PROGRESS REPORT
2019-2020
-- Fall Term --

Team Number ECE-27

Project Luxo

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Executive Summary

Displays are a ubiquitous part of modern society and while their underlying technologies have been improved upon significantly, nearly all screens are stationary and must be physically positioned by the user to suit their needs. Given any screen in your home, whether it be TVs, monitors, or smart home displays, none are able to automatically move in response to humans. You can adjust a mounted TV or rotate a monitor, but these are manual processes. We will explore a system that allows a screen to automatically move, by means of motors, in response to human inputs (i.e. vision and motion sensors).

This could have a variety of applications, from: accessibility to education, and most certainly entertainment. We will build an electromechanical system integrated with sensors that will physically and virtually alter itself based on human input. This project can be broken down into three systems - mechanical, electrical, and computational systems - that will have to be strategically integrated and work synchronously together. We will define an interaction with this system as a vision sensor seeing a person, that person doing something interesting (i.e. moving, gestures), and the screen moving in response to that either as a reaction or control. This interaction could be something useful like if applied to a smart screen in a kitchen the screen could follow someone in the kitchen always displaying the steps or tutorial video while the person is moving around. With this understanding of an interaction we want to create many different and interesting machine interactions.

This project will be funded by the Senior Design Fund and the ExCITe Center. Our primary stakeholder is the Expressive and Creative Interaction Technologies (ExCITe) Center – a transdisciplinary research center at Drexel where undergraduate and graduate students can explore nontraditional fields of study where STEM and the arts intersect. The intersection of robotics, animation, and control is what will set this work apart from others. This project will require us to craft a system that works harmoniously together to interact with people through visuals and movement. The ultimate goal of this project is to create a robotic arm that is able to move a screen with several degrees of freedom based on input from a person that could be movement or gestures, while altering the visuals on the display.

I. Introduction

Displays are a ubiquitous part of modern society and while their underlying technologies have been improved upon significantly, nearly all screens are stationary and must be physically positioned by the user to suit their needs. Given any screen in your home, whether it be TVs, monitors, or smart home displays, none are able to automatically move in response to humans. You can adjust a mounted TV or rotate a monitor, but these are manual processes. We will explore a system that allows a screen to automatically move, by means of motors, in response to human inputs (i.e. vision and motion sensors).

Little has been done to improve screen mobility. Most screens that we interact with today display content in two dimensions. Some attempts to create three-dimensional (3D) displays, such as 3D movies and 3D screens, are met with varying degrees of success. Moviemakers are able to achieve the desired 3D effects by using stereoscopic cameras and having the viewers wear glasses that filter opposite visible light wavelengths to give the illusion of a 3D object. While this is an amusing novelty, we believe that there is an alternate solution - one without external peripherals (i.e. no glasses or headsets). Such an alternate method could solely consist of a screen. This screen would physically and automatically move in relation to the person's current position and perspective, thereby creating the illusion of a 3D space.

We will build an electromechanical system, integrated with sensors, that will physically and virtually alter itself based on human input. What this project hopes to do is create a more personalized and new way for users to interact with their displays so that they can communicate with the user more effectively.

Our primary stakeholder is the Expressive and Creative Interaction Technologies (ExCITe) Center – a transdisciplinary research center at Drexel where undergraduate and graduate students can explore nontraditional fields of study where STEM and the arts intersect. The intersection of robotics and animation is what will set this work apart from others. This project will serve as an example of how different systems, from different fields of engineering, can be integrated into something that enables users to use their screens for new applications. The project combines human-machine interaction and robotic and automation controls with data visualization, creating tools and visuals for live performances, accessibility for the physically impaired, and potential new opportunities to learn through interactive installations.

II. Methods

We will use an iterative engineering process to arrive at the final product. We will design/brainstorm and prototype. This cyclic process will allow us to build upon the good things in the designs and learn from the mistakes. All of the steps in this process are key in that it is difficult to build a physical model without first creating build drawings - and vice versa.

1. *Preliminary Brainstorming*

    1.1. Research Options

    1.1.1. Previously existing information will help guide us through the beginning stages of our project. Our main sources of outside information will be retrieved through Google Scholar or the free online Drexel Library.

