EE183DA: Design of Robotic Systems I
Team Buffalo
Final Project Proposal
Snack Launching Robot - YaoGuai

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1 Problem Statement

On average, Americans spend 2 hours and 46 minutes every day watching television, often eating their favorite snacks while watching [1]. This often involves the need to get up from a comfortable, seated position and refill or replenish the snacks when they are diminished. This leads to the human diverting their attention away from the entertainment they are consuming, meaning less enjoyment can be derived from the entertainment. Another problem that arises when eating snacks while watching television is the fact that handling sticky snacks leads to sticky hands and fingers for the human. These problems are both caused by the way the snacks are consumed by the humans; the root problem is that the snacks must be handled and removed from the container to be eaten, and that the container must be refilled periodically when all the snacks are eaten out of it.

2 Motivation

The team's main motivation for choosing this specific area for the final project was two-fold. Firstly, the team wanted to design a robot that would be able to solve a common problem encountered by many people, thereby improving the quality of life of the average person. Secondly, the team wanted the robot to not simply be a one-off robot, but rather something that could be used by others to learn, as well as continue to be improved by others long after the senior design class has concluded.

In order to meet the first motivation, the team identified the problem introduced in the problem statement as a good candidate for a project. Solving that problem would increase the enjoyment of a leisure activity that the average American spends over 2 hours per day doing. This improvement, though small, would be akin to using a television with versus without a television remote. It is still perfectly possible to watch and enjoy the entertainment without a television remote, but there is always a small annoyance when having to change the channel. Similarly, it is perfectly possible to watch and enjoy the entertainment while having to stand and retrieve snacks, but in an ideal situation, to maximize enjoyment, the snacks would magically appear in the humans mouth whenever they wanted to eat. In reality, however, the closest humans have come to this is having a servant place the snacks in their mouth when they desire. This, however effective a solution to the problem it may be, is unrealistic from a monetary and moral standpoint for the average American. The need to solve this repetitive task that humans do not want to do, provides the motivation to design and build a robot to do it instead.

The second motivation came about from the team's desire to create a project that will not simply be a senior design project, but will be accessible to others in the future. The team determined that the best way to address this was to design the robot with the goal of reproducibility in mind. One of the easiest and most accessible ways to create a basic robot is through 3D printing, with over half a million 3D printers sold in 2018, and a projected year over year growth of 80 % [2]. Thus, the team determined that in order to fulfill this motivation, creating a robot with a mechanical design based on 3D printable parts was the clear way forward. This was cheaper and more accessible to the average person than a machined wood or metal design, and was robust enough to do what it was supposed to, unlike a paper design.

3 Scope and Key Contributions

The scope of this project shall be to solve the problem of getting snacks to humans on command, while the human continues to watch television. The robot designed for this purpose shall be designed such that it can be created with 3D printers, making the project inexpensive and accessible to the largest number of people possible. In addition to the main mechanism of the robot being 3D printed, all other parts should be easily and inexpensively attainable. For example, the delivery mechanism and supporting electronics should be widely available. The robot must also be designed to operate such that it will have minimal interference with the human's entertainment while in use, similar to a friend tossing the human a snack when the human requests it. In order for the human to be able to eat the snack without touching it and getting their hands dirty, robot must be able to deliver snacks directly to the human's mouth, while at the same time being far enough away from the human in order to not obstruct the human's viewing. The robot must also be able to deliver one snack at a time, repeatedly, so that the human can receive one snack after another while continuing to enjoy their entertainment. In keeping with the requirement to deliver a snack that the human can eat without handling said snack, the robot must be able to identify where the human's face is relative to the robot, and determine a viable way to deliver its snack to the human. In essence, the robot being designed should be able to deliver the same effect as a friend tossing a human a snack, and the human catching it in their mouth and consuming it.

