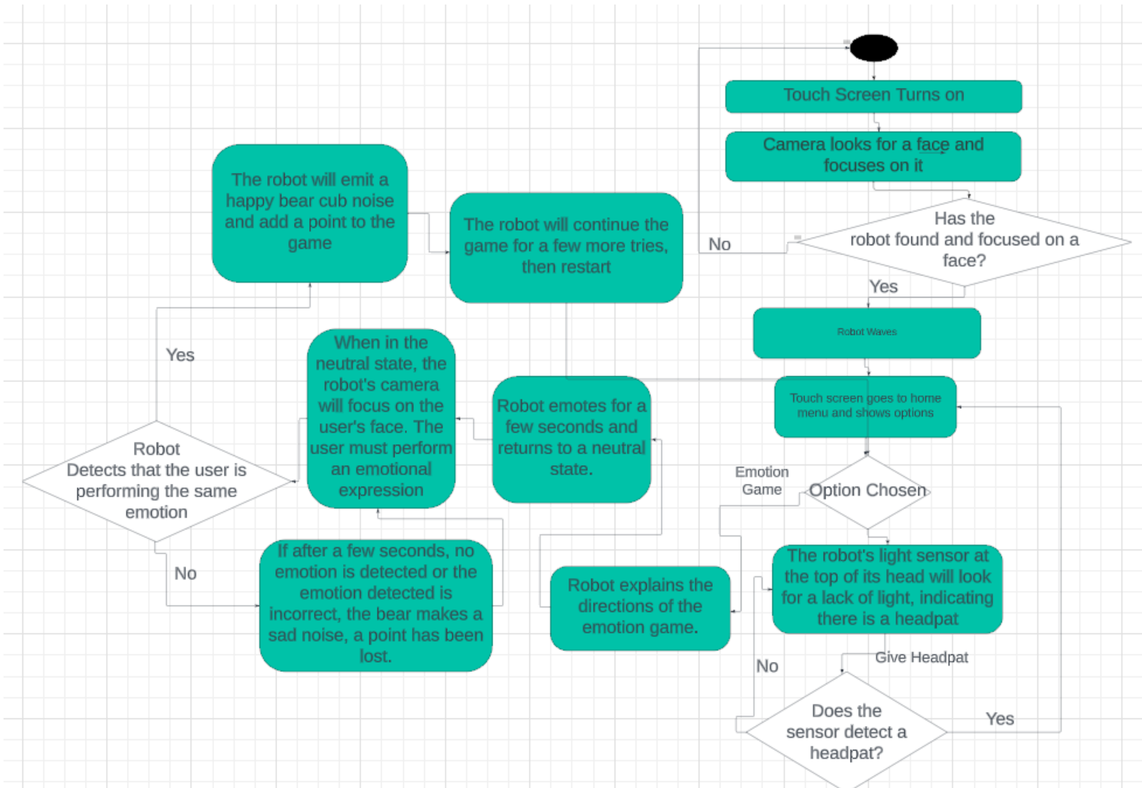


Figure 24: Overall function of the robot

Figure 24 Explained:
This figure attempts to explain how the robot works overall. In this case, when the user turns on the robot, the touch screen turns on and the robot turns on. Once the robot turns on, it will search for a face using its special camera. If the robot does not find a face, it will keep searching until it finds one. Once it finds a face, it will wave to the user. The touch screen, which has been turned on at this point, will then portray the activities the robot provides. These three activities include playing the emotion recognition game and giving a head pat. The headpat function and other activities are expanded on in other diagrams below. Other activities are also expanded upon below. For the emotion recognition game, the robot will emote a specific emotion using its eyes and body language. If it is happy, for example, its eyes will widen and its arms will be raised. After giving these instructions, the game will begin. For each turn, the robot will perform the emotion for a few seconds, revert to a neutral state, then the user has to guess the emotion and perform the same emotional expression. For instance, if the user guesses the robot is happy, they must then act happy in front of the camera. The camera will then recognize the happy face and award a point to the user. Our team also plans for the robot to emit a happy bear cub noise at a correct answer. If the user guesses wrong,

the robot will simply groan a bit, similar to a human saying “awww, too bad”, and continue. This will continue until the game is over.

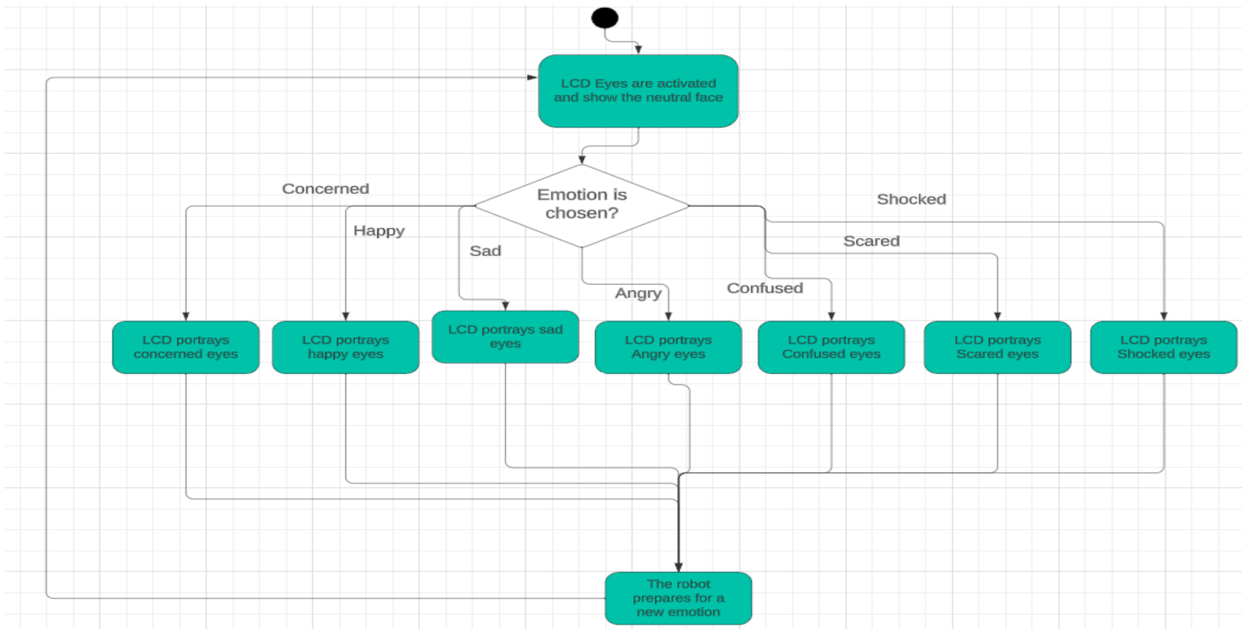


Figure 25: Function of the LCD Eyes

This figure explains how the LCD eyes work on the robot. The LCD eyes are used whenever a robot wants to express an emotion, whether it be in the emotion game or when interacting with the user. Whenever an emotion is provided for the robot to feel, the robot will then portray the specified emotion through its eyes. For example, if the robot is angry, the LCD eyes will portray angry eyes.

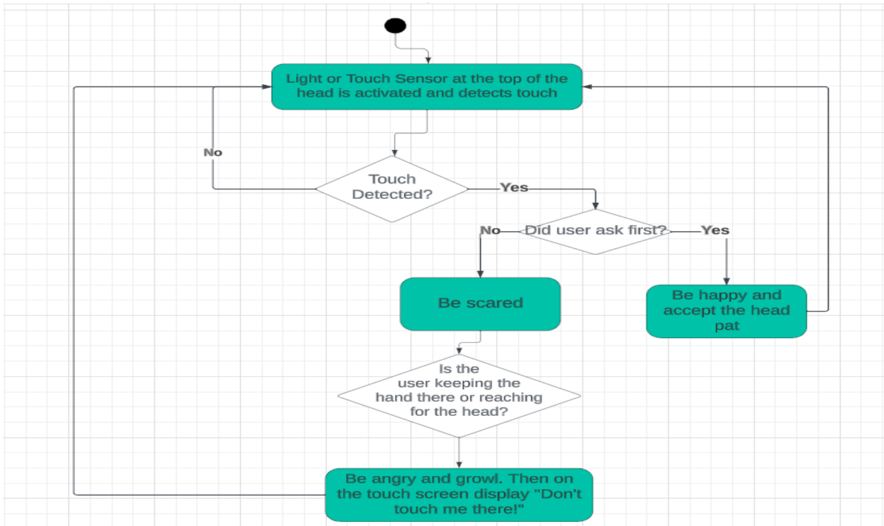
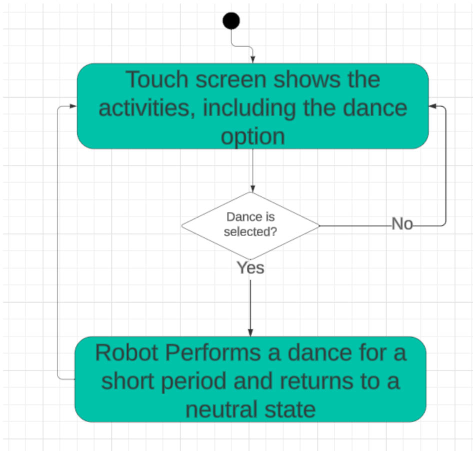


Figure 26: Figure explaining how the head pat portion of the robot works.

The head pat section is one of our most unique additions to the social robot. Not only does it provide a fun way to interact with the robot, it also teaches children the importance of boundaries and consent. The way it works is if a light or touch sensor, the team is still considering which sensor will work better, detects a touch, the robot's headpat protocol will be activated. In this protocol, the robot will consider whether or not the user asked first. If the user did ask first, the robot will happily accept the headpat. However, if the user did not ask and randomly reached for the head, the robot will become slightly angry and will even growl at the user. This behavior allows users to understand that one should not simply touch someone or something whenever they feel like it. That person has to make sure that the someone or something they want to touch must be comfortable. Furthermore, whether or not the subject is comfortable must be clearly communicated.



