

Autonomous Cold Salad Bar

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Project Proposal for ECE 445, Senior Design, Spring 2026
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13 February 2026
Project No. 42

Abstract

This report serves as a project proposal for an autonomous cold salad bar. The project aims to utilize Servos, Steppers, ESP32-S3 MCU, and an LCD display among other components to create an automated food dispensing system, which aims to help increase the speed and efficiency of food service in assembly line systems. We have described in detail the design process of each subsystem which involves the specific method in which different food substances will be released. This also involves the pseudocode for the entire system and how to interact with the drivers for each motor.

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1. Introduction

In the food industry, a huge number of processes are extremely rote and utilize manpower on monotonic tasks that can be replaced by an autonomous system. One such problem is the usage of manpower in assembly-line format restaurants(eg, Chipotle, Forage Kitchen, Qdoba, etc.). Just as in the automation industry, where the assembly line is, in essence, replaced by 6-DoF arms and robot operators, we believe the manpower in restaurants can also be replaced by a robotic system that can provide higher efficiency. We have already seen a large number of processes getting automated in the restaurant industry, such as the automated food bar in sushi restaurants and robotic servers.

At the outset, we would like to mention that the solution does not aim to automate the entire pipeline from creating the dish to serving it. To perform highly technical dishes is a different problem in itself. We aim to make the serving process more efficient and reduce wait time.

In our system, each ingredient will have its own pipe that dispenses one specific type of dish. Once we receive instructions of what food needs to be prepared and the number of ingredients it needs to dispense and in which order, the bowl on a conveyor belt will move back and forth to fill up with those ingredients. These ingredients are funneled from their own pipes that dispense the ingredients, one at a time. The final box will have all the ingredients, and it is served at the end.

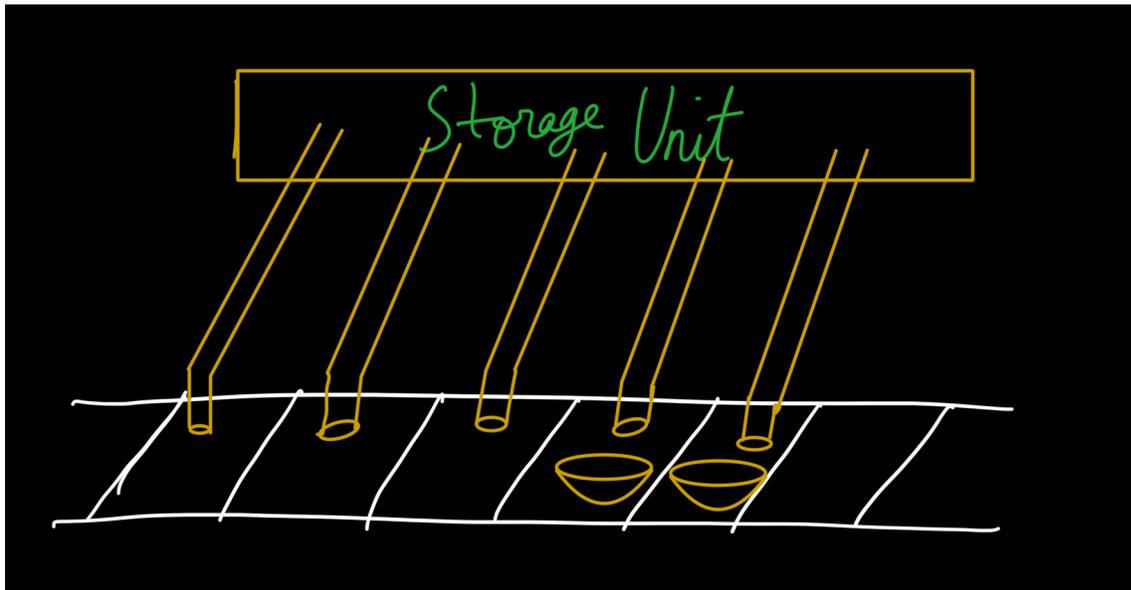


Figure 1 Visual of what we expect the final product to look like

The following are quantitative characteristics that our project should exhibit to solve the problem. The system should be able to dispense at least 3 ingredients with precision. For example, if we wanted to add beans, water, and ketchup, they should be dispensed into the bowl, and exactly 50 grams of each ingredient should be dispensed. The conveyor belt should be able to move consistently in a way that the bowl is under the right dispenser. The system should also be able to work consistently.