The robot is designed to improve on existing snack and delivery beverage systems, while being more inexpensive and accessible. This solution will involve 4 parts: facial detection, distance determination, trajectory determination, and snack launching. The first contribution of the project is to add an increased level of sensing and autonomy compared to the robots already in this space. This means building the robot to be able to determine its target and its required state to deliver the snack to that target, and then performing the delivery, without any input from the human, apart from the initial request for a snack. In order to do this, the robot will use facial detection and LiDAR sensors to find the human's face, and find the distance between the human's face and the robot itself. Developing facial detection will not be in the scope of this project. There are already options for facial detection that can be used that are already in existence, and one of these options will be used. The main reason behind this is that the key contributions to this project to not include developing a facial detection algorithm, and due to time constraints, it was deemed prudent to integrate an existing solution into the robot's design.

The second key contribution of the robot is that the mechanism will be 3D printable, to improve accessibility to others. This will allow others with an interest in robots to replicate our design in order to learn more about the design and building of robotics. Additionally, this robot's accessibility means that it can be improved upon by others in the future. 3D printing the design also allows the robot to be constructed for less than the cost of the currently available robots in this project space [3].

The launching of multiple different kinds of snacks will be an objective of this project. Due to time and budget constraints, the mechanism will be designed to launch only one type of snack: Lemonheads hard candy. This means that having a robot that can shoot several different types of snacks is not one of the key contributions. The reasoning behind this is that the main focus of this project is to not to design and build a robot that delivers a wide breadth of snacks to a human, but rather the focus is to design and build a robot that delivers a snack in better, more autonomous way than any previous solution to this problem. Once the main design is created, this launching on multiple types of snacks is left to future development by others.

4 Detail Context and Related Work

4.1 Overview

Though this project will be an advancement on all other current solutions in the project space, the idea to launch a food or beverage into a waiting human's mouth or hand is not a new one. Here, currently available solutions and their drawbacks will be discussed in order to introduce the reader to the current state of the project space. Additionally, the work and research related to Team's Buffalo's solution will also be presented and discussed.

4.2 Related Work

A current solution in this project space that is actually be marketed and sold as a complete project is known as the Cooler Cannon [3]. This solution is designed to launch a car from a beverage container to the waiting human when given the command to launch. This, however, is not a complete solution to the problem. The main limitation is that it does not do any sensing of its own, and every launch happens at a fixed angle and fixed velocity. That means that unless the human is sitting directly in front of the device, at a distance safe enough that they won't be injured by a launching canned beverage, but not so far that the beverage's trajectory will fall short, the device will not successfully deliver the beverage to the human. This, clearly, is a problem, as humans change positions while watching entertainment, often from sitting up to lying down, and having to re-orient the device each time the human changes position defeats the purpose of the device entirely.

Another solution in this project space is known as PersonalBeerRobot [4]. This is designed to launch a canned beverage to the human when called upon. It has the ability for the human to aim where the beverage is to be launched, meaning that it is an improvement over the Cooler Cannon solution discussed above, however, the aiming takes about 5 to 10 seconds, and the launch power and launch angle is not adjustable, so only the direction can be changed. This creates several problems. Firstly, with the time and effort that it takes to aim the launcher, the human is still distracted from their entertainment. This solution also faces the same problems as the previous solution, where the launch power and angle are not adjustable, so it is not a viable solution unless the human is sitting at exactly the perfect distances away from the robot.

4.3 Safety

Both of these solutions bring up safety concerns when humans are interacting with the respective robots, receiving their beverages from them. The launch angle and power cannot be altered, meaning that an inexperienced user could be injured if they are standing too close to the device, or if they do not know what angle to expect the beverage to arrive at. Furthermore, the robots are completely human controlled. This means that an error by the human when giving the command to launch could lead to themselves or another human being hit with the item if they are in the item's trajectory, since the the robot has no sensing abilities and blindly executes whatever action the human tells it to. These problems bring up the need for a robot that can safely launch a snack to a human anywhere in the room. This means the robot must have the ability to sense a human on its own, adjust its power and launch angle in order to give the best trajectory for the human, and then launch the snack after re-checking that the launch path is clear. It should be noted that the best trajectory would be considered the trajectory that minimizes the launch velocity, making it the easiest for a human to receive.