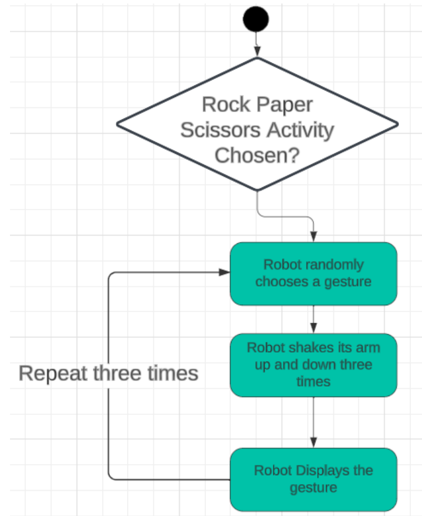


Figure 27: BearMax's Dance Behavior diagram Figure 28- Rock Paper Scissors Diagram

Figure 27 explains Our plan to program into BearMax the ability to dance. The way this would work is the touch screen would include a dance activity. When this is selected, BearMax will perform the dance for a short period of time and return to the neutral state. Figure 28 shows how Bearmax's Rock Paper Scissors will work. When the user selects the rock, paper scissors game as an activity, the robot will choose a random gesture, move its arm up and down three times, and display the chosen gesture. The team has considered implementing ways the robot can see the user's gestures. Training the camera to see and recognize hand positions has even been proposed. For now, though, the team will simply implement this method. Advancing this activity will be considered if the team has time, or can be suggested to the future team.

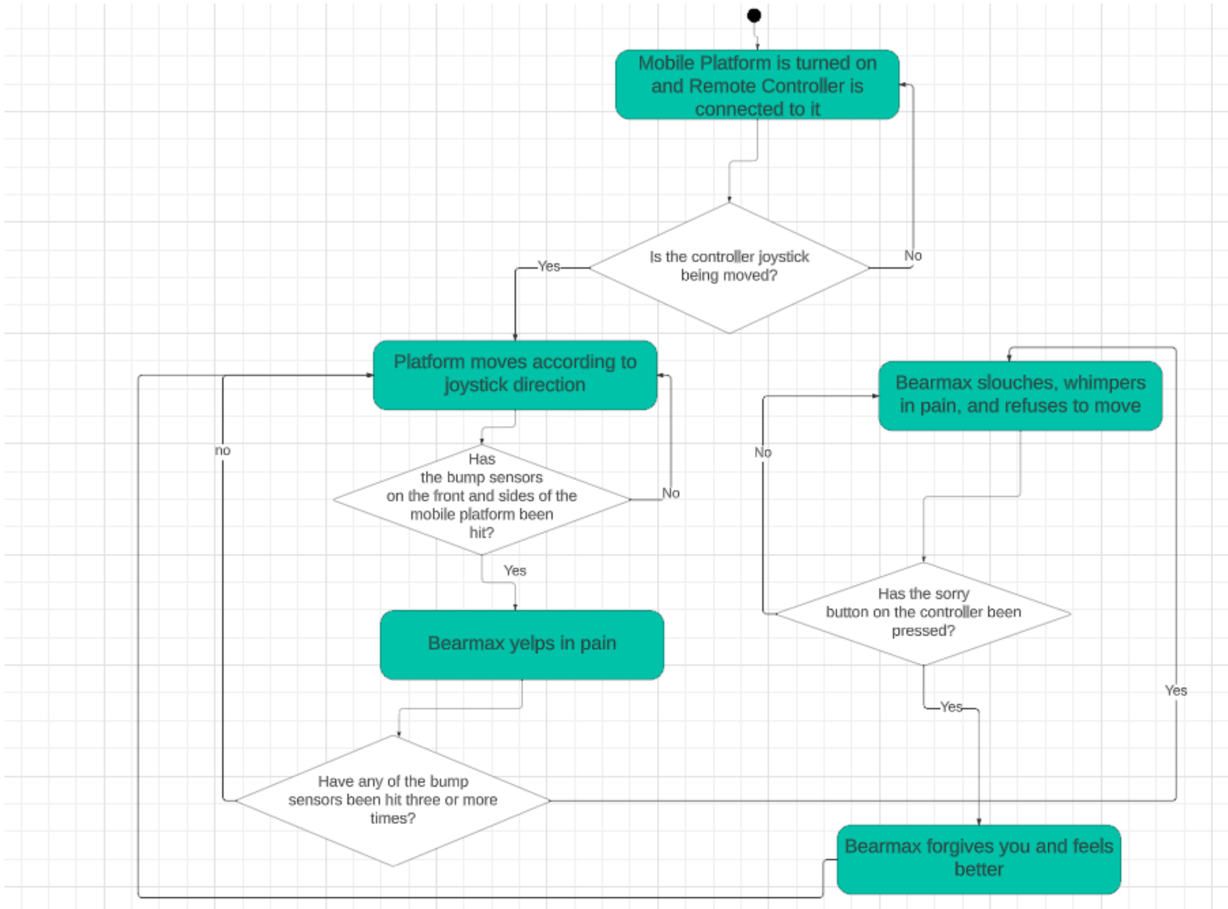


Figure 29: Mobile platform software diagram

For this diagram, the team included a protocol for controlling the mobile platform. The platform will listen for input from the controller and move wherever the controller tells it to. However, BearMax will also have bump sensors on its outer shell, similar to a Roomba. If the bump sensor is pressed or hit, BearMax will yelp in pain. If this is done three or more times, BearMax will actually stop and refuse input from the controller. BearMax will also slump its shoulders and whimper in pain. In order to regain control, the users must apologize to BearMax. So far, the plan to incorporate this is with an “I’m Sorry” button on the controller. Although, it could also be integrated into the touch screen.

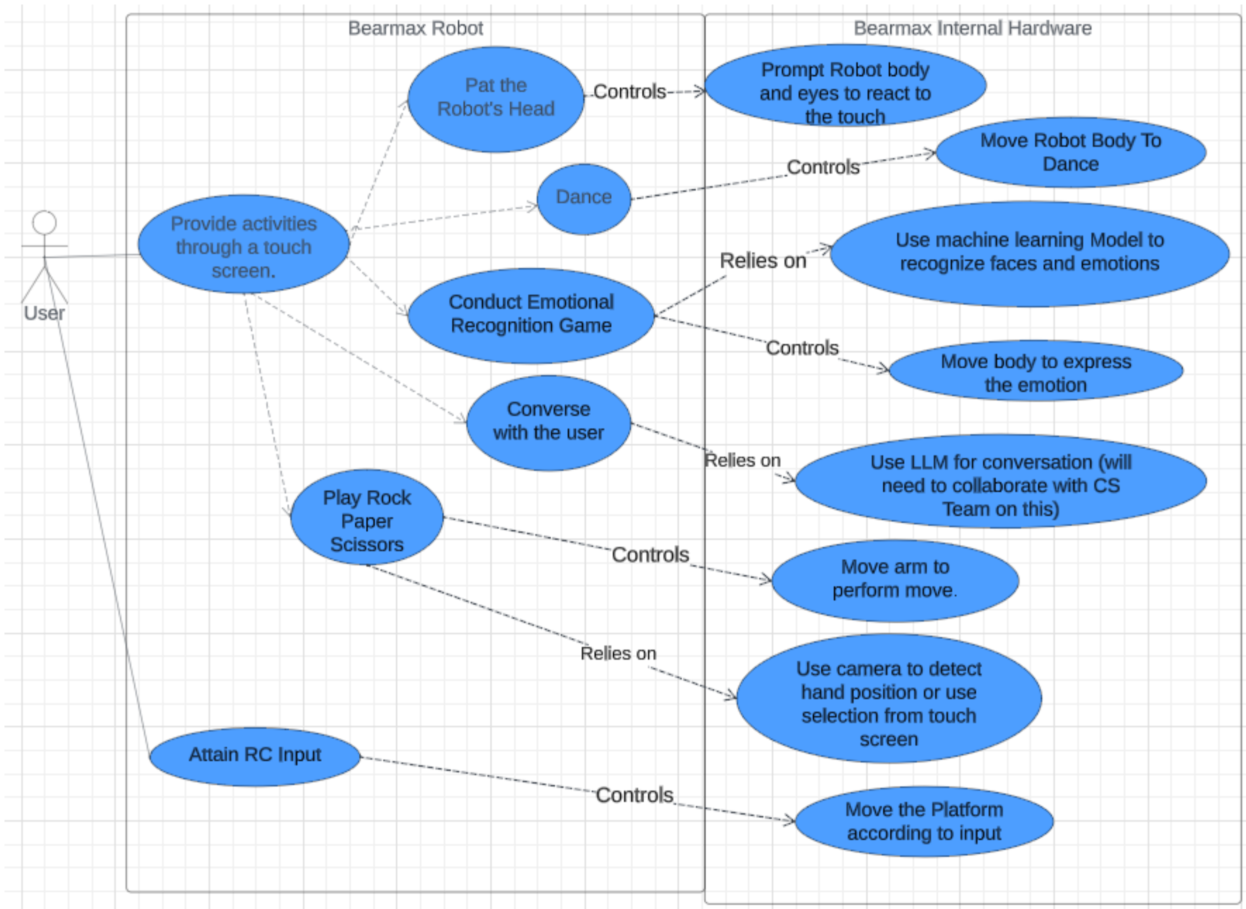


Figure 30: Overall Use Case Diagram

This diagram explains the overall functions of the robot without going into too much detail about how it works. The most basic functions the user can access are controlling the remote controller for the mobile platform and choosing an activity on the touch screen. For the remote controller, it simply connects to the robot and enables it to move according to the direction it gives. The touch screen on the robot provides a list of activities the user can choose from. So far the activities include playing Rock Paper scissors, conversing with the user, conducting an emotional recognition game, dancing, or receiving head pats. For the rock paper scissor game, when the user chooses this, the robot will rely on its embedded game to initiate the game. It will also perform the correct arm and hand gesture for the game. It can also converse with the user if the user so chooses. Although, the team is in contact with the separate computer science team and we will be discussing how to implement this in an effective, ethical, and safe manner. Our current plan is to implement a language learning model, such as GPT, and we will have the user interact with it through a separate mobile application. However, more research and discussion of how it should be implemented must be done before adding this as a feature. The next option to choose is to have the robot dance to music.

