Cost Effective Robotic Arm

Background

- Many small businesses employ workers to perform tedious, repetitive tasks for long periods of time, which can cause joint pain.
- Businesses must hire humans to complete repetitive and tedious tasks, which is not very efficient.
- Small businesses cannot afford current industrial robotic arms, which cost between $5,000 and $60,000.

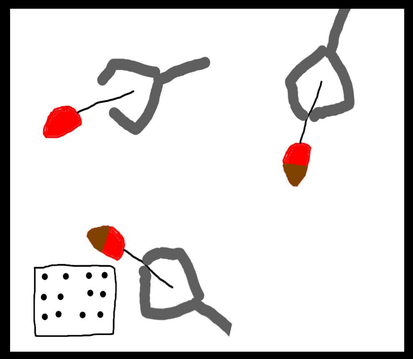
Criteria:

1. Accuracy: The robotic arm should be accurate so that it can complete the tasks properly. This will be determined by the ability of the arm to pick the strawberry up from a specific starting location and place the strawberry in another specific ending location.
2. Consistency: The robotic arm should be consistent in its ability to complete the task repeatedly. This will be determined by the ability of the robotic arm to successfully dip the strawberry in the chocolate each time.
3. Efficiency: The robotic arm should be efficient so that it is worth using in the workplace environment. Therefore, the time it takes to complete the process will be measured, and this will be compared against the time it takes for a human worker to complete the task.

Decision Matrix:

Criteria	Max Points	Design A	Design B	Design C	Design D
1. Can accurately pick skewer from location	105	10	9	9	9
2. Can accurately place skewer in tray	10	9	8	9	9
3. Can consistently perform the same motions	9	7	9	7	8
4. Can dip strawberry with consistent layer of chocolate	7	6	6	6	6
5. Easily adaptable to a variety of tasks	6	1	6	5	5
6. Must Cost less than $500 to manufacture	8	6	2	8	5
Total	50	34	40	44	42
Percent	100%	68%	80%	88%	84%

1. Design A: Conveyor belt style assembly line that places the strawberries and skewers on a conveyor belt, and then lets them run into the chocolate and onto a tray.
2. Design B: LEGO prototype of the arm, with LEGO Mindstorm and EV3 components to operate it. This design was a 3 DOF arm made with LEGO Technic pieces.
3. Design C: 3D printed 5 DOF arm controlled by an Arduino Uno and Servo motors
4. Design D: Metal arm with an aluminum skeleton and powerful servo motors.



A graphical abstract showing the picking, dipping, and placing process of the arm,

Problem statement: Many small businesses employ workers to perform tedious, repetitive tasks for long periods at a time. This is not cost effective or efficient for the business. Additionally, workers can also develop joint pains due to the repetitive motion.

Engineering goal: The aim is to design a cost-effective robot that can dip fruits consistently and accurately. The initial robotic arm will focus on consistently dipping strawberries into chocolate and accurately placing them in a tray. The goal is that the final product will cost less than $500 per unit to manufacture.

Testing

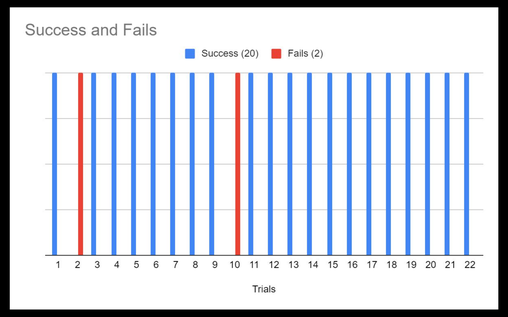
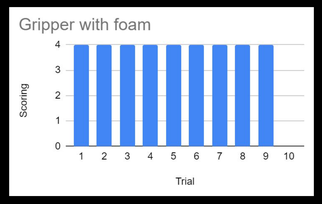


Figure 1: Accuracy and consistency test for the final arm. The arm was able to pick and place the strawberry 90.91% of the time.