4.4 Launch Method

In determining the type of launch mechanism to use, several were considered. All were variations on an impulse launcher, as trying to launch the snack simply with gravity would not provide enough force, and launching it via a reaction (such as a rocket) is not feasible for such a small item. The decision then came down to deciding how the impulse was going to be applied to the item [5]. The criteria for deciding was the need for a variable launch velocity that can be finely adjusted, the need to provide enough sufficient launch power, and the need to be feasibly created on a 3D printer given the time and budgetary constraints of the project.

The first type of launcher that was considered was a catapult. The main problems with this launcher were concerns over the ability to finely control the launch velocity, as well as the mechanical implementation, specifically, the problem of having to draw back the catapult and then detach from it in order for it to fire. This detaching was necessary, otherwise the motor or other mechanism that was used to draw back the catapult would introduce a resistance into the launching system. The mechanism required to draw back the catapult, detach, and then reattach after launch was an area of concern, particularly because the team does not have a lot of mechanical design experience, and therefore this method was not chosen.

The second type considered was a pneumatic launch system. This system would be able to easily provide enough force to launch the item. Additionally, once a way to regulate the pressure was designed, the system would be very fine tune-able, as specific launch velocities could be mapped to specific amounts of pressure [6]. However, it was determined that to produce a pneumatic launcher would require a lot of parts that were both costly and could not be 3D printed, such as an air compressor and variable pressure regulator [7]. As a result, it was determined that this type of launcher would not fit the scope of the project and would not meet the key contribution requirements that had been defined.

The third type considered was a friction based launcher, which used contact between a stationary part with its speed electronically controlled, and a moving part, containing the item to be launched, to impart the appropriate impulse. There were concerns with noise due to slippage between the parts, but it was determined that by modeling the system using actual data collected, the noise would be accounted for in the model. Because the impulse was imparted using friction and not a mechanical linkage, there would not be concerns with attaching and detaching linkages in between launches, like there was with the catapult launcher. Ultimately, this approach was deemed the most viable solution.

4.5 Electrical Design

4.5.1 Facial Detection and Aiming

Because of time limitations, and because designing facial detection is not in the project scope, the team will use Open Source Computer Vision Library to help with this component of the robot [8]. OpenCV is a strong tool to do real-time applications which is free for both academic and commercial use. It has a very large human face database which means it can achieve face detection well [8]. Using open CV, the team will apply their methodology to the robot as it is used in a very similar way to great success and simplicity as Techbitar did, which seen in the write-up on Instructables [9]. The challenge in this part is to achieving face detection and aiming over a long distance. This necessitates a good webcam because face detection has minimal pixel requirements. Determined through research, the minimal recommended distance between eyes are 32 pixels for basic detection, but 64 pixels are recommended distance for facial recognition [10]. This means that the higher definition the webcam is, the better the performance will be.

4.5.2 LiDAR Sensor

As the fundamental definition of a robot states, the ability to sense the environment is a must. For the team project, determining the distance between the user and the launcher is one of the major parts since the trajectory calculation requires it as one of the inputs. In order to measure the distance, the first thing needed is to decide on which kind of sensor is most suitable for the project.

There are different kinds of range of sensors available. Ultrasonic sensor and LiDAR sensor are the ones that are frequently used in similar applications. After comparing both sensors, the team decided that a LiDAR sensor is the best fit for the project. There are two main advantages of using LiDAR sensor over the ultrasonic sensor. The first one is that the LiDAR sensor has a faster response time. The way that range sensors measures distance is by sending out a signal to the environment and recording the time that is needed for the signal to bounce back [11]. Since LiDAR sensor uses light as the signal source which travels with the speed of light, the time that is needed for the signal to reach the object and bounce back will be shorter for LiDAR sensor than for the ultrasonic sensor. Since the response time of the LiDAR sensor is short, the main program will not need to pause and wait for the reading from the sensor. Using LiDAR sensor will overall reduce the computational time of the program.