In this project proposal, we will go over our project design, subsystem descriptions, how we will check if the system works, costs related to the system, and a conclusion. The conclusion will include uncertainties and ethical considerations.

2. Design

The entire system will communicate with I2C, and the motors will communicate with PWM signals. We will run an ESP32-3 MCU to control the various subsystems in this design. We will use a 10V power system to run the entire system and 5v for all of the motors. Each of our systems will require 1-2A from the power system and since it is a direct power supply usage we will not be describing it as a subsystem.

The overall design of this system is as follows:

The user will interact with an LCD display with buttons that have food buttons. Once the food is chosen, a signal is sent to the MCU to start rotating the conveyor and dispensing food. The instructions given to the conveyor belt would be to simply reach a certain pipe stop, wait for a signal from the load cell saying the right amount of food has been dispensed, and move to the next pipe. This process will continue until all the ingredients are added. The food dispensing will be explained in detail below. Once the food is dispensed and weighed, it is ready to be taken by the user.

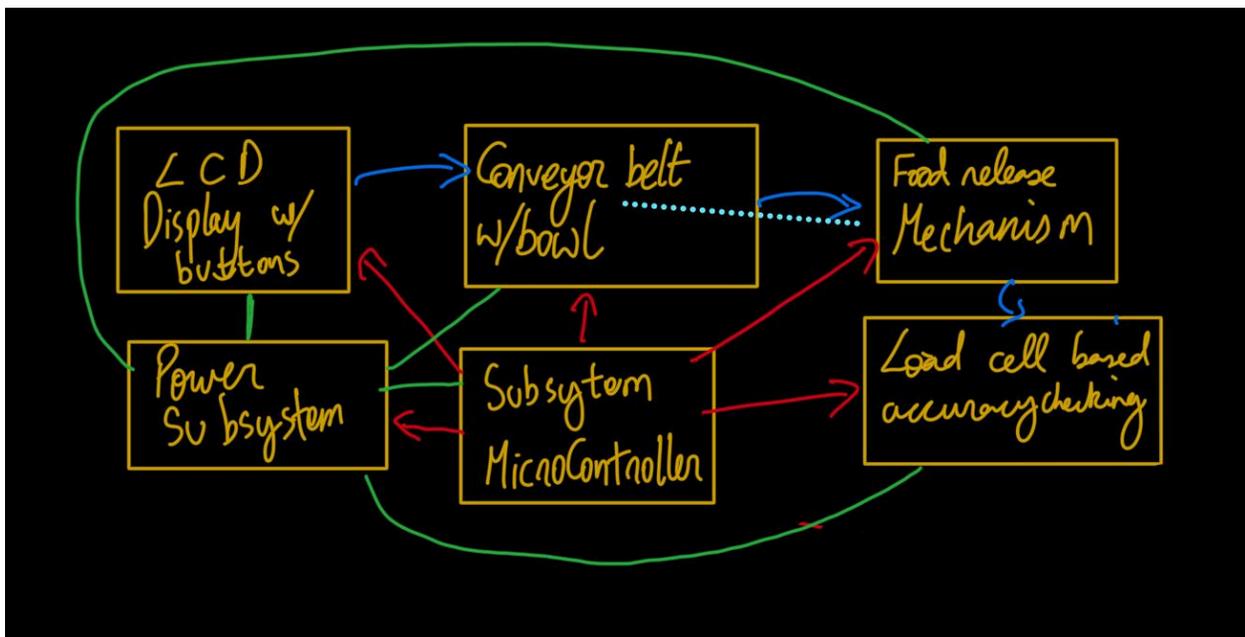


Figure 2 Block Diagram of Subsystem Connection

2.1 Motion and Food Dispensing

The bowl must be moved around the pipes to get filled. This is what we propose:

Conveyor belt: 4 idlers, 2 head pulleys, 1 NEMA 23 motor(or other), 1 gear reducer, 1 motor driver(TB6600)

1 Food storage basket, 5 individual dispensary pipes, 5 servo motors, 1 servo motor PWM controller

The dispensary pipes will be pumping out food using a servo pump filler mechanism, where the servo motor will push down on the contents of the pump (in a piston-like motion) and squeeze out the food. We will use the ESP32 Microcontroller series

The dispensing mechanism for sticky and liquid like substance will work as follows:

We will use a piston-like motion as mentioned above. This would work using a linear actuator. The idea is that the sticky substance will be filled in a syringe-like cylinder and will have a top cover on the cylinder that is attached to a linear actuator. The actuator would move down, pushing the substance out of the cylinder. If the linear actuator is too expensive, a second solution would be to use a stepper motor and a lead screw, which technically performs the same linear motion, and we can buy a NEMA 17 and get a lead screw from the metal shop. This mechanism should also be testable to simply see if the syringe releases the liquid. Also, to prevent dripping, when not in use, we would simply pull the linear actuator back, thus reducing pressure in the air column of the syringe, sucking back the liquid and preventing dripping. This is what I believe is a mechanical solution to the problem. If this solution does not work we will test with an inlet/outlet valve mechanism where there will be a physical blocker when there is no pressure, and the blocker will move when pressure is applied. This will likely resemble the nozzle mechanism in hand-wash dispensers. Where there is no leakage, the same linear actuator idea will be used on the nozzle head.

The dispensing mechanism for food will work as follows:

For demo purposes, the "food" we will be using is beads, because in cold salad bars, we normally have extremely dry foods, and the only sticky substances are sauces for which we have provided a dispensing mechanism. For the bead dispensing, we will have a rectangular pipe filled with beads all pointed downwards. The end of the pipe will be a small opening with a stepper motor-controlled "gate". Imagine it to be a vertical rectangular bead storage with the opening at the bottom looking like a slope, which is closed by a motor-controlled gate. The gate will be opened using a motor that moves slowly and lets the beads out.

The closing mechanism will be described below with the load cell description.

Sample dispensing images and circuitry:

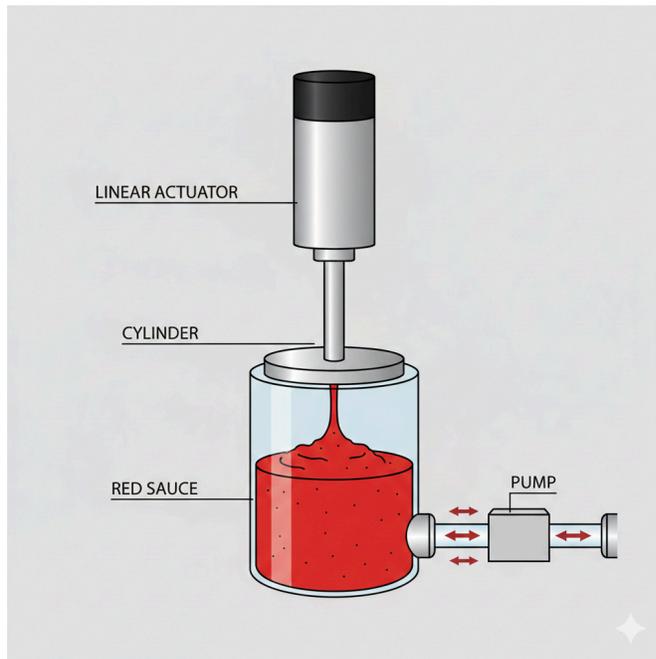


Figure 3 Linear actuator and Sauce setup

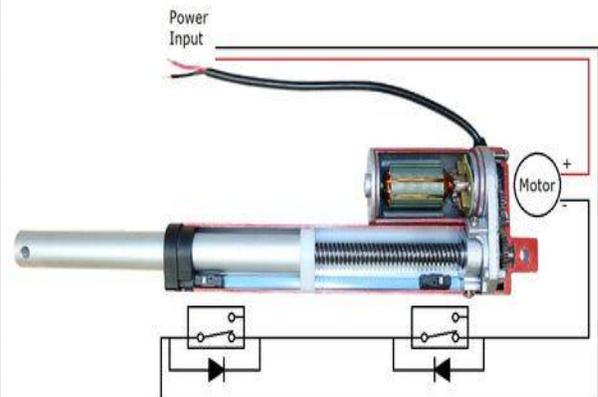


Figure 4 Linear actuator circuitry and setup

2.2 User Interface

For initial testing, simple buttons to determine which dish is chosen. The final device will involve a screen, natural interface. The simple buttons will just be regular tactile buttons. The final screen would be an ST7789 LCD that would show the user what food has been ordered. It will show the user what options they have chosen for their salad and how to add/remove particular items with a button press. Our options on the interface will include 3 different types of salads representing 3 different options: Coleslaw, Taco salad, and Pizza Ranch. Below is an image of what the system would look like.

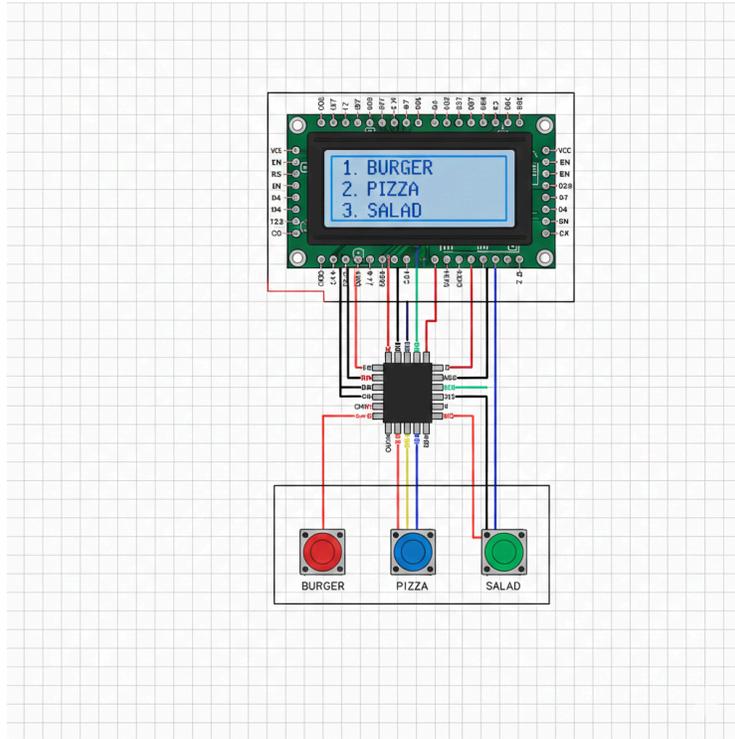


Figure 5 Circuit depiction of User Interface

2.3 Accuracy Checking

A major part of this project is to ensure efficiency. So we will incorporate a weight sensor (mini load cell). This weight sensor will track the weight of the bowl as items are being dispensed, and will serve as a checker to stop the machine from over-dispensing. The weight-sensing mechanism will be as follows. The conveyor belt at all times will have a plate on it. This plate will be attached to a load cell, which gives weight measurements. The bowls will always be placed on the plate, and whenever the belt is stationary, a reading will be taken to check the weight. So when we dispense sauces or beads, the conveyor belt has to be stationary. This then sends a signal to the controller to check the weight as the food is being dispensed. If the weight is reached, the dispensing stops, the motor gate for beads closes, and we wait 5 seconds to see if the weight has stabilized to the right amount. If so, we move to the next pipe; if not, we add some more food. In this way, the load cell won't give us erroneous outputs, and the motor gate will also work efficiently. This is the calibration portion per ingredient. Please note that the motor gate isn't completely opened or closed. It opens up very slightly to allow the beads to fall out until the desired weight is reached. Also note that the amount per ingredient is an arbitrary choice by us, for eg, 100g of rice and 20g of sauce, etc.