    1.2. Axes of Rotation

1.2.1. The desired axes of rotation for our project will be determined through the construction and iteration of a K’nex model. This will allow us to alter a physical model until the desired motion is achieved - confirming the locations and directions of movement.

1.3. Input/Output

1.3.1. The input that the robot system will respond to will be the motion of the user standing in front of the system (whether it be facial movement or gestures)

1.3.2. The response of the system will be to either mimic the human motion or perform a command indicated by the human gestures.

2. Prototype

2.1. Digital Design

2.1.1. The individual pieces of the prototype will be designed using Autodesk Fusion 360, a modeling software that is available for free to Drexel University students.

2.2. Prototype Piece Fabrication

2.2.1. Some of the pieces will be fabricated by 3D printing the designs created using Fusion 360. The 3D printer will be provided to us by the ExCITe Center.

2.2.2. Some of the larger pieces will be constructed in Drexel University’s wood shop and machine shop, both available to Drexel students.

2.3. Design Specifications

2.3.1. Force / moment balance techniques will be used to determine the proper locations and sizes of different pieces of the robot arm.

2.3.2. Material for the different pieces of the prototype will be chosen using a mechanical properties analysis technique.

2.4. Motor Control

2.4.1. The motors that we will use for this project are Parker motors, which will be given to us by the ExCITe Center. They will be controlled via TCP or serial protocols. Parker provides their own proprietary software that allows the user to control and program their devices with a more graphical interface.

2.5. Input Reading

2.5.1. Machine vision will be used to track the human’s movements/gestures, sending the information to the computational system.

2.6. Computation

2.6.1. An embedded computer will be used to process input from sensors and generate a reaction in the physical and visual systems.

2.7. Visuals

2.7.1. A screen will display visuals generated from a visual scripting language and altered by sensor input.

III. Design Description

1. Concept

Robots of the present come in all shapes and sizes. Many of these robots have been given artificial personalities, whether it be a “smiley” face displayed on a screen or animated characters such as Mickey Mouse or Pikachu. Our goal for this project is to create a robot display that is capable of responding to human movement, altering the position and direction of the robot as well as the content on the screen. This added element of interactivity between the human and the robot will help give it a lifelike feeling.

In order to get ideas for what our project could possibly look like, research was done on the different types of robots. As defined by ISO standard 8373, an industrial robot is defined as “An automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications” (ISO 2012). According to the International Federation of Robotics (IFR), there are five main classifications of robots: linear robots (Cartesian), articulated robots, SCARA robots, parallel robots, and cylindrical robots. With these in mind, we further investigated the three most likely choices: cartesian, cylindrical, and articulated.

A cartesian robot is one in which the central movement piece can move along three distinct axes – the x-axis, y-axis, and z-axis. A simple example of this type of robot is a 3D printer, which is capable of creating a precise 3D design using those axes. Our cartesian concept would have the frame as its base, with the arm attached to the top of the central movement piece. This track would allow the screen to be moved up and down, left and right, and forward and back to copy the motion of whoever is interacting with it.

Similar to the cartesian robot in the sense that it is named after a coordinate system, a cylindrical robot also has three axes of movement; however, these axes are different from those of a cartesian robot. Since the cylindrical robot operates in the cylindrical coordinate system, its motion types are as follows – the arm can extend outward or pull back inward to increase its distance from the central vertical axis, it can slide up and down along that vertical axis, and it has the ability to rotate about the vertical axis at the base. For our project, a cylindrical design would have the screen mounted on the end of the arm, allowing for rotation as well as linear motion of the screen.

An articulated robot is a robot whose arm has at least three joints at which rotation can occur. One of these points is a primary rotation point at the base, where the robot can rotate about the central vertical axis 360 degrees and about the horizontal axis of the base 180 degrees. Another is higher on the robot arm, allowing for the center of the robot arm to rotate 180 degrees about the horizontal axis of the joint. The last joint usually lies at the top of the arm, allowing for the top of the arm to tilt and pan. For our concept, these joints would most likely be simplified. The part of the arm attached to the base would likely rotate about the vertical axis, but it would always stay straight up and down, not tilt. The top of the arm would likely only tilt up and down, not pan left and right, due to the fact that any motion of that sort could be covered by the rotation of the base piece.