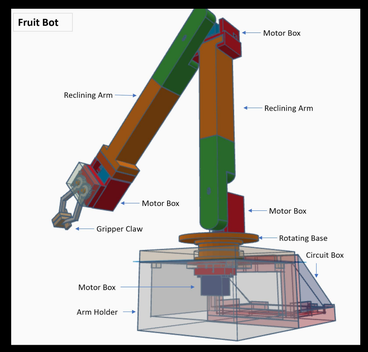


Foam gripper: This gripper was designed using foam as it squeezes the skewer and scrunches around it providing friction and a tight grip preventing the skewer from slipping and falling. The design had an average score of 3.6 and was able to hold the skewer consistently. This was the best design due to the high score.

Data Summary

Groups	N	∑x	Mean	∑x²	Std. Dev.
Group 1	10	20	2	80	2.1082
Group 2	10	22	2.2	74	1.6865
Group 3	10	24	2.4	96	2.0656
Group 4	10	9	0.9	21	1.1972
Group 5	10	36	3.6	144	1.2649
Total	**50**	**111**	**2.22**	**415**	

The Anova test for comparing the 5 different materials: LEGOs, LEGO H-connectors, rubber bands, LEGO tires, and foam. The means and standard deviation were compared, with foam being the best material.



Methodology:

The arm was fed a playdough strawberry. It then moved through the movements of picking, dipping, removing excess chocolate by shaking, and finally placing the strawberry in a specific location.

5. Angled Gripper

Trial	Scoring
1	2
2	3
3	2
4	3
5	3
6	3
7	2
8	3
9	3
10	2

Angled gripper: The angled gripper was designed to reduce the space between the grippers to ensure equal gripping ability in both the front and back of the gripper. This ensures consistency and accuracy. This gripper had the highest mean and was the most successful 3D printed gripper.

Data Summary

Groups	N	∑x	Mean	∑x²	Std. Dev.
Group 1	10	22	2.2	50	0.4216
Group 2	10	0	0	0	0
Group 3	10	22	2.2	56	0.9189
Group 4	10	26	2.6	70	0.5164
Total	**40**	**70**	**1.75**	**176**	

The Anova test for comparing 4 different grippers. Group 1 was the LEGO gripper as a control. Group 2 failed to work, and it was found that group 4 (the angled gripper) was the best design to increase accuracy and consistancy.

Existing Models

- Existing models are available in a range of prices.
  - Four-axis robotic arms start at $5,000 while six-axis robotic arms start at $15,000, and can cost up to $60,000 (Universal) (UFACTORY).
  - These models are expensive as they are designed to safely lift heavy objects, which my model does not need to do.
  - In order to be more cost-effective, my robotic arm will sacrifice heavy lifting in exchange for affordable prices.

Future Extensions:

Future extensions of the robotic arm include features like sensors and remote capability:

- Laser distance sensor to increase the accuracy of the arm's movements (Lattanzi et al., 2012).
- Remote control of the robotic arm to allow for more efficient operation (Rahman et al., 2019).

Other applications of the robotic arm include:

- Pick and place in warehouse and manufacturing setting.
- Sorting items in warehouse.
- Self-service in stores.

Goal:

- The goal was to design and construct a cost-effective robotic arm.
- The arm would need to accurately pick and place strawberries, and dip them in chocolate.

Method:

- A prototype of the arm was made with LEGO Mindstorm and LEGO Technic pieces, controlled by a LEGO EV3 brick.
- This arm was built to test the overall shape of the arm, as well as to test what gripper materials best worked for the robotic arm to pick up the strawberry.
- The result of this test was that foam provided the most friction and was soft enough to consistently hold the strawberry.
- Different claw types were tested to see if the shape had an impact on the arm's ability to grab.

Findings:

- It was found that an angled gripper had the highest accuracy and consistency for picking the strawberry.
- A final arm was made with 3D printed pieces and servo motors, controlled by an Arduino Uno.
- The final arm was tested to pick up and place the strawberry, as well as complete a dipping motion. The final arm had an accuracy of being able to pick and place the strawberry 90.91% of the time.
- The cost of the arm is less than $500 and the successful runs show that the arm can move on to the next steps of testing it in a business environment.