When the user chooses this feature, the robot will dance to a song for a specified amount of time. Finally, the user can also choose to pat the robot's head. When the user does this, the robot will respond to the head pat according to its protocols, as explained in figure X above.

Section 8: System Circuit Design

In this section we will go through the steps we plan to take to design the power routing and component connections for the BearMax project. This section will be broken up into parts covering the design of the power schematic, the connections to the Arduino Mega Rev 3 development board, and the overall schematic diagram. To summarize each section, the system power section will comprise a flowchart for the power in the system and a calculation of the power specifications from the individual component power consumptions. The microcontroller connections will explain the functions of each of the devices we have selected and decide how and where each device will connect to the Arduino MCU. Finally, the schematic section will use the information from both of these sections in order to develop a diagram that will fully model the system circuit of BearMax.

8.1 System Power Flow

For the purposes of this project, the Printed Circuit Board, or PCB, is the component that would serve as the central hub for power distribution to all components and additionally would connect parts together in order to allow them to communicate with one another for control of the robot. The PCB would first connect to our power supply and from there route power to the various parts such as the Arduino, the Jetson, the LCD screens, motors, as well as a step-down converter for the parts that do not require the 12 volt input that the power supply will provide to some parts. The first step in PCB development is to model the flow of power with the components to be used. To give an idea of the flow of power, we refer to Figure X below.

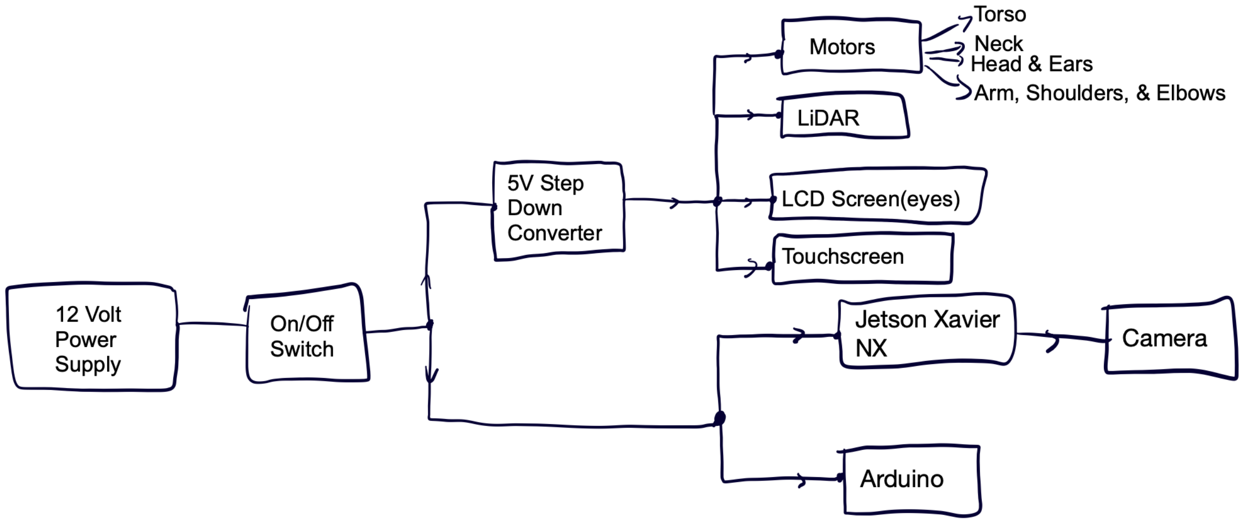


Figure 31: Initial Component Power Flow in BearMax

System Power Specifications

Device	Voltage	Power Consumption
Arduino Development Board	12 Volts	0.2 W
NVIDIA Jetson Xavier NX	12 Volts	0.4 W
LCD Screen Eyes (x2)	5 Volts	5 W
LCD Touchscreen	5 Volts	5 W
LiDAR	5 Volts	0.7 W
Camera	5 Volts	1 W
Stepper Motor	5 Volts	6 W (per MG995 x 7) 2 W (per MG90S x 4)
Speaker	1 Volt	1 W

8.2 Preliminary Schematic Design

We will further need to wire the various components to the microcontroller in order to allow us to control, configure, and collect data from said components. For example, the Arduino will be the main hub for all component connections, such as the motors for control of the limbs and digits of BearMax, or the LiDAR receiving distance information. Some parts will instead be wired to the Jetson such as the camera for computer vision purposes. A rough idea of what our final schematic will consist of can be seen within Figure Y, showing multiple components and how they are planned to be wired to the microcontroller.

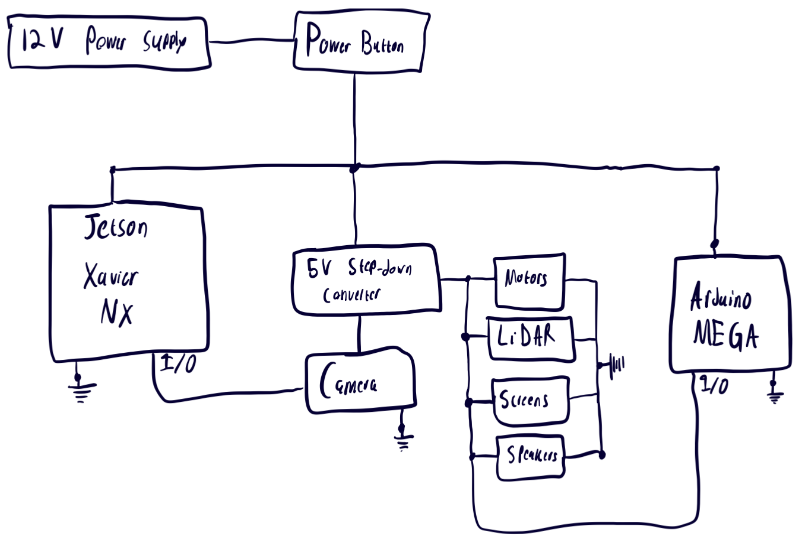


Figure 32: Initial Schematic Overview

8.3 Microcontroller Connections

Arduino

In order to fully realize the functions of BearMax, we will have to program the various components in the manner that we require. The components that must be connected to the Arduino are the motors in order to change the position of the robot's various limbs and digits, the LiDAR sensor in order to gather distance information from an object, the LCD screens for the eyes in order to help display images to convey the emotional state of BearMax, the LCD touchscreen will be setup in order to allow a user to provide input to BearMax, and the speakers in order to transmit audio from the robot. In this section we will show our plan for how the devices will be connected to the Arduino Mega Rev 3 Development Board and configured as well as give specific pin connections for the various components to the Arduino and Jetson connections.

When we consider the LiDAR module, the wiring is simple due to the module only having 4 pins: one for power, one for the ground, and an RXD and TXD pins used to send and receive data. This module connects to the Arduino and communicates through the I2C protocol, which requires the RXD and TXD pins to connect to SDA and SDL (the data line and clock line) respectively. The Arduino Mega board we use has our SDA and SDL on digital pins D20 and D21 respectively. Finally, we connect the VCC pin on our LiDAR module to the 5V out pin on the Arduino.

To connect the eye displays to the system, we follow a similar type of procedure. The LCD displays have pins VCC, GND, SCL, SDA, RES, DC, CS, and BL. Connect the VCC to the 5V Arduino out, and ground to the common ground. Then, the SDA and SCL pins can be connected to the same digital pins that the LiDAR module used for SDA and SCL (D20 and D21). The RES, DC, and CS pins (reset, connection, and chip select) all can be wired to any digital pins. Finally the BL pin (backlight or LED pin) will be connected to the 3.3V out on the Arduino to power the backlight of the display screen. An important thing to note, since we are using 2 LCD SPI displays, the wiring is very specific, as certain pins such as SCL, SDA, RES, VCC can simply be shared nodes and pins between the 2 screens, but the RES, DC, and CS pins must all be unique for the two screens in order to be interfaced correctly.

The servo motors that we will be using for the various limbs and digits will be the MG90S and MG995R servo motors. These will be used in the ears, arms, neck, and fingers in order to control individual joints for full motion. The difference between motors being connected to the arduino compared to other components is that they must be connected to the PWM (pulse-width modulation) pins specifically, which allow for digital signals to be converted to analog voltages. Essentially, through PWM pins we can generate a voltage which will control the intensity of the motor and speed at which they mode. For this reason, our single Arduino Mega board may not provide enough PWM pins for us to use as compared to the number of motors needed. However, this may be alleviated by integrating secondary station boards, Arduino Nanos, allowing the addition of additional PWM pins that could be controlled from the master board through proper configuration.

Below we have the pin designations on the Arduino Mega Rev 3 where the many components will be connected to.