Table 1: Decision Matrix - Choosing the Robot Type

Robot Type Weighted Decision Matrix							
		Design Options					
Criteria	Weighting (1-5)	Articulated Robot		Cartesian Robot		Cylindrical Robot	
		Score (1-5)	Total	Score (1-5)	Total	Score (1-5)	Total
Range of Motion	5	5	25	2	10	4	20
Fluidity of Motion	5	5	25	2	10	4	20
Weight	3	2	6	4	12	2	6
Complexity	4	3	12	5	20	4	16
Cost	1	3	3	5	5	4	4
Overall Weighted Score:			71		57		66

As shown in *Table 1* above, there are a couple of things that are very important to the success of this project. One is that the robot must have enough degrees of freedom to help successfully orient itself any way that the human decides to move. Along with that, the robot should be able to move fluidly. Those two necessities are what will determine the concept that we will choose to carry on with for our project.

The cartesian robot would have the desired freedom of movement linearly, as it is capable of moving along three linear axes. On the other hand, it would not have the rotation required to really track the human's movement while still giving them the same field of view, due to the fact that the cartesian robot does not have any rotary pieces.

The cylindrical robot has the required level of rotation, as its base can spin around 360 degrees. It also has most of the linear motion required, due to the fact that it can move up and down as well as out or back. Even with all of this, the cylindrical robot does not necessarily have the desired tilt axis that would adjust the screen at varying heights to give the user the same field of view at all times.

The articulated robot is the most desirable option for this particular project. This type of robot can rotate, alter the height of the top of the arm, and tilt the middle and top of the arm all at the same time. Due to the fact that it possesses the greatest combination of linear and rotary motion, the articulated robot arm is the one that we will build for the project.

2. *Embodiment*

In order to physically visualize the proposed design, we will be using both 2D and 3D computer aided design (CAD) tools. We will be using software programs including Autodesk AutoCAD (2D) and Autodesk Fusion 360 (3D) to help us design the mechanical aspects of the project. These programs will allow us to quickly sketch out our ideas and see them virtually.

In addition to visualizing models on the computer, we will use processes such as 3D printing and will use a wood shop and machine shop to physically see each component of the project. 3D printing allows us to take the designs that were drawn up in 3D CAD and produce physical pieces. In addition, we will be using a wood shop to create the main structure of the robot arm. These wooden pieces are not necessarily incredibly detailed, but they provide a quick and easy way to create the structure. Similarly, the machine shop will be utilized to create more complex and stronger pieces - i.e. created out of metals such as steel or aluminum. All three of these prototyping processes (3D printing, creating in the wood shop, and creating in the machine shop) will allow us to physically visualize how each component of the robot arm will fit together - prior to arriving at the final model.