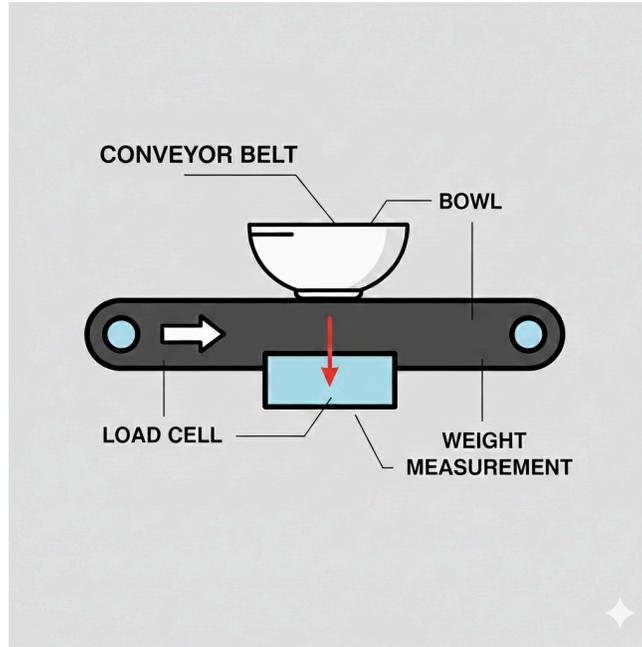


Figure 6 Load cell under conveyor belt

Another main component that we will add is food-safe tubing to ensure that the food does not get contaminated. How we will ensure food safety and cleaning is by having a designated cleaning day. This process will not be autonomous and will involve us cleaning the pipes and tubes. We would do this by simply filling the tubing with an industry-standard chemical disinfectant solution filled with caustic soda, nitric acid, hydrogen peroxide, and peracetic acid. The tubes will run one cycle of dispensing these liquids, and they should be as clean as new. If this doesn't work, the other 2 solutions include manual cleaning and simply replacing the tubes since they are inexpensive(unfortunately wasteful)

The food we will be using for the demo is beads for solid foods and ketchup for sticky sauce.



Figure 7 Bead Drop mechanism

3. Design Verification

Each subsystem has its own verification component.

3.1 User Interface

We will run a 50-pass test to ensure that the switch press is received by the microcontroller and that it turns on the exact subroutine. A 50-pass test is essentially that we will run 50 inputs, one-by-one, and track the rate of error. Normally, we would expect, apart from misinput, an over a 95% accuracy rate. If this is achieved, the system is VERIFIED.

3.2 Motion and Food Dispensing

3.2.1 Conveyor belt accuracy

Once the User Interface test passes, we can then send commands from the button via the MCU to the motors controlling the conveyor belt. The idea is that it follows a pipe order. It will go to pipe a, then pipe b, and so on. We will run a visual check over a 50-pass system. The idea is that for each of the 50 inputs, the conveyor belt will have to move a bowl from one pipe to another, and it has to move it accurately, which is defined as a $\pm 2.5\text{cm}$ tolerance. If this is achieved reliably over the 50-pass test, then the conveyor belt is VERIFIED.

3.2.2 Load-Cell Test

We will use weighted, accurate blocks to test this. We will have multiple different weighted blocks, and once the load cell is attached and the conveyor belt passes its verification, we will check the load cell by adding the weighted blocks. We will measure the weights when the belt is moving and ideal. This will help us understand the extra forces that are in play, like friction and pulley tension, which can lead to erroneous weight measurements. This will help us decide when we should weigh the food. If we can check the load cell performing correct measurements when stationary, that will mean the load cell is VERIFIED.

3.2.3 Linear Actuator Test

Linear actuator ketchup push test

- Fill the syringe/cylinder with ketchup and attach the plunger to the linear actuator.
- Place a bowl/cup on a scale under the nozzle.
- Command the actuator to move down a fixed stroke (or fixed time) to dispense.
- Record: dispensed mass (g) and any stall/jam events.
- Retract the actuator by a small fixed amount (anti-drip pullback) and wait 30–60 s.
- Pass criteria: ketchup dispenses smoothly with no stall, dispensed mass is within your target tolerance across repeated trials (e.g., 20 runs), and no visible dripping during the wait period.

