PROPOSAL FOR MULTI-PURPOSE AUTOMATED ROBOTIC ARM

PROJECT PLAN

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- ISU: An acronym for Iowa State University

- Computer Vision: A technology which allows a computer to receive information from a camera or similar device and process that information in such a way as to interpret it and produce a response accordingly

- Iowa State: An abbreviation for Iowa State University

- mpARM : multi-purpose arm

- IEEE : acronym for "Institute of Electrical and Electronics Engineers", a professional organization

1. Introductory Material

1.1 Acknowledgement

The Multi-Purpose Automated Robot Arm team would like to kindly thank Professor Stoytchev for allowing members of our undergraduate team to participate in his graduate level course on computer vision which provided our team the ability to develop our ideas into reality. Additionally, we would like to thank Iowa State University for providing the necessary funding for our team and allowing us to utilize a wide range of campus resources over the course of the project's development phase. We would also like the time to thank the designer of the THOR arm AngelLM and the rest of Team 3 of the Hackaday who made their robotic arm plans available online. The designs they provided drastically decreased the amount of time and money needed to produce a robotic arm.

1.2 Problem Statement

As a result of increasing production costs for food-related products in the restaurant industry, coupled with work-related injuries in the kitchen and a lack of product consistency, both the producer and consumer are negatively affected. Food producers are forced to increase costs to deal with ever-increasing wages as well as cover medical expenses for injuries sustained in the workplace. As costs increase so does the price of the goods consumers purchase. Consumers must also accept that at times as a result of human error, the food they get might be inconsistent with the previous experiences they've had at the same establishment.

To combat this issue, automation in the form of a robotic chef will be implemented in the workspace. This solution aims to revolutionize the restaurant workforce with not just better service, but with a better product. While the end goal is to produce an automated system which could produce a variety of different food options, our team will be solely focusing on the production of pancakes as a proof of concept. Equipped with multiple arm utensils coupled with computer vision, this system will be able to perform the same tasks as a human cook and more. An automated cook could work highly efficiently and would require no breaks, not suffer from fatigue and create a consistent product every time. With the implementation of an automated chef arm the cost of labor included in preparing the food could be greatly reduced.

1.3 Operating Environment

The intended operating environment for which this product is being designed to function in is that of an industrial and/or home kitchen. This product needs to be able to withstand the intense heat produced from an oven, grill, or similar heat source, as the product will be in close proximity to these on a regular basis. Additionally some components directly interact with these hot surfaces, and thus must be heat resistant to match. High humidity, caused by boiling water, is also an expected environmental hazard.

This could lead to condensation on the product, and thus requires a degree of waterproofing to prevent the products electrical components from shorting out or metal components from corroding. The product is likely to be used in a kitchen environment near human employees, and as such proper safety features are incorporated to accommodate this. Finally, our product will be handling food intended for public consumption. This requires that our product meets strict standards for sanitation, as failure to do so could lead to health concerns for the consumer, and possibly lawsuits.

1.4 Intended Users and Intended Uses

Project mpARM aims to modernize the cooking experience in both professional and home kitchens. As a result of having two possible environments, mpARM will have two primary users, the first being restaurant employees who regularly work alongside and interact with the product in the workplace. The second user base will be the everyday person looking for assistance in preparing meals in their own home. While the primary objective of both users is similar in that they both require help in food preparation, the two groups will expect different end results as their needs are slightly different from one another.

On a commercial scale restaurant employees will require the ability to produce a handful of carefully crafted recipes quickly and efficiently. Having the ability to perform a lot of tasks is important, however, it is just as important to deliver a product that is consistently good as well as quickly produced. In commercial kitchens it is unlikely to find a single employee performing all the tasks as it would result in a bottlenecking of the system. It is much more common place to see a variety of workers focusing on a limited amount of tasks at a set number of stations. By working in unison, a group of cooks are able to produce a variety of dishes at an intense speed. It is necessary that individuals working in a commercial kitchen keep in sync with one another so as to not disrupt the flow of food leaving the kitchen. These employees (and effectively our users) will expect that whatever product is provided to them does not hinder the system they have already established, but rather enhances it.