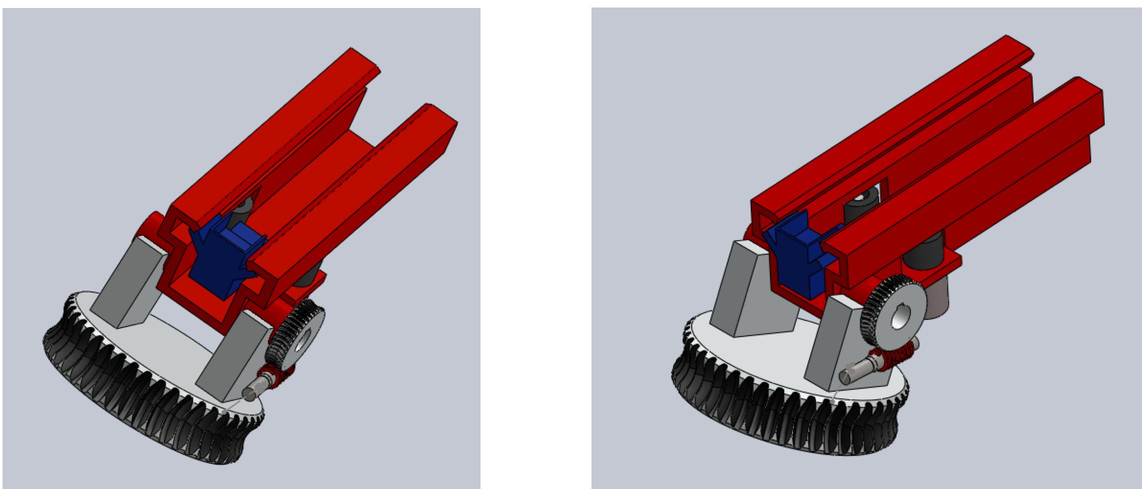
The second advantage of LiDAR sensor is that it has a smaller limitation on the operating environment. LiDAR sensor sends out a light signal at a specific angle and wavelength. In order for the light in the environment to interfere with the sensor, the light will have to enter the photo-detector of the LiDAR sensor with the same angle as the original signal. And only part of that light can enter the photo-detector since the sensor is designed to only receive a specific wavelength of light. The intensity of the interfering light will be lower than the original signal, therefore, the error from it will be negligible [12]. The ultrasonic sensor has a limitation on the operating environment. It is susceptible to temperature fluctuation since the speed of the ultrasonic sound wave depends on temperature [13]. The sensor will need to be re-calibrated if the temperature of the operating environment is different from the testing environment. This lowers the robot's reliability since the user may be in a different area than the testing area.

5 Task Breakdown and Team Solution

5.1 Mechanical Design

5.1.1 Overview

The mechanical design of the robot solution can be seen in fig. 1, in the 3D CAD prototype design. It is designed such that the base upon which the entire mechanism rests can rotate in the phi direction, and launch rail can be rotated in the theta direction when looking at the actuation in spherical coordinates. The launcher is designed to load and launch 1 snack at a time to the human once the launch angles and launch velocity have been determined by the robot's other systems.



(a) Rear View (b) Side View

Figure 1: 3D CAD Prototype of Launcher

5.1.2 Snack Loader

Due to budget limitations, the team decided to only design the robot to launch one type of snack. Lemonhead candies were chosen, as they are a consistent spherical size and are uniform in weight, which means the trajectory can be determined by kinematic equations. They will be stored in a 3D printed container above the launcher, and will be dispensed one a time by a servo controlled corkscrew mechanism. The team understands that individually loading these snacks may result in jamming and drops. Since the robot is being 3D printed, the design can be modified throughout the quarter if the first prototype does not function as intended. The problem of dropping can be mitigated by the fact the hopper containing the snacks and loading device will be placed above the launch cart, where the snacks are meant to be loaded. This way, in the event of a drop or slight loading error, the snack should still fall into the snack receptacle in the launch cart. Jamming is a concern, however the design of a rotating corkscrew is chosen because it is simple, requiring only 1 servo, and it is commonly used in vending machines. Therefore, the problem of jamming, if it occurs, can be solved with slight modifications to the design until it is optimized to handle the snack of choice.