3. *Detail Design - Electrical*

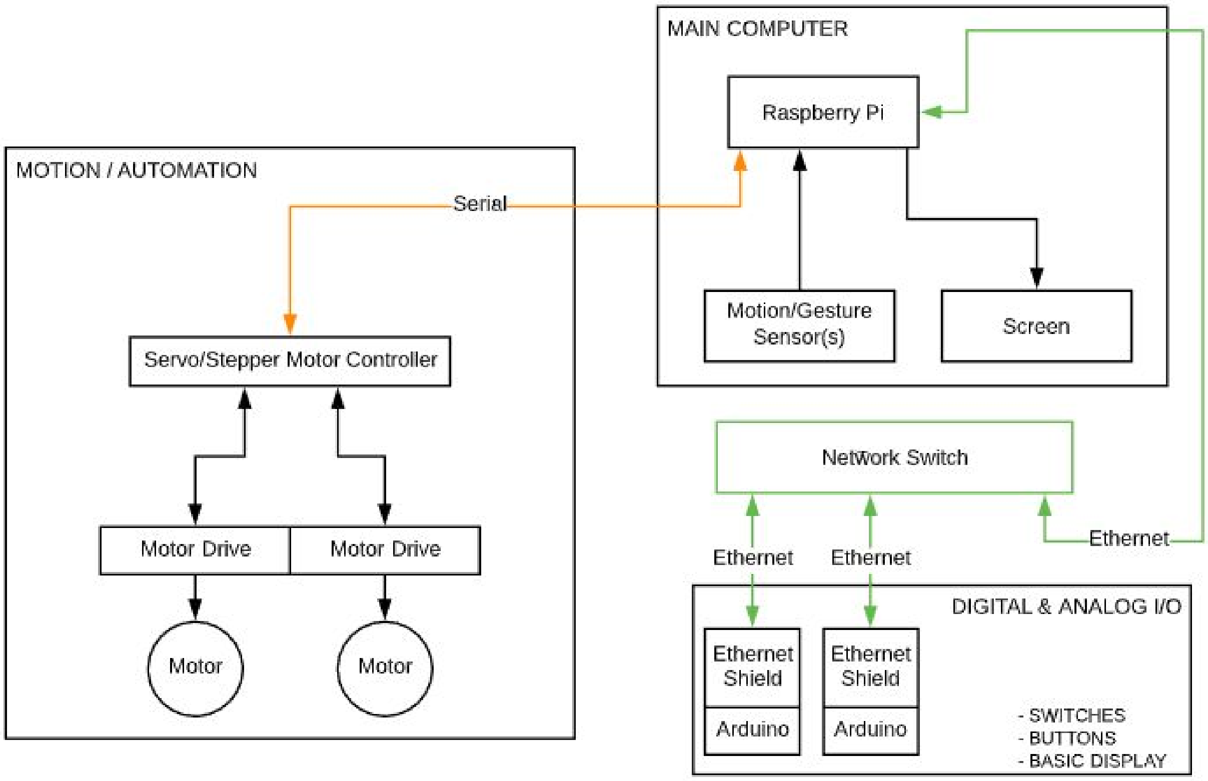

Figure 1: Basic Electrical System Architecture - Component and Signal Flow Chart

The above flowchart shows the general electrical system architecture of the robot arm. The robot consists of three major components: the motion/automation system, the main computer, and the analog and digital I/O system.

The motion/automation system consists of the physical motors, motor drives, and the stepper motor controller. The motors are 24VDC 2-phase stepper motors. These motors accept a step direction input from the motor drives and will move the given number of steps in either the positive or negative direction. The motor drives control the motors by accepting a calculated position, acceleration, velocity, and deceleration setpoint from the stepper motor controller. The stepper motor controller is a platform for the user to program the motor drives and allows the user to store specific programs that run at given intervals.

The main computer is a central computer that allows for the integration of all electrical systems. The main computer will act as a server and will accept and route data to its required location. The motion/automation system will accept a position setpoint according to the gesture/motion sensors. The motion/automation system will send its current position so that the content on the screen can update accordingly.

The digital and analog I/O provide quick feedback to the user about the state of the robot arm. Some digital I/O will include LED indicators, an e-stop button, buttons for specific presets. Some analog I/O will include a screen for basic troubleshooting or indication, potentiometers for manual position control, etc.

4. Detail Design - Mechanical

The robot arm will consist of three main pieces: the base, the main rotate, and the arm. The base (*Figure 2*) will house the main rotate motor and all electronic components that allow the robot to run. The main rotate motor will gear drive the main rotate body so that slippage is minimized. The gear on the motor will be smaller than the gear on the body so that torque is maximized. The base will be made out of wood and the center pin/rotate axis will be made out of a metal rod. The frictionless material will be a piece of 3D printed PLA. The electronic components that will be housed in the base include: power supply, main computer, and analog and digital I/O microcontrollers.