Everyday people preparing food for themselves in their homes operate on a different system entirely compared to restaurant employees when it comes to making food. These individuals likely require a variety of different food options when compared to restaurants. These users will also be less likely want a device to help them cook so much as do all the cooking for them. Speed is just as important for the individual at home as it is for the team working in an industrial kitchen. These users require a system that can make excellent food with little assistance on the user's behalf.

1.5 Assumptions and Limitations

Assumptions:

- The input product such as batter is of consistent viscosity.

- Once the system is programed to work in certain conditions those conditions remain the same. An example would be once the robot is set up for a particular height of a stovetop, the user doesn't change that height.
- The location of the pancake once the batter has been poured remains the same.
- If any additional tools are required to prepare the dish, those tools remain in designated locations.
- The location where the dish is being outputted remains the same.
- Robot will be consistently fed required inputs such as batter and will not be required to prepare its own.
- A standard 120 volt power supply is available for the machine at all times.

Limitations:

- The system will require users to provide required materials such as pancake batter.
- The cost of the unit must remain under $1,500.
- Set of required space must allow for a robotic arm to fully maneuver
- System will assume that it will be provided with the required materials. For example, if the user placed materials for making burgers, but selected the pancake setting the robot would assume that the materials placed in zones corresponds to making pancakes not burgers.
- System will assume systems like the stove top are properly prepared and ready to perform desired tasks upon.

1.6 Expected End Product and Other Deliverables

The final product will be split into two parts. the first step is to produce a mechanical system that can reliably and accurately produce pancakes. The second part is comprised of computer learning system which can determine the status of the dish. When in unison the system will be able to determine the status of the dish and act accordingly so as to provide the perfect product on a consistent basis. The final product should specialize in the industrial environment, but should be applicable in a household system. Consideration should be taken in regards to the power as a standard 120 volt power supply should be applicable to all models. The automatic pancake making system will be user friendly, being easy to operate and maintain. The dates and corresponding deliverables leading up to the final product are given below.