Jetson Xavier NX

The role of the Jetson Xavier NX board is different compared to the Arduino. While the Arduino carries the load of the connections to specific parts, the Jetson will act as the “brain” for BearMax. This means the emotion and object recognition algorithms will be running on the Jetson and this is where the computing will happen for that model. The

Jetson will connect through USB to the camera component we will use, due to the computer vision capabilities of the Jetson. Furthermore, the Jetson will also connect to the Arduino Mega board through an additional USB port, and host the Arduino code onto it. Functionally plugging the Arduino into the Jetson board is the same as plugging the Arduino into a regular computer, but having the Jetson as a component allows for the operation of a robot without a computer being needed.

8.4 Schematic Diagram

Using the information in the previous section we will develop a preliminary schematic design showing the connections that the components of BearMax will make to the Arduino microcontroller as described before. The schematic made will become the basis for the design of the PCB, which will allow for the power flow to be more reliable to the components. In this section we will describe the process and software used to develop the schematic.

Schematic Software

PCB design is a major part of any electrical engineering project and now there exist many different software commonly used for design, such as Eagle, Altium, Cadence and many others. Choosing between these many different software was difficult, but for our purposes, we believe that the software found that meets the best criteria is EasyEDA, an online design platform. The main reason this was utilized was due to easy accessibility, as the platform is web-based and can be worked on with many different devices, as well as not requiring any dedicated download to a device. Furthermore, the library for parts was extremely simple to use. Where most softwares requires downloads of external files and libraries to use certain parts, EasyEDA allows for user generated parts to be used as well, meaning even some parts that are obscure and have limited documents for support can be searched for. Another reason to use this software over the others for us was that the software can be used to develop most sizes of schematics for free, where others would charge a fee for a premium version. The downside from using free software like EasyEDA comes from the unreliability of certain things. Documents could be lost through network error, as well as improper closing of the browser may lead to loss of progress and documents. Furthermore, the user generated parts that are available through the software's search engine, while convenient, at times are unreliable. When searching for specific parts that are produced on a smaller scale the risk is run of not being able to find anything to represent it properly, or something like a component's symbol not containing the write pinout as per the datasheet of the part. We have considered the following benefits and downsides and choose to move with EasyADA for our schematic design.

Schematic Description

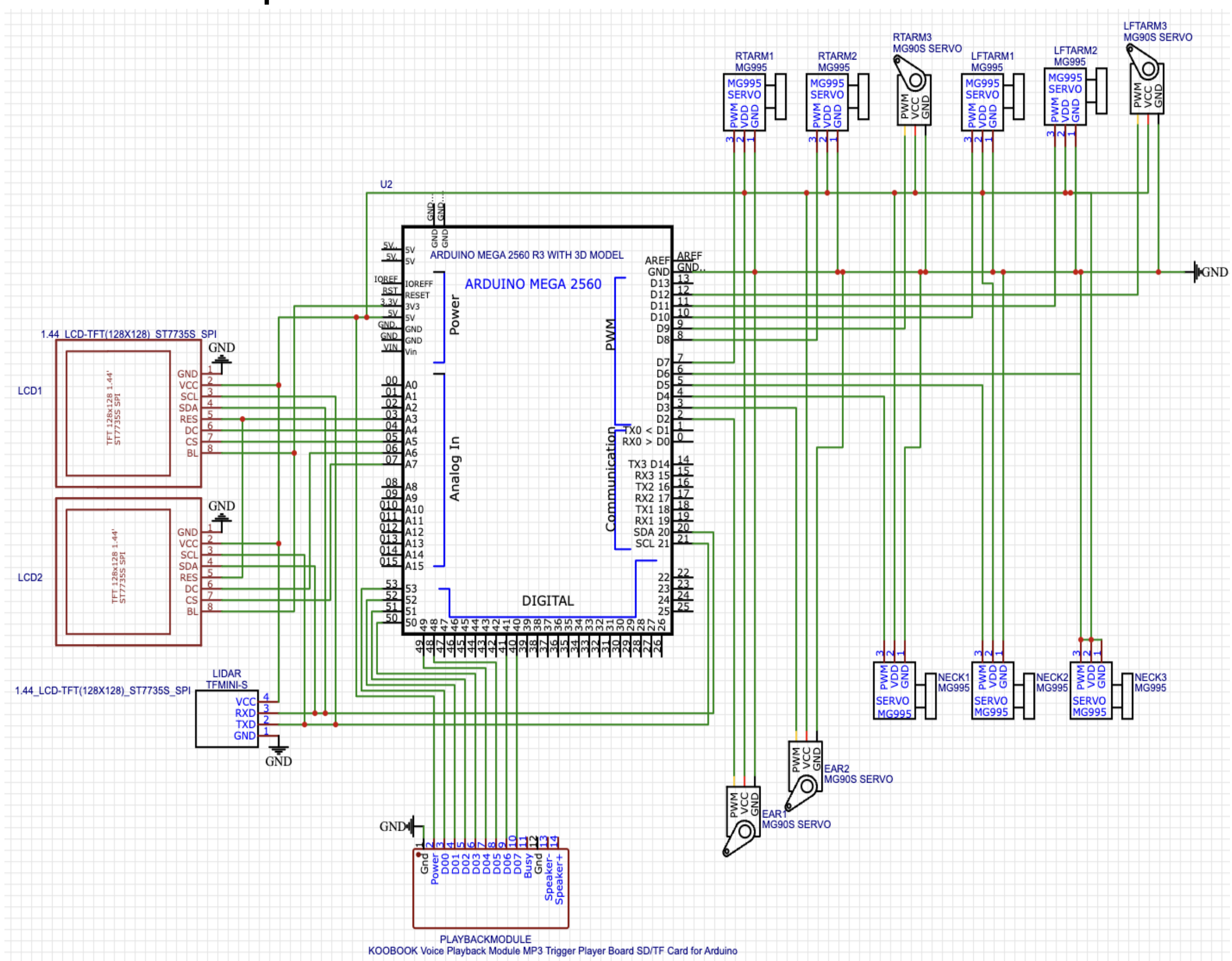


Figure 33: Preliminary Schematic Diagram for BearMax

The basis behind the entire schematic for BearMax is the Arduino Mega 2560 board. The symbol used is a user designed model which lays the symbol in the format of the physical board as well. Furthermore, the specific pins for the power, analog, PWM, serial, and digital pins are all labeled for easy reference for the other parts' wiring. Some important notes about the pins on the Arduino board include that there are additional functionalities of some of the pins that are not labeled, such as the additional PWM pins at 43-45, as well as the USB port that will be used to connect the Arduino to the Jetson Xavier NX. We also are currently connecting all the components to the 5V out pin on the Arduino, rather than wiring them to a step down converter currently as for testing purposes that has been the integration, so this may be subject to change once the project moves forward with additional design additions. Finally, the different ground pins on the Arduino are all wired to be a common ground, meaning all pins can connect to the ground on either side of the board and it would function the same.

Starting off with our LiDAR module we see that the VCC pin is plugged into the Arduino's 5V out pis, and is grounded at the common ground. The RXD and TXD pins represent the SDA and SCL connections, which are connected on the Arduino at digital pin 20 and 21 respectively.

Moving onto the LCD eye screens, we can see that each has a ground, power, SCL, SDA, Reset, chip select, connection, and backlight pin. The ground and power pins are also connected to the common ground and 5V out pins. The backlight pins are also wired to the 3V out of the Arduino, as the backlighting in the screen consumes a bit of power in order to make the screen a bit more viewable under direct light. The reset pins of both screens can be mapped to the same pin, so we chose pin 3 on the Arduino. The chip select and DC pins must be unique to each screen, so for LCD 1 we choose pins 4 and 5 for CS and DC, and for LCD 2 we choose pins 6 and 7 for CS and DC. Finally, the SDA and SCL pins will be connected to the same wires as the LiDAR. This is due to the fact that for the I2C and SPI protocols used we are able to connect multiple devices to the same SDA and SCL lines and as long as the devices have unique addresses they can be used separately.

Furthermore, we have the Kooback audio playback module, which allows sounds to be uploaded into them and a speaker to be attached in order to play audio that we want. This allows BearMax to “speak” to the user. The module must be connected to ground and power like before. Then it has 8 control pins which can be connected to any pins, for the preliminary design we decided to choose the digital pins 40, 41, and 48 to 52, skipping the additional PWM pins provided in this section to reserve for other components that may need it. Finally the module supports a 4-8 Ω speaker to actually transmit audio from the playback module which will be connected across that terminal.

The final components present within the current schematic design of BearMax are the motors for the ears, neck, and arms that will be present in the final robot. We have labeled the motors in the schematic for what part they are going to be used for, as well as placing them near the motors that will be located near them. For the motors currently we have only 2 types: the MG90S servo and the MG995 servo. These motors have the same pins to connect to the Arduino, so we will refer to them in the same way, but they are slightly different and offer differing precision and power. Finally, all motors require the PWM pins in order to be properly used by the Arduino for the robot. For the ears, we only require 2 motors, so we connect the VCC and GND pins, and then connect PWM to pins 2 and 3 for ears 1 and 2 respectively. For the 3 motors in the neck, we connect to pins 4-6. Then the 6 total motors for the arms are connected to pins 7-12. It's important to note the missing motors for the fingers of BearMax, and this is due to the actual mechanical design of the fingers not being fully developed to fix this. Right now the plan is to have at least 3 fingers per hand, with each finger maybe having 2 motors minimum. This comes out to about 12 motors under our ideal circumstances. This wouldn't be a major issue, if it weren't for the fact that the Arduino Mega 2560 only offers PWM pins from pins D2-13 and some at D43-45. With the limited number of PWM pins, we may be forced to configure a different system to combine the hands to the rest of the components. The first version of BearMax came into a similar issue, running out of PWM pins as they are only few offered by even the largest Arduino board, which they solved by configuring Arduino nano devices as followers to the main Arduino. This can be done by connecting the serial ports of one Arduino to the other, allowing for the nano to accept an instruction and configure the motor through this manner.