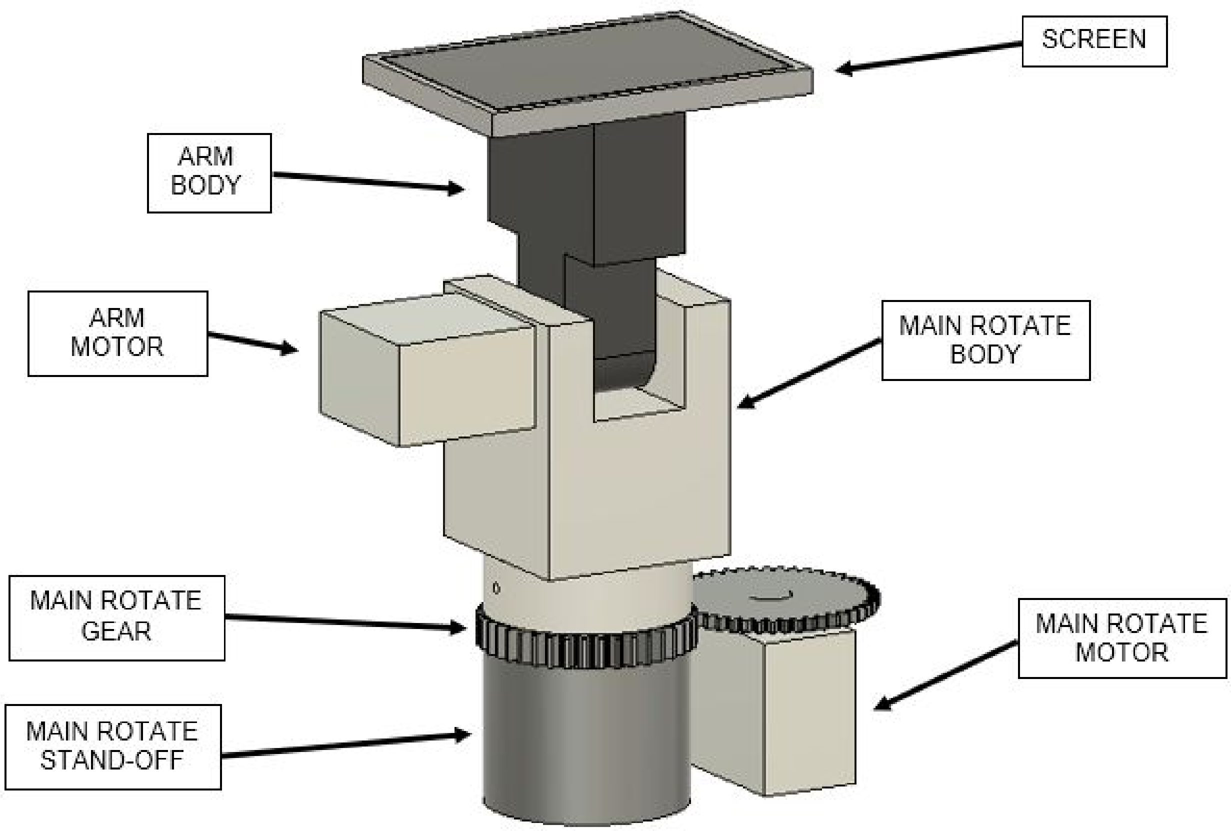

Figure 2: Robot arm CAD model with component callouts

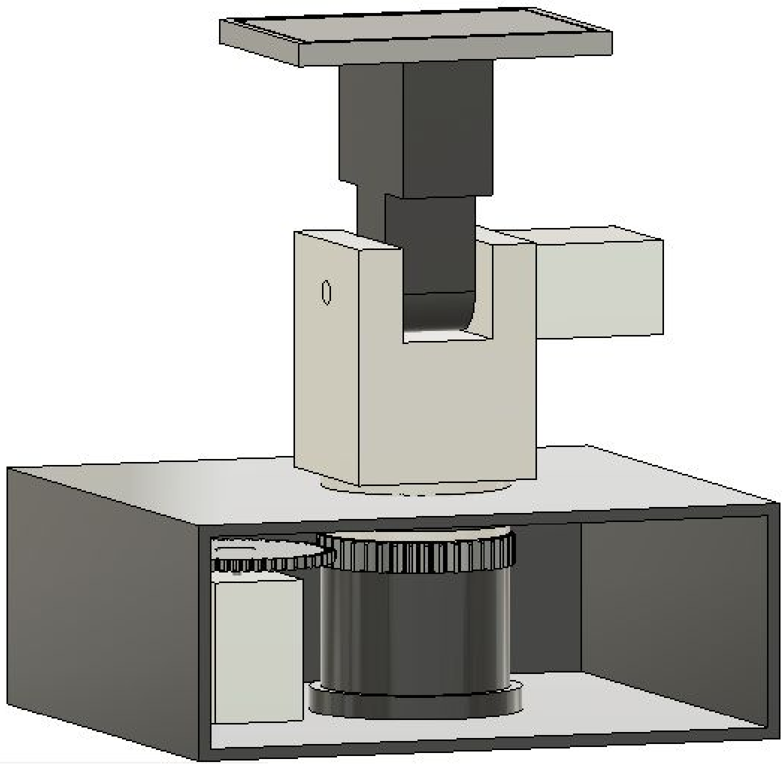

Figure 3: Robot arm CAD model with base enclosure

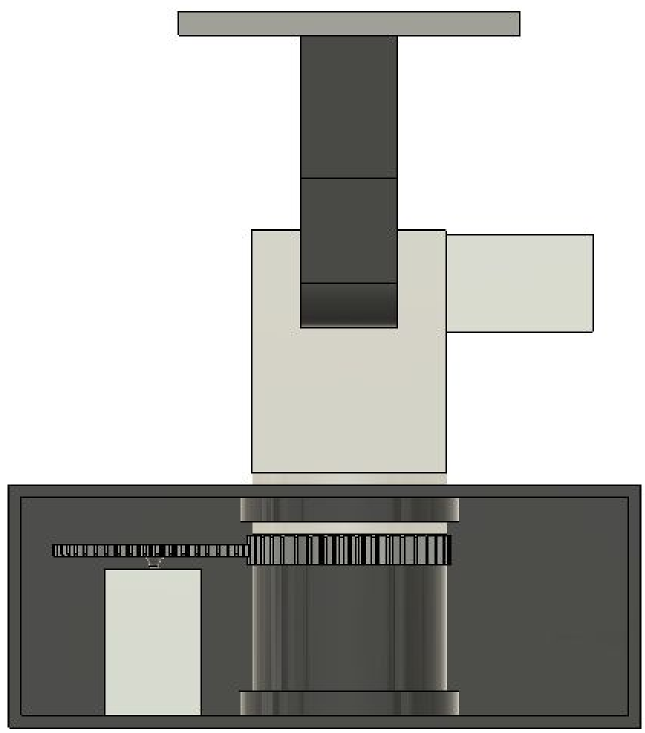

Figure 4: Robot arm CAD model - Back View

The main rotate is the main rotating piece of the robot arm. This piece will be gear-driven by the motor located next to it and will rotate a full 360 degrees. In order for the gear on the motor and the gear on the base to line up properly, there will be a stand-off. This stand-off will be stationary. The main rotate body will have a circular lower half and a rectangular upper half. The circular lower half allows the piece to rotate inside the base. The rectangular upper half allows the arm motor to be mounted on the side (shown mounted to the right side of the main rotate piece in the model above). The main rotate piece will be machined out of aluminum or steel.

The third piece of the robot is the arm. The screen is mounted to the end of the arm. The arm is directly driven by a motor mounted on the main rotate and will be able to rotate a full 180 degrees. This reason behind directly coupling the motor to the arm is to maximize torque. The arm will be machined out of aluminum.

5. Specifications and Standards

Python (2.7/3.6)

Python is an object-oriented scripting programming language that is currently the leading programming language in popularity. Raspberry Pis are single board computers that are made to easily interface with Python for control over things like the GPIO pins. Also libraries such as OpenCV, an open-source library for facial tracking and recognition are built off of Python.

TCP/IP (RFC 793/RFC 1180)

TCP (Transmission Control Protocol) and IP (Internet Protocol) are used in communicating between the main computer and the automation system and between the main computer and the various Arduinos (used for digital and analog I/O). TCP, specifically, provides reliable, ordered, and error-checked data transfer between two devices. TCP requires that each device set up and maintain certain sockets or ports of communication. In this project, the sockets chosen are in the range of numbers that are generally unused by common applications.