5.1.3 Launcher

The launch cart will sit at the end of the rail whenever it is not in the action of being launched. The way this launch cart will be accelerated down the track is through contact with friction wheels. These wheels will be placed one on either side of the launch car, such that when the launch cart is resting at its normal position at the end of the track, the wheels will be just short of making contact with the side of the launch cart. The reasoning for this is that once the necessary angular velocity of the wheels for the desired trajectory is determined, the wheels must be spun up to that speed without making contact with the launch cart before they reach that speed. The launch wheels will be spaced such that one wheel makes contact with one side of the launch cart, and one wheel makes contact with the other side, and they exert a large enough normal force such that there will be no slippage between the wheels and the launch cart during launch. The mechanism will be designed such that the spacing can be adjusted, and this exact spacing will be determined experimentally. In order to have the launch cart make contact with the wheels once they are up to speed, a method was needed that could be electronically controlled, but was not physically linked to the launch cart, as any physical linkage would introduce unwanted friction into the system. The way this achieved in the design is by having a permanent magnet attached to the launch cart, and an electromagnet at the end of the rail. Once the wheels are spun up to the appropriate speed and it is time to launch, the electromagnet will be turned on by the microcontroller, and the magnet repulsion will generate enough force to push the launch cart into the wheels, which will accelerate it down the launch rail.

It should be made clear at this point that the method of propulsion is not the magnet repulsion between the permanent magnet on the launch cart and the electromagnet. The purpose of that magnet repulsion is simply to push the launch cart into the spinning wheels. These spinning wheels will be what provide the impulse that accelerates the launch cart. After the launch cart has been accelerated down the track, it will stop when it hits the stop at end of the track, but the snack resting on the launch cart will keep moving, as it is unconstrained in the forward direction, on its trajectory toward the human. When the launch car hits the stop, it will push a bump switch, sending a signal to the microcontroller to make the wheels stop spinning. Then gravity will return the launch cart to its normal resting position, ready to be loaded again.

In order to allow the human to get a snack without interrupting their entertainment, they must be able to give the robot a signal that they want a snack. The solution is a simple IR remote, which the human will use to send a signal to the robot to give the command to launch. This will allow the human to request a snack as easily as changing the channel on a television, without leaving their comfortable seated position.

5.1.4 Rotation

The rotation of the base is required to be very precise, while utilizing a small motor to move the relatively large mass of the entire mechanical mechanism. Additionally, the rotation of the launch rail requires a significant amount of torque, as the motors that will turn the launch wheels, as seen in the 3D CAD, are mounted to this rail, meaning they will impart a moment on the rail that must be overcome with the motor that is rotating the launch rail to the correct angle and then holding it there. In order to solve the problem of rotation, the design uses worm gears, which create a large reduction, allowing for increased torque and slower speed when making fine adjustments [14]. Turning these worm drives will be stepper motors. The reasoning behind using stepper motors over dc motors is that stepper motors move in discrete steps, allowing for discrete adjustment in the rotation angles, which, when combined with the large reduction of the worm gear, will allow for very small, discrete, angle adjustments [15]. Additionally, the nature of stepper motors that allows small, discrete movements also means that they are good at holding a fixed position while drawing a small amount of current. This is particularly useful considering the launch rail has to be held in place in order to correctly launch.

5.1.5 Response to Concerns

Concerns about the design of the robot will now be addressed. This design uses lemonheads as its snack, because, as mentioned in key contributions, the solution is intended to show the viability of a launcher that, when it receives the command to launch, will automatically detect where the human is and launch a snack to the human. In the future, if someone desires to launch a different type of snack, they can use this design as a base. By slightly modifying and, if necessary, appropriately scaling the overall size of the launcher for a heavier or larger snack, the core of the robot, meaning the facial detection, orientation, and launching capabilities, can be used to launch any type snack. Besides the loading mechanism, which may require modification to be able to handle different types of snacks, the robot can be used to launch any general snack desired.