Another connection not displayed as of yet, is the Jetson's connections to the Arduino mega and the USB camera. Both of these connections are done through USB and are not shown due to the schematic symbol's exclusion of the USB port on the Arduino, as well as the USB camera not being found within the library of parts. Regardless, the Jetson only connects to the rest of the system through USB and is the main brian of the project as described previously. Essentially, the job of the Jetson is to run the AI emotional detection model and classify the state of a user, then allow instructions to be sent to the Arduino, which will configure the screens to display a specific image, motors to configure the limbs to a proper position, and the speaker to play an audio cue.

An important point of note is how the movement of BearMax will be done. Currently the main strategy we've decided to move forward with is using a prebuilt track piece that we will construct the body and head for BearMax on top of. This was done to streamline the process of having movement, as additional motors wired to the Arduino board would put us well out of place with the number of pins available for the rest of the motors. For this reason we have chosen to keep this track kit as our "legs" piece for BearMax, meaning we consider this kit as one whole part as a whole. The track will be powered by the same method of other components.

Moving forward for Senior Design 2 (SD2), we plan to move forward with a plan for a finalized schematic, including the components that we are missing in that initial schematic, such as the motors required for hands, or the power supply and step down converter. Other improvements in the schematic can be done such as optimizing the layout of these components and which pins they connect to, as currently the pins were arbitrarily selected for ease of the schematic's viewability. This means that the specific wirings will be changed. Furthermore, by incorporating the power supply we will also have to devise a system for which components should be powered on first, as upon startup if we just allow the robot to power all components on in an instant we may run into issues such as improper distribution, or damaged components. This would further benefit us as it would provide a better idea for the physical layout of certain components as well. Additionally, we seek to finalize the actual components of the robot and put it in that order so that we are able to test and fully develop a PCB within the schedule we want.

Section 9: Testing Plan

After completing this report, our next step will be constructing and testing the robot to see if it moves and interacts in a way that fulfills our objective. Firstly, it needs to be moveable via a remote controlled wheeled platform using treads. The treads are designed so that the wheels cannot be snagged on carpet. Moreover, the treads need to be designed in such a way to prevent children's fingers from being caught in there and hurting the child. The platform also needs to be smooth and rounded so as not to hurt the child if it bumps into one. Finally, it must be light enough so that if it runs over a child's foot, it will not hurt the child. Secondly, the robot's body must be able to move dynamically and be active. Its arms, shoulders and torso must be able to rotate in a human-like way. It must be able to express its body language in order to express different emotions. For example, its shoulders must slump, its head must lower, and its arms must limp at its sides when it is sad. Similarly, its chest must elevate, its arms must rotate until they face upwards, and its head must be upright if it wants to emulate happiness. The robot must also be able to dance using its whole body. Thirdly, and most importantly, the robot must be able to interact with child users in a welcoming and encouraging manner. Its eyes must be able to express different emotions such as happiness or sadness. Its eyes and body must also respond appropriately to different emotions that the child expresses. Finally, the data it collects must be connected to a companion mobile application, which will be developed by a separate Computer Science team that will also be working on the machine learning, facial recognition, and emotional recognition capabilities. To test the capabilities of this robot, each element will be tested individually before being integrated together. The individual elements that must be tested are the LCD eyes, the mobile platform, the camera used for facial and emotional recognition, the attached touch screen, and the individual joint mechanisms. These can be tested simultaneously. After initial tests, we will begin to test the integration of all these elements. This will include integrating the camera to control the LCD screens, testing how the whole robot body moves, and testing how data will be transferred from the robot to the mobile application.

To test the LCD eyes, the team will take one LCD screen and one Arduino Nano and write them according to the schematic diagrams. After that, the team will design several eye expressions using a digital drawing software called Aseprite, which specializes in pixel art. We will take a pixel art approach since our LCD screens only have an area of 128 by 128 pixels. Next, one of our Computer Engineering students will program the Arduino Nano to upload each eye expression to the LCD screen. One expression after another will appear so the team can see how each one appears on the screen. If any modification of the drawings are needed, the team will open the drawings again and change them accordingly. Once that is completed, the team will then proceed to testing how the robot will switch between emotions. To start, the team will make a test program that allows the programmers to switch between emotions based on the input given. For example, if the team decides to write a program that takes in input from a terminal and portrays an emotion based on that input, the team will do so. Such a test could simply be a programmer entering the number one into a terminal to make the robot eyes appear happy. Similarly, the other emotions will be assigned a number so that when a programmer enters that number into the terminal, the associated emotion will appear. If successful, the team will then test how the light or touch sensor on the robot's head, which detects head pats, works in conjunction with the LCD eyes. To test this, the sensor will send a certain input if a hand or object is close to it. If it is, the team will first program the eyes to adopt delighted expressions at the head pat. Later on, however, the team will then program a condition into the robot. If the user asked for permission to give a head pat, then the robot will happily accept it, which will be shown in the eyes. Otherwise, the robot's eyes will look fearful. Next, the touch screen will be connected. The touch screen will have an option for the user to ask "Can I give you a head pat?" to the robot. Once this option has been selected, then the robot will receive headpats with delighted eyes. Otherwise, the robot's eyes will be fearful. If this test proves to be successful, the team will then proceed to testing how the robot's touch screen input will affect the emotions. For example, on the touch screen, a message could appear and ask how the user is feeling. At first, the options will range from "good", to "meh", to "not good." If the "not good" option is chosen, the robot's eyes will show concern for the user. It might even ask what's wrong. Next, the user could choose from a list of negative emotions such as sadness, anxious, or angry. Depending on which emotion is chosen, the robot's eyes will respond in kind. For example, if the user chooses "sad" as an emotion, the robot will adopt a sad demeanor through its eyes as a way of showing sympathy. If the option "anger" is chosen, the robot's eyes will adopt a concerned demeanor as it asks the user why they are angry. After finishing this test, the team will then test how its emotional recognition algorithm affects eye expressions. For this to work though, the Computer Science team will have to develop a working emotional detection algorithm. As such, this team anticipates that this test will be done very late in the Senior Design semester. When this test is done, the team will test the emotional recognition technology by acting out different emotions, such as happiness, sadness, or anger. This will primarily test if the emotional recognition algorithm works. If it does, the algorithm will then send a certain input to the computer in order to communicate which emotion is detected. Then, depending on that input given, the robot's eyes will then adopt a specific demeanor. After testing all these elements, this team will be confident that the LCD eyes work exactly as we designed them.

Once the eyes have been successfully tested, the mobile Platform will be tested next. This platform will be a platform with treads that can roll on many floors and go over carpets. First, the remote control device must be created for the platform and must be able to connect to it. Once that is done, the team will test the remote controller and see if there are any inconsistencies or weaknesses with the way it works. Next, the team will put bump sensors on the platform. These bump sensors will detect when the platform bumps into a wall or object. If it bumps into one three times or more, the mobile platform must stop until an “I’m sorry” button on the remote controller is pressed. Then it will go again. Once that is finished, the team will run the robot for a long time to test how long the robot can go until its batteries run out of power. If the time is too short, the team will look for an alternative source of power. Finally, the team will do a weight test and see if the platform can carry as much weight as the robot. Once that is done, the team will then attach the robot to the platform and test its normal functions. We will test if the robot can move, emote, and perform its other necessary tasks while being supported by the platform. We will also note how long the battery lasts during this test. If the battery life is not sufficient, we will search for a better alternative.

Testing the camera used for emotional recognition will occur later on in the process, as training the artificial intelligence and developing the algorithm will take a considerable amount of time. Once they have been developed, we will then test the camera by first checking if it recognizes faces. Then, we will check if it can focus on one particular face instead of the others. Next, the team will test the emotional recognition capabilities by acting out different emotions in front of the camera. If the algorithm can correctly identify these emotions, we will be satisfied with the test. After that, we will test how it connects and communicates with the other components. We will first test how it connects to the LCD eyes. We will test how the data given by the algorithm will determine what expression the eyes will adopt. For example, if the algorithm detects sadness, the LCD eyes should respond with a look of concern. The team will then test how to connect the algorithm to the robot’s touch screen display. Once again, the touch screen’s display will change depending on the information provided by the algorithm. For example, if the algorithm detects that the user is feeling sad, angry, or any other negative emotion, the algorithm will send that data to the touch screen, which will then display a pop up that asks the user “Are you okay?”, or “Is everything okay?”, or “Is something wrong?” The user should respond with either “No, I’m okay” or “I’m not feeling well.” Depending on the option, the robot will respond accordingly. Once this testing is finished, we will then be confident that our emotional recognition algorithm works as intended.