3.2.4 Food Dispensing Test

Bead drop test

- Fill a rectangular box with beads
- Send a command to drop “rice.”
- Record: The mass of beads dispensed and the accuracy of the servo gate.
- Pass: If over 20 runs, the rice dispenses reliably.

4. Pseudo Code

#food 1: [5, 3, 2, 4, 1] ingredient list

#food 2: [1, 2, 3] ingredient list

etc

//on button press

retrieve dispenser order

sol 1

rotate conveyor belt to dispensing pipe

rotate NEMA23 of circular dispenser to positions in ingredient list

open pipe by rotating servo and dispense

rotate conveyor to shaker

rotate shaker for x seconds

pick up food

sol 2

rotate conveyor belt to disp pipe

open individual pipes by rotating servo and dispense base on ingredient list

rotate conveyor to each ingredient pipe using conveyor and then to shaker

pick up food

5. Costs

5.1 Parts

Table X Parts Costs					
Part	Manufacturer	Retail Cost (\$)	Bulk Purchase Cost (\$)	Actual Cost (\$)	
NEMA 23 Stepper Motor x2 (1 for conveyor belt, 1 for liquid dispenser)	OSM Technology Co., Ltd (Model: 23HS22-2804S)	\$26 (~\$10 with Source 2)	\$15 per unit	\$52 (\$20 with Source 2)	NEMA23 Stepper Source 1 NEMA Stepper Source 2
V Groove Idlers (with bearing slide) x2	QWORK (Model: QS8341)	\$13 for a set of 2	\$4 each	\$13	V Groove Idler Bearing Set
Conveyor Belt Frame (Aluminum Extrusion) x2	VICHSAMWY (Model: 4p-2020V-800)	\$20 for 2	\$5 per extrusion	\$20	Conveyor Belt Aluminum Extrusion Frame
Gt2 10mm timing belt	Hanglife Group	\$5 per meter	\$3 per meter	\$20	GT2 10mm timing belt
Gt2 timing pulleys x2	WINSINN (Model: TBL10MM205)	\$8 per set of 5 (\$3.20 for 2)	\$1 per pulley	\$8	GT2 Timing Pulley
Food storage containers x3	Vtopmart (Part: SVM02029)	\$30 (for 24 containers) \$5 (for 3)	\$1 per container	\$30	Food Containers
SG90 Micro Servo Motors x3	WWZMDiB (Model: SG90)	\$7 (for 3 motors)	\$1.50 per motor	\$7	SG90 Micro Servo Motors
ESP32 Microcontroller	AiTrip (Model: 15363)	\$9.50	\$5	\$9.50	ESP32 Microcontroller
ST7789 LCD Display	EastRising (Model: ER-TFT020-2)	\$5	\$4	\$5	LCD Display

Motor Driver (TB6600) x1	EBYSAICO (Model: tb6600)	\$10	\$8	\$10	TB6600 Motor Driver
Weight Sensor (Load Cell + HX711)	NOYITO (Model: NOLDKHX711-10)	\$7	\$5	\$7	Load Cell + Hx711 Weight Sensor
Food Safe Tubing (Dispensary Pipe)	McMaster-Carr	\$6.25 per foot	\$2 per foot	\$12.50	Food Grade Tubing
Total		\$164.80	\$95.50	\$194.00	

5.2 Labor

- CAD every individual component in a miniature form to depict the real system (1 week)
- Use Dev board with motor drivers to demonstrate bread board working of individual components based on the Design Verification criterions. (1 week)
- Attach devboard solution to CAD physical model to take into account motor backlash and other physical constraints like power supply issues and overheating (1 week)
- Start PCB design based on the chosen direction. Soldering and debugging (3-4 weeks)
- Final assembly and testing(1 week)

6. Conclusion

This project addresses inefficiencies in repetitive assembly-line-based restaurants. This project proposal has gone into detail on the different parts of the system and how each part interacts with the others. This conclusion will summarize the system and go over the ethical and regulatory considerations of the project. It will also go into the impact of this project.