As discussed in the section on Related Work, research into different launching mechanisms was done, and it was concluded that the use of friction wheels was the most viable solution that fell within the scope of the project. Additionally, as mentioned previously in this section, the launch impulse will be provided with the friction wheels, the small magnetic impulse is only to push the cart into the friction wheels. In addressing safety concerns, it is understood that the human catching the snack in their mouth can be a cause for concern. This solution relies on the user understanding what catching a snack in their mouth entails and knowing if they are able and willing to take the small risk of having the snack possibly miss their mouth and land on them. Even if this were to happen, there is virtually no risk on serious injury given the snack that is being used. In the event that the user does not feel comfortable catching the snack in their mouth, they can always catch it in their hand and then eat it, however they must understand that they then are taking the risk of getting their hands sticky as a result of handling the food. Additionally, the overall design of the robot adds an element of safety; the robot can "see" for itself and determine where to shoot, and more importantly, at what angle and speed to shoot. This eliminates the largest safety risk in a device of this type, which is a user being too close to the robot and having the snack be fired at too high a velocity relative to their distance from the robot.

5.2 Electrical Design

5.2.1 Facial Detection and Aiming

For our project, the robot should be able to find out the location of the human to which it is shooting the snack. This means face detection and aiming will be very necessary. In the team's plan, a webcam will be connected to a computer through USB cable instead of using wireless methods. Thus the video caught by the webcam can be transmitted to computer quickly and directly. Once receiving the data, the program will start working and doing analysis on the video, trying to find the human's facial characteristics. Once the program finds the facial characteristics, it can be assumed that a human face has been detected. Based on this detected face, the program will continue to simulate a circle around this face and calculate the center of circle, representing in (x, y) position form. This will be stored as the goal point. Then the program will being comparing the current aiming point with goal point and generate out the actions needed for moving the webcam, and by extension, the launcher. Next, the computer will send these commands to Arduino and the motors will start to move the current aiming point close to the goal point. The computer will repeat these actions until the distance between the current point and goal point is acceptably small. After aiming is finished, the robot will move on to determining the distance.

5.2.2 LiDAR Sensor

Although the LiDAR sensor is suitable for this project, there are still two challenges that need to be overcome. The first one is that the LiDAR sensor is sensitive to angular changes. From the paperbot lab, the robot changing one degree of a heading angle results in few centimeters of LiDAR reading difference. Clearly, the paperbot lab showed that the LiDAR sensor is susceptible to angular change [16]. This problem will scale up for the team's project since the robot will need to measure a distance of several meters. The team's solution to this problem is done in the robot's mechanical design where it utilizes a worm drive to control the robot's rotational movements. The worm drive is a gear reduction device that allows the robot to make small amounts of angular changes that result in a more precise rotational movement. This allows the LiDAR sensor to accurately measure across the space. A detailed description of the worm drive will be discussed on the launcher design section. The second challenge is that the maximum range of the LiDAR sensor will vary based on the object surface. For the first part of the paperbot lab, the model of the LiDAR sensor was required. From reading through the datasheet of the LiDAR sensor that was used for the lab, the maximum range of the LiDAR is tested with either a white or a grey surface [17]. For this project, the LiDAR sensor will point to a human face. Therefore, the LiDAR sensor's maximum range will change. The solution to this problem is to test the LiDAR sensor through experiments on a human face and model the sensor based on that data. Several tasks need to be accomplished, the first being picking the appropriate LiDAR sensor that has the maximum range stated as double that of the planned operational range of the robot to ensure it can operate within the operating environment. This will be at most ten meters. Then the next task will be testing the LiDAR sensor experimentally on a human face with different distances and angles and record the data. With the data from the experiment, the team will create a mathematical model that can represent the LiDAR characteristics. Next, the model will be verified through another set of experiments. After the launcher finished being assembled, the team will mount the LiDAR sensor onto the launcher and test if the mathematical model still holds for the situation.