Serial

Serial communication is used between the main computer and the automation system. Serial communication requires three wires: transmit data (TxD), receive data (RxD), and ground. These three wires allow for back-and-forth communications between two devices. The main computer will be sending the motion controller position setpoints. In return, the motion controller will be sending the main computer its status and its current position.

C++ Programming Language (ISO/IEC 14882:2017)

C++ is a programming language based off of the C language. C++ provides additional data types, classes, templates, exceptions, namespaces, operator overloading, function name overloading, references, free store management operators, and additional library facilities. C++ is used to program the Arduino microcontroller.

Industrial Robot Definition (ISO 8373:2012)
An automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

IV. Context and Impact

1. Economic Analysis

In terms of the upstream economics of the project, the team does not actually have to spend that much money. A lot of the raw materials for the prototypes and the real design are being provided by either Drexel University (through the wood shop or machine shop) or through ExCITe (Parker motors, 3-D printing, etc…). The main cost of the prototyping process is the time that the team has to spend first creating the individualized subsystems and then figuring out a way to successfully integrate them into one dynamic system.

When the production of the display system gets ramped up, the price will definitely differ from what it is costing the team now. Some of the primary necessary components, such as the Parker motors that will drive the movement in the robot will have to be purchased in bulk, even though they were free to our team during this process. Some of the raw materials that will be purchased, however, will end up being cheaper once they get converted to bulk quantities.

The largest downstream costs for our project will be manufacturing this robot, were it to be scaled. The cost of real gears, raw materials, and a proprietary computing platform, to avoid licensing fees, would all cost money, driving up the cost of the product. Some of the cost of materials would be lowered due to the fact that we would be purchasing them in bulk quantity, however, the labor needed to properly assemble this product would increase the cost.

2. Social Impact Analysis

This project has several different applications that could impact society in important and exciting ways, some of which have yet to be considered. Digital accessibility has long been an issue and recently there's been a surge of new features in consumer technology that allows more people to take advantage of these products. For those people with trouble orienting themselves so they can see the content on a screen, this project could potentially benefit them. It would allow these people to have control over their screen without the need to physically orient it themselves. Another application our team saw for this project was education. For example, museums today are constantly looking for new ways to engage their audiences. A display that could interact with the user could be a great way to keep children engaged and learn something new. There is a much greater connection between a stagnant screen with words and a screen that gesture towards an exhibit while explaining different aspects of it.

Perhaps the most universal application would be entertainment. Live performances are known to have some of the most over the top visuals to accompany the performer. Large-scale screens that interact with performer or potentially the audience while displaying 3D images is something that hasn't really been done before and we think it could really add to a performance. People could also interact with it as an installation whether it be at some type of festival or public area. This kind of setting could be something that the community comes together and share experiences over this project and that though exhilarated us to work on this project. Furthermore this kind of exciting and new entertainment application could inspire a new generation of engineers that could get their start from one of these screens.

These impacts made a couple of things clear about the design. The robot needs to have as many degrees of freedom as possible to allow for fluidity of movement and allow for greater control over the screen. Also, however we decide to build the base of this robot should be able to be scaled in size and quantity with ease. While the first goal of the project is to get a relatively small screen moving and interacting with the user scale plays a part in the long-term goals of this project.

3. *Ethical/Environmental Analysis*

One of the big issues in today's world of modern technology, as seen by tech behemoths like Facebook and Google, is need for user privacy in an age for data is the name of the game. People don't like the fact that what they feel to be a private interaction is then being saved and sometimes even sold. While not entirely the same, this general concept applies to our project in terms of the cameras and/or sensors on the front of the machine. A lot of people probably wouldn't be okay with video of them being taken and distributed. To avoid potential fear of the users, our project will feature real-time motion sensing computation and will not store the picture data long term. This was a concern of the public for products such as Google Glass or Facebook Portal as these companies, who are known for tracking and assessing user data, now have products that are constantly monitoring them. Our project will have a simple on/off toggle so the user can be at ease knowing the system isn't watching them.