Once these parts are tested, the next part to test will be the touch screen on the robot’s chest. We will first have to determine how the user interface, or UI, will be developed. Our UI must not only be visually appealing but must also adhere to accessibility standards, such as those for color blindness and other conditions. We will be researching and implementing a multitude of standards and guidelines so that no user will be unable to use our robot. After that is done, we will test some of the individual functions of the touch screen. To do this, we will be collaborating with our computer science team to create a usable interface. We will first test the initial state of the touch screen, which is when the robot asks how the user is feeling. The user will then enter their answer. When we figure out this part, we will then add the responses to the touch screen. For example, if a user claims to be feeling a negative emotion, such as sadness or anger, the touch screen will ask the user what is wrong through subtitles. This test will also be a good moment to test whether or not subtitles can fit onto the interface. Subtitles will be a vital element as it is the primary way that the robot communicates with the user. After testing this part, the touch screen will then offer a list of activities for the user to participate in. Once that is done, we will look into how the touch screen can be integrated into the robot. The first method we will test is how the LCD eyes will express themselves based on the user's responses. Specifically, when the display asks the user how they are doing and the user gives a response, the LCD eyes must respond accordingly. Subsequently, the team will test how the LCD screen can be integrated with the touch sensor on top of the head. When the touch sensor detects a hand or object and permission is not given for headpats, the LCD screen must display "please do not touch me." If detected again or if the hand stays for a prolonged period of time, the display should display "I said please do not touch me." Finally, if the hand has stayed there for an extended period of time, the bear's eyes should become angry and the display should say "I told you not to touch me!" Once this happens, the display should display the message with the option of saying "I'm sorry." Once I'm sorry is pressed, the display should give the message "It's alright. Just please do not touch me without asking again." However, if the user asks permission using the right options on the display, the display should then say "Yes! You may pet me!" When this happens, the robot will not have an angry reaction. Finally, the data collected from the display to the Jetson should be able to connect to the external database developed by the Computer Science team. Once we test this, along with testing the other elements, we will be sure the display achieves our goals.

The final individual test will be on the joints. The most important one to test will be the neck joint. This joint is a rather complex structure and consists of a platform and multiple servos. The neck should allow the robot to look up and down, turn its head side to side, and rotate its head to the left and to the right. Once the individual neck is tested, we will test the other joints. The shoulder joints will be more complex as it will require that the arm can move forward and backward along with up and down. Once that test is successful, the other joints will be tested. Luckily, the other joints are far less complex and require only one or two servos. These joints include the elbow joints, the torso joint that allows the whole robot to rotate left and right, the torso joint that allows the robot to lean forward or backward, and the finger joints that allow the robot to play rock, paper, scissors with users. After these tests, the skeleton with the servo motor-controlled joints will be assembled. Once that happens, we will then test the overall integration of the movement. First, we will test how the robot can move its body to adopt specific body language for different emotions. An example will be when the robot lowers its head, leans forward, and moves its arms up to its face in a crying motion to show that it is sad. Similarly, when it is happy, it will raise its arms in the air like it is cheering. We anticipate that this process will be an incredibly difficult undertaking as it requires an extensive amount of programming to make sure all the limbs can be moved in all the right ways and with all the right speeds. As such, this testing will be a long and arduous process that will likely take much of the semester. Nonetheless, we will dedicate ourselves to writing the best program possible. Once we test all this, we will then integrate the movements into the Jetson so that emotional inputs given by the camera's data and user responses affect the movement. For instance, if a user reports that they are happy or if the camera recognizes that the user is happy, the robot will adopt a kind of excited body language. Its body will stand upright, it's head will tilt to the side slightly, and the eyes will look happy. This process will be done for every emotion. After this is done, the robot will be tested on how it reacts to its bump sensors on the mobile platform being pressed. If the sensors are pressed three or more times, the robot should slump forward, slump its head forward, and adopt a hurt demeanor. It will stay in this state until the user presses an "I'm sorry" button on the remote controller. After this, we will test if the robot can play rock paper scissors with the user. This will involve testing the way the robot can detect what the user chooses and will test the robot's movement and its hand gesture. Once that is done, we will look into incorporating different types of dancing into the robot. These dances will include fun dances to specific songs and calming dances for managing anger or other negative emotions. By testing all these elements, we will be able to design a robot that moves in an expressive way to users.

Once these individual tests are finished, we will move onto testing how all these elements will be integrated. As mentioned before, these tests will include testing how the LCD eyes will be connected to the emotion detection algorithm, how the robot's movements will be connected to the emotion detection algorithm, and how the mobile platform moves and operates while supporting the robot. In addition to testing all these elements, the team will also need to test and devise a way for the robot to send data to the mobile application and its database for healthcare information collection. We will need to test how the robot and the mobile application will be connected, likely through sockets where they will send each other data back and forth. Once this system is figured out, the team will test different ways to make the data transfers secure. After all, privacy and the safety of children's personal information is of the utmost importance when designing robots and artificial intelligence for children. This method may be implemented through encrypting the data before sending it, anonymizing the data by omitting names, or through finding other secure methods. If the team has time, we may even be able to attempt penetration tests to ensure that the robot is as secure as possible. This, however, will require that the data transfer system be developed first, which is likely going to take a long time. As such, this goal will be a stretch goal. Another test goal the team would like to have is to test this robot among a crowd of autistic children and autism specialists. That way, we can test to see how well the robot performs among children and can be provided with valuable feedback on how to improve the robot in the future. If we are going to be developing this robot for autistic children, it would be wise to test it among autistic children. However, this test requires a fully functional robot, which is likely going to take a long time to design and develop. As such, this test shall be a goal we will undertake only if we have sufficient time by the time our robot is completed. By thoroughly testing the individual elements of the robot, testing the elements working in conjunction with each other, and, if there is time, doing security tests and tests with autistic children, we can ensure that the robot functions exactly as outlined. While we feel our test plan is feasible, we do not expect to fulfill all these tests. We understand that difficulties may arise that can hinder our progress. Members can get sick, computers may stop working, or parts can become lost or broken. As such, we will prioritize testing the most important goals of the project. These goals include ensuring that the LCD eyes work properly and convey emotion, making sure the robot body can express emotions through body language, designing the mobile platform to move while also supporting the weight of the robot, testing how the LCD screen works for users, and testing how the robot will connect to the mobile application. If we manage to complete these tests and if we have sufficient time, we will then look into further testing, such as testing the security and testing how well the robot interacts with autistic children. Although this team is well aware of the challenges of this project, we are still determined to design this robot to be the best social robot it can be.

Section 10: Administrative Content

The goal of this section will be to highlight and go over the various administrative content we've encountered throughout the BearMax senior design project. We will go over the milestones, budget estimates, actual bill of materials, and the distribution of work we decided for ourselves.

10.1 Milestones

Upon beginning the Senior Design 1 course, our first milestone took place our first week upon entering the course, we would be tasked with forming a group and finding the specific topic we sought to begin our project on. Once many people had considered project topics, we were allowed to begin project and group selection, where we were allowed to brainstorm for project ideas and groups. Although, for our project due to the interdisciplinary nature of the project, involving both the Mechanical & Aerospace and the Electrical & Computer Engineering departments. For this reason we received some delay during the initial phases of our project, involving a mistake within the department of nature of BearMax and who exactly was working upon the project. For this reason, we also have integrated mechanical engineering milestones as our project involves both departments. Once that was figured out, we moved to the Divide and Conquer portion of our project, the first real major milestone. This tasked us with writing the first 10-20 pages which were to give an outlook on the project and what we hoped to achieve fully and partially. The divide and conquer consisted of the project motivations, engineering specifications, and projected dates for when we would finish the remaining milestones.

The next major deadline for our team was the 60-page draft, which contained the technology comparison and parts selection, design constraints, our comparison of ChatGPT, as well as the beginnings of the design for the new components of BearMax, such as the neck. The research done by this milestone allowed for us to compare other social helper robots that have already been made, and what features we could replicate or expand upon during the course of the project. Furthermore, the mechanical engineering team had to focus on the design of the CAD model to provide a slight idea on how the future design of BearMax will look. Coinciding with this deadline for the 60-page draft was the MAE M2 milestone, which included various engineering specifications on what BearMax could do in certain situations, such as reacting to an emotion, or the physical dimensions of the robot.

The final major deadline for our team so far is the 120-page finalized document, which has the remaining sections pertaining to the specific plan of design of the hardware and software of BearMax, as well as the preliminary electric schematic that will be used for PCB design and testing plan for major components. Such components such as the development board, and LCD screens had been tested in order to come up with an idea for how they would be integrated and configured to BearMax. Once the 120-page document was finalized our group began the plan for the upcoming milestones for senior design 2, which would allow for our team to create a foundation for which the project may be completed within the short time span left in the remaining months.

Table 28: Senior Design 1 Milestones

Milestone	Start Date	End Date
Form initial group	8/21/2023	9/01/2023
Divide & Conquer 15-pages	9/01/2023	9/15/2023
Quizzes A-G	9/30/2023	10/20/2023
60-page Draft	9/15/2023	11/03/2023
Final Document Due	11/03/2023	12/05/2023

Table 29: Senior Design 2 Planned Milestones

Milestone	Start Date	End Date
Finish CAD design	12/05/2023	TBD
Finish PCB design	12/05/2023	TBD
Testing designs	TBD	TBD
Build Prototype	TBD	TBD
Prototype Testing	TBD	TBD
Modifying Prototype/Finalizing Design	TBD	TBD
Peer Reviews	TBD	TBD
Final Report	TBD	TBD
Final Presentation	TBD	TBD

10.2 MAE Competence Evaluation and Topics Utilized

Table 30: Mechanical Engineering Design Competence Evaluation

ME Design Areas	Critical / Main contributor	Strong contributor	Necessary but not a primary contributor	Necessary but only a minor contributor	Only a passing reference	Not Included in this Design Project
Thermal-Fluid Energy Systems				✔		
Machines & Mechanical Systems		✔				

Controls & Mechatronics	✔					
Material Selection			✔			
Modeling & Measurement Systems		✔				
Manufacturing	✔					

Table 40: Mechanical Topics Utilized in this Senior Design Project:

Topic	Criticality to Project	Section and Pages
Thermal-Fluid Energy Systems	Necessary but Minor	III. 31-36, 49-51 IV. 62 VI. 71, 97
Machines & Mechanical Systems	Strong	VI. 68-93
Controls & Mechatronics	Main	VI. 64 -90
Material Selection	Necessary	II. 16-18 III. 46-48 VI. 67
Modeling & Measurement Systems	Strong	VI. 70-93
Manufacturing	Necessary but Minor	III. 46-47

10.3 Budget Discussion

One of the primary goals for our project is to keep the costs relatively cheap and within a reasonable budget for ourselves to produce. For this reason, we had designated the budget to be limited to about $300, to account for most slightly expensive parts we may need for motors or the LiDAR sensor. Further, many of our parts were provided by our project sponsor Dr. Joon-Hyuk Park of the WEAR lab for no cost, and have been labeled as such within our budget in order to reflect this. These parts consist of the Arduino board and most of the parts used in the previous BearMax project, as we plan to build upon that design for version 1 for version 2. As of the finishing of senior design 1, our costs are approximately $120, meaning we have about $180 left for surplus parts that we may need or things such as the PCB fabrication and materials for building the actual body of BearMax.