6 Weekly Milestones and Challenges

<table>
<tr><td rowspan="8">Week 1</td><td>Goal</td></tr>
<tr><td>Have a finalized mechanical design
Electrical sensors specified</td></tr>
<tr><td>Task</td></tr>
<tr><td>Complete conceptual design of entire mechanical mechanism
CAD design of mechanism
List requirements for both LiDAR sensor and webcam, particularly performance and cost requirements
Find all options for each sensor that meet the requirements
Use a decision matrix for each sensor to decide which option is best</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>Creating a viable snack loading mechanism
Finding sensors that are within budget and meet the performance requirement</td></tr>
<tr><td>Deliverable [points]</td></tr>
<tr><td>Completed 3D CAD model [5]
Electrical sensors bill of materials [5]</td></tr>
</table>

Table 1: Week 1 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 2</td><td>Goal</td></tr>
<tr><td>Determine the distance to an object using LiDAR sensor</td></tr>
<tr><td>Task</td></tr>
<tr><td>Use the LiDAR sensor to measure the distance between the human face and the sensor with various distances and angles
Plot the data using Excel/Matlab to graphically obtain the mathematical model
Verify the model by testing random distances and compare the experimental distance produced by the mathematical model with a theoretical value measured by a retractable metal ruler</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>Obtaining accurate reading from a human face</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>A graph that plots the distance from LiDAR model vs actual distances [10]</td></tr>
</table>

Table 2: Week 2 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 3</td><td>Goal</td></tr>
<tr><td>Detect a face and find the center point
Decide on all necessary motors and motor drivers</td></tr>
<tr><td>Task</td></tr>
<tr><td>Install driver of webcam to make sure the webcam can catch video successfully
With the help of the OpenCV library, the computer can run the program and find out face properly
Calculate the required motor power for all motors in the robot (base and launch rail actuation, snack loader, and launch wheel motors)
Using motion study in Solidworks, verify hand calculators of required motor power
Find potential options for motors and drivers
Use a decision matrix to decide on option to order for each motor needed</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>Detecting multiple faces
Finding motors and drivers that are within budget and meet the performance requirement</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>Demonstrate with a video the webcam detecting a face, and displaying a circle around it and a red point at the center of the circle [5]
Bill of materials of motors and motor drivers [5]</td></tr>
</table>

Table 3: Week 3 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 4</td><td>Goal</td></tr>
<tr><td>Be able to find trajectories for any distance
Control the speed of the robot's motors</td></tr>
<tr><td>Task</td></tr>
<tr><td>Determine the correct trajectory equation to use
Write a program in Arduino that calculates the slowest trajectory whose height does not exceed the maximum height
Program should take distance as the input, and output the launch angle and launch velocity required
Wire motors and motor drivers, and wire Arduino to motor drivers
Write a program on the Arduino that takes motor angular velocity as the input and can spin the motors at the given angular velocity</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>Be able to find optimal trajectory given a distance
Having robust communication between Arduino and the motor driver</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>Demonstrate live that the Arduino program can calculate the trajectory requirements when given a distance as input [5]
Demonstrate that the motors can be spun at any desired RPM input [5]</td></tr>
</table>

Table 4: Week 4 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 5</td><td>Goal</td></tr>
<tr><td>To have a completed 3D printed mechanism</td></tr>
<tr><td>Task</td></tr>
<tr><td>Convert 3D file to .STL file
Take each individual piece to makerspace in Boelter Hall to be printed
Inspect print quality, adjust design if necessary
Assemble the completed 3D printed assembly
Spec and order IR detector and IR emitter
Wire IR emitter to send a signal when a button is pushed
Write code on Ardino to turn on an LED when it gets signal from emitter (LED will show that signal was detected and it is working)</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>Make sure gears mesh smoothly
Make sure there is no obstruction in the sliding mechanism due to material choice</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>Bring and show the 3D printed mechanical assembly [5]
A working IR remote that can light up LED connected to Arduino [5]</td></tr>
</table>

Table 5: Week 5 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 6</td><td>Goal</td></tr>
<tr><td>Measure distance between the launcher and the wall in front of it</td></tr>
<tr><td>Task</td></tr>
<tr><td>Mount the LiDAR sensor onto the launcher
Collect data from the LiDAR sensor with it mounted on the launcher
Compares the result from the model to the actual distance. If the model doesn't fit, repeat the experiment from week 2 and come up with a mathematical model that fits the current setup</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>As the launcher moves, LiDAR sensor must consistently output accurate reading</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>Datasheet of the result from the mathematical model and the actual distance measured. If the model doesn't match, the deliverable will be a graph that represents the mathematical model along with the datasheet of the experiment [10]</td></tr>
</table>