6.1 Accomplishments

Upon the conclusion of this project, we would like to have a system that would be able to automatically serve assembly-line-based food. This would be in a modular design, which has 6 subsystems. The LCD with buttons, power subsystem, conveyor belt with bowl, subsystem microcontroller, food release mechanism, and the load cell-based accuracy checking subsystem all work together to ensure the right ingredients and amounts are dispensed into the bowl. Finishing this project successfully means that we will have a closed-loop dispensing system using a weight sensor in order to prevent over- and under-dispensing. We have a coordinated motor control using NEMA 23 motors, servo drivers, and an

ESP32 microcontroller. We also have a mechanical integration of conveyor positioning with ingredient piping. Lastly, we have a user interface pathway that uses tactile buttons and an LCD system.

6.2 Uncertainties

There are a few uncertainties that we have going into this project. The obvious one is that we are unsure about the long term reliability and maintenance of this system, especially in a real restaurant environment. Food particles, both liquid and solid, can degrade components. We have a cleaning mechanism at the moment; however, we need to ensure that it consistently works.

Another uncertainty is being able to dispense food of different textures consistently. The linear actuator system does not behave the same for different ingredients. We will try to tackle this by having different calibrations across many different food types.

Lastly, there is an uncertainty in being able to implement this system in a real restaurant. This is because food-related technology has a lot of regulations, which include food safety certifications. Additionally, we would have to conduct electrical compliance testing and liability testing.

6.3 Ethical considerations

We will have to consider public health, safety, and welfare, considering economic, environmental, social, cultural, and global factors when working on this system.

IEEE Code of Ethics I 1 and ACM Code of Ethics and Professional Conduct 1.1 mentions the importance of health safety. It is important when working on this project that we consider ensuring that the food is clean when being dispensed from our system. Food safety is of the highest priority, and therefore, we have to ensure no cross-contamination and consistent cleaning. We have to ensure that the tubing is food safe and that the cleaning process works.

ACM Code of Ethics and Professional Conduct 1.2 mentions the importance of avoiding all harm, including physical harm. There are many moving parts in this system, including the conveyor belt and tubes. These moving parts create opportunities for people to get hurt. We will have stickers warning people of areas not to touch. We will wire everything in an organized and safe way. We will also ensure to have an emergency stop feature.

ACM Code of Ethics and Professional Conduct 3.2 mentions the importance of reducing harm to the public and society. This system can lead to labor displacement as it could automate jobs in the food service space. When creating this system, we are looking at it from a perspective of not taking away jobs but ensuring that people work in less monotonous areas, as well as making it easier to work in these types of restaurants. Work for humans will still be there, such as overseeing food preparation, quality control, and customer interaction.

6.4 Societal, Economic, Environmental, and Global Impact

Societal Impact

This system will reduce wait times and increase consistency with everyone's food. On the other hand, it is possible that there could be a reduced workforce in assembly-line-based restaurants due to this product.

Economic Impact

This system can lead to increased production, which can meet the demand during peak times. This will lead to more money being made. Other positives are less food waste, as all the food is going straight into the bowl, which could lead to lower operational costs in the long term.

Environmental Impact

This system can lead to less food waste. On the other hand, there will be increased electricity usage due to this system. Working in restaurants that have clean energy will get rid of that issue.

Global Impact

This type of system could lead to a change in all restaurants with an assembly line. It could become a new industry standard.

6.5 Regulatory Considerations

Because this system will be a food product, approval from the FDA is needed for it to be in use. All parts of the system need to be FDA-approved, including the tubing and dispensing materials. Also, local food safety authorities would regularly check restaurants, so it is important that the food is always kept in a clean environment.

Additionally, there are OSHA regulations for workers when they work with machinery. Therefore, it is important that we are able to teach others properly and safely how to use the system.

6.6 Future Work

Being able to scale this system to be practical for a real restaurant with 10 plus items would be the obvious next step. There are other smaller steps to take, such as having different settings programmed in for different textures of food, adding a nutritional tracking system, and improving the hygiene of the system.

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