Table 41: Project Costs

Part	Cost per Unit	Quantity	Total Cost
Development Boards			
Arduino Mega R3 Development board	N/A	1	N/A
Jetson Xavier NX	N/A	1	N/A
Electrical/Mechanical Components			
Arducam USB Camera	N/A	1	N/A
Small LCD Screen (Eyes)	N/A	1	N/A
MG90S Motor	$3.50	4	$14.00
MG995 Motor	$7.00	7	$49.00
7” LCD Touchscreen	$43.11	1	$43.11
LiDAR Module	$40.00	1	$40.00
KOOBACK Voice Playback module	$11.99	1	$11.99
DC Buck Converter	N/A	1	N/A

10.4 Gantt Chart

Template retrieved from:
https://www.vertex42.com/ExcelTemplates/excel-gantt-chart.html

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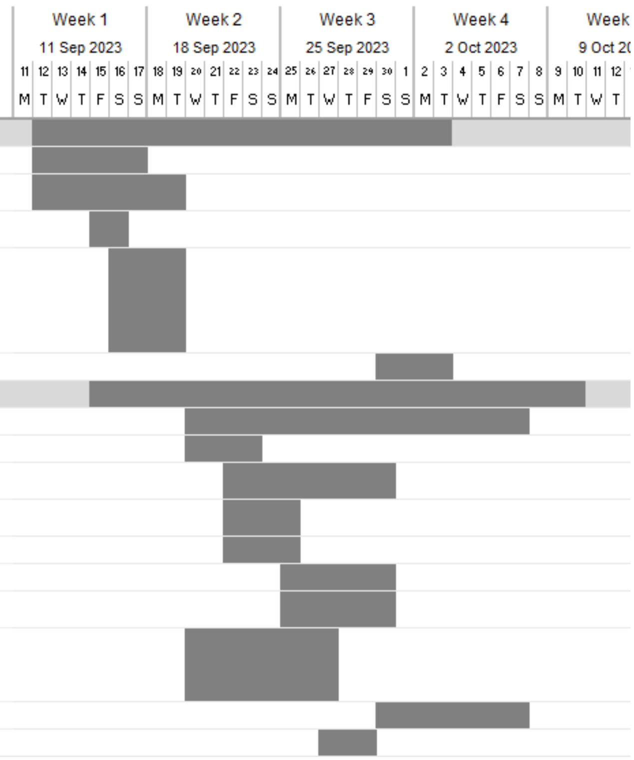
Project Start Date	9/12/2023 (Tuesday)	Display Week	1
Project Lead	ME and CPE Teams		

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
1	**Milestone 1**		Tue 9/12/23	Tue 10/03/23	21	100%	16
1.1	Team Contract	ME	Tue 9/12/23	Sun 9/17/23	5	100%	4
1.2	Technology Study Memo	ME	Tue 9/12/23	Tue 9/19/23	7	100%	6
1.2.1	Discuss division of work with team	ME	Fri 9/15/23	Sat 9/16/23	1	100%	1
1.2.2	Research and write about relevant and existing products relating to project; begin learning about project and become familiar with project ideas and goals generally	ME	Sat 9/16/23	Tue 9/19/23	3	100%	2
1.3	Peer Evaluation 1	ME	Sat 9/30/23	Tue 10/03/23	3	100%	2
2	**Divide and Conquer**		Fri 9/15/23	Tue 10/10/23	25	100%	18
2.1	10 page document	CPE, ME	Wed 9/20/23	Sat 10/07/23	17	100%	13
2.2	Project Description	CPE	Wed 9/20/23	Sat 9/23/23	3	100%	3
2.3	Engineering Specifications	ME	Fri 9/22/23	Sat 9/30/23	8	100%	6
2.3.1	Hardware Flow Chart	ME	Fri 9/22/23	Mon 9/25/23	3	100%	2
2.3.2	Software Flow Chart	CPE	Fri 9/22/23	Mon 9/25/23	3	100%	2
2.3.3	Budget Estimations	CPE, ME	Mon 9/25/23	Sat 9/30/23	5	100%	5
2.3.4	Components / materials research	CPE, ME	Mon 9/25/23	Sat 9/30/23	5	100%	5
2.3.5	Function and Component Breakdown Diagrams	ME	Wed 9/20/23	Wed 9/27/23	7	100%	6
2.3.6	Initial CAD Model	ME	Sat 9/30/23	Sat 10/07/23	7	100%	5
2.5	Initial Website	CPE, ME	Wed 9/27/23	Fri 9/29/23	2	100%	3



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Project Start Date: 9/12/2023 (Tuesday) — Display Week: 4

Project Lead: ME and CPE Teams

Week 4 (2 Oct 2023) · Week 5 (9 Oct 2023) · Week 6 (16 Oct 2023) · Week 7 (23 Oct 2023) · Week 8 (30 Oct 2023) · Week 9 (6 Nov 2023) · Week 10 (13 Nov 2023) · Week 11 (20 Nov 2023)

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
3	**Milestone 2**		Tue 10/03/23	Tue 10/31/23	28	100%	21
3.1	Requirements Definition	ME	Tue 10/03/23	Tue 10/17/23	14	100%	11
3.1.1	3 Column Table	ME	Thu 10/05/23	Sun 10/15/23	10	100%	7
3.1.2	Relationship Matrix	ME	Thu 10/05/23	Thu 10/12/23	7	100%	6
3.1.3	Competitor System Benchmark	ME	Thu 10/05/23	Tue 10/10/23	5	100%	4
3.2	Peer Evaluation 2	ME	Sat 10/28/23	Tue 10/31/23	3	100%	2
4	**60 Page Document**		Tue 10/03/23	Sat 11/04/23	32	100%	24
4.1	Technology Comparision	CPE, ME	Thu 10/05/23	Fri 10/20/23	15	100%	12
4.2	Standards and Design Constraints	CPE, ME	Thu 10/05/23	Tue 10/10/23	5	100%	4
4.3	Official Standards/Guidelines from UNICEF, ASME, etc.	CPE, ME	Sun 10/15/23	Fri 10/20/23	5	100%	5
4.4	CAD model of select components	ME	Sat 10/21/23	Thu 11/02/23	12	100%	9
4.5	Chat GPT Comparision	CPE, ME	Fri 10/20/23	Thu 11/02/23	13	100%	10
5	**Milestone 3**		Tue 10/24/23	Sun 12/03/23	40	65%	29
5.1	Motivation and Solution Approach	ME	Fri 10/27/23	Tue 10/31/23	4	100%	3
5.2	Needs Analysis	ME	Tue 10/31/23	Sun 11/05/23	5	100%	4
5.3	Technology Assessment	ME	Tue 10/24/23	Fri 11/10/23	17	100%	14
5.4	System Requirements	ME	Sun 11/05/23	Fri 11/17/23	12	100%	10
5.5	Concept Generation and Selection	ME	Tue 10/31/23	Tue 11/14/23	14	100%	11
5.6	Preliminary Engineering Analysis	ME	Fri 11/17/23	Thu 11/30/23	13	0%	10
5.7	Gaant Chart and Major Deliverables	ME	Tue 10/24/23	Tue 10/31/23	7	100%	6
5.8	System Concept Evaluation Plans	ME	Fri 10/27/23	Fri 11/10/23	14	0%	11
5.9	ABET Matrices	ME	Tue 11/14/23	Tue 11/21/23	7	0%	6
5.10	Failure Modes and Effects Analysis	ME	Sun 11/05/23	Tue 11/21/23	16	100%	12

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Project Start Date: 9/12/2023 (Tuesday) — Display Week: 8

Project Lead: ME and CPE Teams

Week 8 (30 Oct 2023) · Week 9 (6 Nov 2023) · Week 10 (13 Nov 2023) · Week 11 (20 Nov 2023) · Week 12 (27 Nov 2023) · Week 13 (4 Dec 2023) · Week 14 (11 Dec 2023) · Week 15 (18 Dec 2023)

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
6	**120 Page**		Sun 11/05/23	Tue 12/05/23	30	59%	22
6.1	PCB Diagram	CPE	Sun 11/05/23	Sat 12/02/23	27	100%	20
6.2	Electronics and parts comparison	CPE	Sun 11/05/23	Sat 12/02/23	27	100%	20
6.3	Gaant Chart Update	ME	Mon 11/27/23	Sat 12/02/23	5	100%	5
6.4	House of Quality	ME	Sun 11/05/23	Fri 11/24/23	19	100%	15
6.5	Pugh Matrix	ME	Sun 11/05/23	Fri 11/24/23	19	100%	15
6.6	FMEA expansion	ME	Fri 11/17/23	Sat 12/02/23	15	0%	11
6.7	Prepare for Meeting with Committee	CPE, ME	Sat 12/02/23	Mon 12/04/23	2	0%	1
7	**Finalize design and parts**		Sat 12/09/23	Sat 12/23/23	14	0%	10
7.1	Compatibility of components	CPE,ME	Sat 12/09/23	Mon 12/11/23	2	0%	1
7.2	Parts list, purchase order form	CPE, ME	Sat 12/09/23	Tue 12/12/23	3	0%	2
7.3	Parts list needed from SD inventory	CPE, ME	Sat 12/09/23	Sun 12/10/23	1	0%	0
7.4	CAD modeling of 3D printed components	ME	Mon 12/11/23	Wed 12/13/23	2	0%	3
7.4	CAD modeling of laser cutting components	ME	Mon 12/11/23	Wed 12/13/23	2	0%	3
7.6	3D printing select components	ME	Tue 12/12/23	Sat 12/23/23	11	0%	9
7.7	Program LCD Eyes	CPE	Sat 12/09/23	Fri 12/15/23	6	0%	5