Table 6: Week 6 Milestones and Demonstration Goals

Week 7	Goal
	• Move launcher using information obtained from webcam • Launch snacks the required distance, not necessarily to a specific place
	Task
	• Webcam should be mounted onto the launcher • Code should be able to generate the necessary actions and send it to Arduino • Arduino should be programmed to be able to rotate webcam to desired target • The computer will be allowed to detect a photo. Once that photo is detected, the photo will be slowly moved. The webcam should follow the photo when the photo moves • Attach motors to launch wheels, base, and launch rail • Attach electromagnet to assembly • Write Arduino Code to spin up the motors to the correct point • Place snack in launch cart by hand • Spin up motors with Arduino, and activate electromagnet with Arduino to launch snack
	Challenge
	• The snacks launched distance should be within 5 % error relative to desired distance
	Deliverable
	• Show a video of webcam tracking dynamic photo [5] • Demonstrate the launching of snacks without jamming or a structural failure of launcher [5]

Table 7: Week 7 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 8</td><td>Goal</td></tr>
<tr><td>Launch a snack to a desired location
Have a working snack-loading mechanism</td></tr>
<tr><td>Task</td></tr>
<tr><td>Set up 3D printed loader mechanism, including servo motor and corkscrew
Be able to move servo with arduino to dispense 1 snack
Assemble loader mechanism onto launcher
Write code on Arduino be able to load a snack, spin up launch wheels to desired speed, turn on electromagnet to push launch cart into wheels
Measure distance of launch
Try several distances, determine maximum feasible launch
Collect data on how launch parameters (launch angle and launch wheel speed) relate to actual launch distance
Verify trajectory model</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>The snack landing position should be within 5 % error relative to desired location</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>Demonstrate that Launcher can load and launch a snack a desired distance [10]</td></tr>
</table>

Table 8: Week 8 Milestones and Demonstration Goals

<table>
<tr><td rowspan="8">Week 9</td><td>Goal</td></tr>
<tr><td>Find the distance between the robot and a face located within 2 meters of the robot</td></tr>
<tr><td>Task</td></tr>
<tr><td>Detect the face within the room with the webcam
Robot should align itself using the previously shown ability to orient itself towards a face
Once orientation is achieved, the Arduino Code should take the distance measurement from the LiDAR sensor
The LiDAR sensor model should be used to determine the distance, and distance should be outputted by Arduino
Check the measured distance with actual distance to confirm that the setup is working properly</td></tr>
<tr><td>Challenge</td></tr>
<tr><td>The measured distance must be within 5 % error relative to actual distance</td></tr>
<tr><td>Deliverable</td></tr>
<tr><td>A table that compares actual distance of the human face from the robot to the distance measured by the sensor
A graph that graphs that percent error in the distance determination versus the distance</td></tr>
</table>

Table 9: Week 9 Milestones and Demonstration Goals

Week 10	Goal	• Detect a huan face and launch a snack to the face on command
	Task	• Integrate mechanism and sensor • Test as many scenarios as possible to determine if there any short-comings • Outline final report • Demo on the final day
	Challenge	• Repeated successful launches of snack from robot to human
	Deliverable	• A working snack launching robot - YaoGuai • Outline of Final report

Table 10: Week 10 Milestones and Demonstration Goals

7 Conclusions

The team's project provides not only engineering value, but also educational and commercial value. This project serves as excellent hands-on experience for beginners that are interested in the field of robotics and circuitry since all of the mechanical parts of the robot are pre-designed. From an educator's standpoint, it is effortless to integrate this project into the school's robotics and circuitry course since most of the mechanical parts are 3-D printable, along with the low cost of other parts of the robot. From a consumer standpoint, the project improves the quality of life of the user as it allows the user to focus on their work or entertainment while having snacks. The team's design takes the user's safety into consideration and has a lower cost, making it a safer and more accessible compared to similar products currently available. With a longer development time and a higher budget available, the team's design can be improved to be capable of shooting many different types of snacks. In the future, the team aspires to encourage people to improve this conceptual design so that it can be integrated into society as a legitimate consumer product.

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