Another ethical issue is procurement of different parts and the waste of metals associated with creating a robot like this. We addressed this by using all upcycled parts from the motors and drivers to the screen. These parts would've otherwise found themselves in a landfill, but we were able to make them useful components in this project.

V. Project Management

1. *Team Organization*

Our team is made up of a set of engineers with a diverse set of skills that will allow this project to thrive. Yoni is our electrical engineer on the team who is responsible for the power systems architecture and motor controls. Ian is our mechanical engineer on the team who is responsible for fabricating the structure of the robot and designing the mobility. Emre is our computer engineer on the team who is responsible for the computing system of the robot, the sensor that allow for computer vision, and the visuals on the display. Each member is trusted to make decisions corresponding to their own responsibilities and only consult the team when the decision could change the project as a whole. To keep all of our work organized we have a Google Drive for all of our documentation, code, notes, and sketches. Emre will also maintain a Github project for all of the code. And for communication, our team has a text message group chat for quick conversations and a Slack channel with our advisor for more important matters.

2. *Schedule and Milestones*

Appendix 3 shows a Gantt chart of the proposed progress for the first 11 weeks of the project (Fall Term 2019-2020).

In order to deliver a successful product at the end of this project and to keep progress moving forward, the schedule has been purposefully made to be rigorous and the milestones have been reasonably set in relation to each member's work load.

Throughout the first 11 weeks (Fall Term 2019-2020) working on this project, we hope to mechanically create a working model of what we wish the final product to be. This model will consist of the major components of the robot arm - i.e. the main rotating body, the main arm, and the screen attachment. The main rotating body will be able to rotate automatically via a controlled motor.

Additionally, during this term we will begin integrating the various systems together. The automation system will be integrated with the main computing platform (so that it may receive position inputs and move accordingly). The sensor system will also be integrated with the main computer. There will be programs on the main computer that will receive sensor data and determine how to control the automation system.

We will successfully implement basic visuals on the screen that are able to respond to the surroundings. These visuals will also be driven by the main computer.

Over the next few months (Winter Term 2019-2020 and Spring Term 2019-2020), we will repeat the designing, fabricating, and testing processes to create a better model of the system. We will also integrate all systems so that they will be able to run automatically without human interaction.

Throughout the entire process of this project, every team member will document their research, findings, sketches, code/algorithms, and issues faced.

3. *Project Budget*

Our budget as can be seen in *Appendix 1a* is rather simple because of the wealth of resources Drexel University and the ExCITe Center has at their disposal. The only foreseeable costs for the initial prototype would be the Raspberry Pi for the computational system and potentially some vision sensors depending on how well the sensors ExCITe provides perform. Because of the generosity of ExCITe we were able to procure the motors involved in the prototype, the display, and the arduinos that will interface with the motors. Drexel University provides materials and access to a machine shop that will allow us to fabricate the initial structure of the robot. Through the senior design fund we've been allotted $200 and approximately $500 from the ExCITe Center so for the first phase of our project in constructing the prototype we wanted to be as cost conscious as possible and use the resources available to us.

References

1. **Robot Definition**
   a. **https://ifr.org/img/office/Industrial_Robots_2016_Chapter_1_2.pdf**
2. **TCP/IP**
   a. https://tools.ietf.org/html/rfc1180
   b. https://tools.ietf.org/html/rfc793
3. **Serial Communication**
   a. **https://www.electronics-notes.com/articles/connectivity/serial-data-communications/rs232-v24-basics-tutorial.php**
4. **C++ Programming Language**
   a. https://www.iso.org/obp/ui/#iso:std:iso-iec:14882:ed-5:v1:en

Appendix

1. *Detailed Project Management*
   a. Detailed Project Luxo Budget

Project Budget			
Part	**Price**	**Quantity**	**Total**
Raspberry Pi 4	$62.00	1	$62.00
Cables	$10.00	1	$10.00
Total Spent:			$72.00
Amount Remaining:		$628.00	

2. *Programming, drawings, key product development files, etc.*
   a. As needed, where they are important to understanding the project but too large or tangential to include in the main body text
3. *Gantt Chart*