Senior Design I - BearMax

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Project Start Date: 9/12/2023 (Tuesday) — Display Week: 18

Project Lead: ME and CPE Teams

Week 18 (8 Jan 2024) · Week 19 (15 Jan 2024) · Week 20 (22 Jan 2024) · Week 21 (29 Jan 2024) · Week 22 (5 Feb 2024) · Week 23 (12 Feb 2024) · Week 24 (19 Feb 2024) · Week 25 (26 Feb 2024)

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
8	**Milestone 4**		Mon 1/08/24	Mon 1/15/24	7	0%	6
8.1	Statement of Work	CPE	Mon 1/08/24	Mon 1/15/24	7	0%	6
8.2	Preliminary Design Revision	CPE	Mon 1/08/24	Mon 1/15/24	7	0%	6
9	**Milestone 5**		Mon 1/15/24	Fri 2/16/24	32	0%	6
9.1	Engineering Analysis	CPE	Tue 1/16/24	Wed 1/31/24	15	0%	1
9.2	Test Plans Written	CPE	Wed 1/31/24	Tue 2/13/24	13	0%	2
9.3	Prototyping potentially	ME	Mon 2/05/24	Fri 2/16/24	11	0%	10

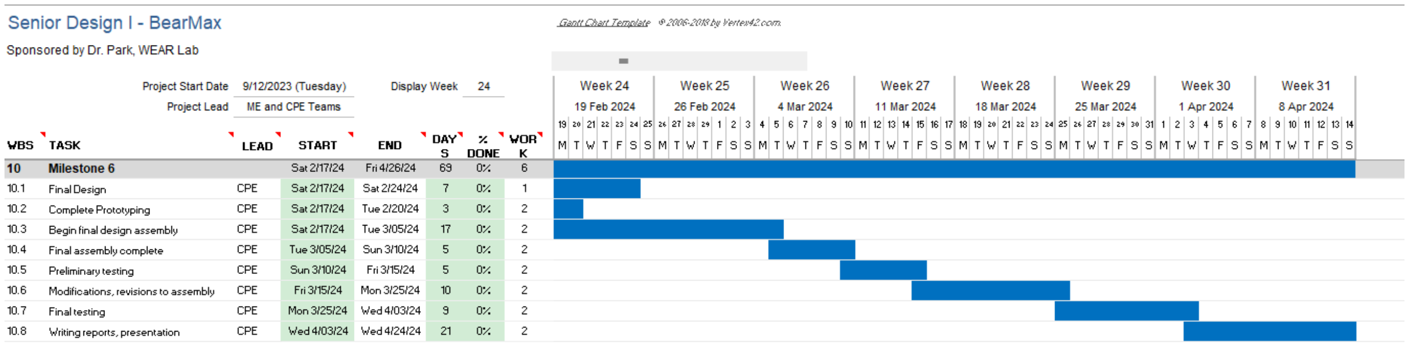

Figure 34: Gantt Chart

10.5 Individual Contributions

Zachary Larson

I contributed to the team by scheduling meetings with the professors, organizing meetings and updating the review committee, and maintaining this team's website. For the paper, I contributed to the preliminary research section, the ChatGPT section, the Standards and Design Constraints section, the software diagram section, the Senior Design 2 Test and development plan, and part of the conclusion. In my contribution to the preliminary research section, I wrote about the Pepper Robot, its successes, and its drawbacks. Reading it helped me understand the kind of approach this team will need to follow if this project is to be successful. It also provided us ideas of what we can incorporate into our robot, such as a means for expressing emotions and the ability to hold conversations. For the Standards and Design Constraints sections, I researched and wrote about the UNICEF guidelines for artificial intelligence for children, the IEEE standards for robotics, and the recommendations named from the paper "Designing the mind of a Social Robot." Reading and writing about these guidelines further solidified our understanding of what is required of this robot and how we should be constructing it. From this, we have been able to consider ways to construct this robot in a way that respects the rights and safety of its users, especially child users. For the ChatGPT section, I wrote about its potential uses for writing and coding help, but specified reasons why I was hesitant to use it. Designing the software diagrams and explaining what they mean allowed me to not only understand how the robot works overall, but also provided an outline for how the programming can be written. When writing the senior design test plan section, I needed to come up with a methodical approach to successfully constructing the robot. Doing so became reassuring to me, as I felt confident that our plan is reasonable while also fulfilling the senior design requirements. Finally, I, along with Bhavani, contributed to the conclusion section by summarizing our ultimate goal with this project and writing about what we have had to learn throughout this semester while working on designing the robot.

Raahym Khan
I contributed to the team by helping delegate tasks focusing on short term goals from week to week to help guide our group for certain tasks such as getting the report and pages in on time. A big contribution I made was working on the technology and parts comparison section, choosing the specific parts we needed for things such as range sensing and LCD screens. Another contribution I took on was the design for the printed circuit board, or PCB, that will be used to power all the different components and connect them to the microcontroller. This required me to use the parts I had previously selected and read through the manuals and datasheets in order to properly find a way to configure the wiring. I also chose to write the parts of the administrative content section pertaining to the milestones and budget, as well as designing tables to organize said information. Finally, I assisted in the overall organization and format of the final report and document, choosing the spacing standard used.

Nicholas Buchberg
I contributed by gathering the team together early and emphasized the need to meet more frequently. This kept us from falling behind at the start which played an important role in our progress up to now. My technological contributions centered around the joint designs. Bhavani and I divided our joint systems to split up the workload. I was tasked with designing the torso, neck and track system. I have made the neck system in solidworks and devised concepts for both the track and adjacent torso. Besides the more mechanical contributions, I got in contact with a local machine shop near UCF to obtain parts. This will amplify our ability to build parts quickly. In terms of administrative documents, I did most of the M2 chart, the system breakdown chart, CAD comparison, speaker comparison, motor comparison and both the pugh matrices.

Bhavani Sivakumaar
I contributed to the team by making the team contract and scheduling additional meetings when necessary with the team to discuss our progress and upcoming deadlines. I made contributions to Sections 1, 2, 3, 6, 9, and 10. Some things I contributed with specifically include the preliminary research section, robot comparison chart and robot material comparison, the house of quality, Gantt charts, content in the hardware tables, failure modes and effects analysis, among some others.

Section 11: Conclusion

BearMax is a project with immense potential to be incredibly beneficial to young children with autism. By providing a friendly, and frankly adorable, outward appearance, providing a variety of activities, and utilizing tools to enable social and emotional learning, it can be an effective robot for helping young autistic children learn to socialize and to understand their own emotions. Of course, this robot can not and should not be used on its own. It works best when under supervision of a therapist, teacher, or some other trained professional. It, in no way, is designed to replace therapy. It is only designed to be a tool to enhance therapy.

Designing and developing this robot has proven to be quite a challenge. Through this process, this team has had to quickly learn new skills, such as Computer Aided Design and hardware design, and has had to conduct immense research to understand how previous attempts at similar robots were conducted, what approaches must be taken to constructing such a robot, and what standards and design requirements are needed for building this kind of robot. Understanding the basics of robotics is essential to this project. The basic systems and components of a robot that are essential to this project include manipulators, drivetrain, control system, and the frame. While the basics of a robot are required, the team also aimed to increase expressiveness. To do this, animatronics needed to be studied and considered. The neck design was inspired by an animatronic project and it allows the robot to greatly increase the amount of expressions and severity of the expressions that it is able to portray. Furthermore, it was also necessary to consider therapy robots in general. There are several robots on the market that were researched and designed to aid with social-emotional learning, therapy, or to aid in school lessons for children. These robots also provided inspiration to design this robot.

As a result, we now understand exactly what approach must be taken when designing this social robot for young autistic children. We are especially aware of the importance of privacy and security for children along with the need for a supervisor, such as a therapist or other kind of mental health professional, to be present alongside the robot. From this research, we are also aware of how other social robots were constructed and implemented for the purpose of aiding autistic children. We were able to learn what successes they were able to achieve, such as successfully teaching the children to socialize and giving them an opportunity to learn how to be in touch with their emotions. We know how those previous robots succeeded and we are looking to implement them in our own project. In addition, we are also aware of the drawbacks of the previous robots. The studies we found analyzing the successes and downsides of these robots even listed which areas need to be fixed or improved. One aspect we have noticed is that often these robots have no way of emoting or expressing any emotions with the user, which can limit the social and emotional learning possible. We plan to implement this feature and will devise plans to mitigate any further downsides we discover.

Placing the technical challenges aside, it has definitely been a learning experience collaborating and communicating with multiple team members from multiple disciplines. While the computer engineering and mechanical engineering team are a team, the computer science peers are also working on BearMax in a different capacity. Having to keep in constant communication, making compromises, and understanding that final decisions need to be made as a collaborative effort has been a learning experience. Scheduling was the most difficult part, coordinating a singular meeting with 8 people, however, learning to adapt to different scenarios that arise has been a rewarding experience. As a team there have been several accomplishments, and it is just as important to recognize the individual members' contributions.

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