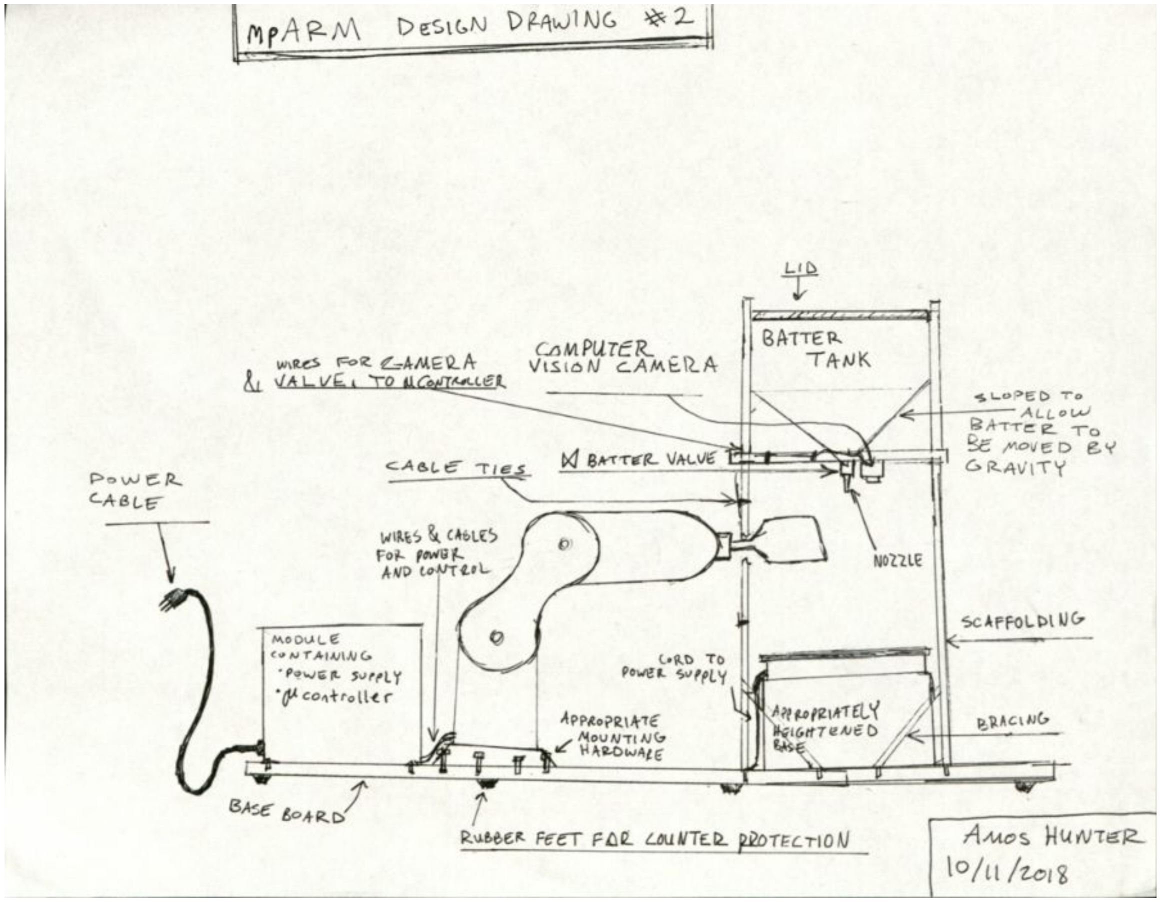


Figure 1. Macro-level system diagram

Prototype - December 6th, 2019

- The prototype will be a proof of concept and will consist of a rough design 3D printed robotic arm with basic motion abilities. At this point the computer vision is unlikely to be completed, but the physical design should be well on the way.

April 27, 2019

- The system should be able to fully function on both a physical and logical level.

· Project Proposal Accepted

o Expected Delivery Date: 1 Month

o Description: The proposal is accepted, and the project can continue.

· Demonstrate a responsive user interface o Expected Delivery Date: 6 Months

o Description: The chassis will be assembled by then and the beginning of the software program will be tested.

· The mixture is poured properly onto the flattop.

o Expected Delivery Date: 7 Months

o Description: The robotic arm will be assembled with working stepper motors and encoders, demonstrating controlled pre-planned movement from one position to another.

· Computer vision system detects when a pancake is ready

o Expected Delivery Date: 8 Months

o Description: The computer will be connected to the camera and be able to tell when the pancake is ready to flip via analyzing the surface bubbles on top of the cooking pancake or reading the internal temperature utilizing an infrared camera.

· The robotic arm can move on demand and flip a pancake

o Expected Delivery Date: 9 Months

o Description: The robot arm can move quickly enough to flip a pancake in the same place with demonstrated efficiency.

· Pancakes are made

o Expected Delivery Date: 10 Months

o Description: The entire system is working properly together, where users are able to submit their request, and have it served to them a set amount of time later.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

We will produce a working prototype of a machine which can automatically make pancakes (and, in principle, other foods as well). We intend it to take the form of a robotic arm which is enabled with computer vision and other technologies. It will be a proof-of-concept work which could show potential applications in the foodservice industry. It will be a physical machine, electrically powered, and incorporating some 3D printed parts.

2.2 Functional Requirements

This machine will:

- efficiently, automatically, and uniformly make pancakes

- be safe for all people who come into contact with it and with what it produces

2.3 Constraints Considerations

Non-Functional Requirements

Industrializability - Having the ability for the prototype to be manufactured on a commercial scale.

Low Maintenance - Customer needs to be able to have the autonomous cook function without failure. If the device happens to function incorrectly, the solution to having it work correctly is easily attainable by the user and does not require third party assistance like a technician.

Reliability - Users require that the device be able to make the correct dish without fail so as to avoid the use of additional resources and time.

Space Delegation - System needs to take up space in such a way that it does not interfere with the other work being conducted within the same workspace.

Operation - users will need to be able to operate the device with ease. Having the system be very intuitive will be critical in having everyday people being able to operate the device.

Standards

The protocols being followed while implementing the various modules is constant in-line code documentation followed by javadoc for user readability. Our team is focused on making the system reproducible so that it may used for commercial and private sector use. Academically, students should be able to follow the project proposal and the design document to see the practices the team followed, the approaches researched, and the results of the prototyping and testing stage. The tests performed by the team will be thoroughly documented This follows IEEE standard 829, Standard for Software and System Test Documentation (Reference 9), by establishing a common framework for test processes, activities, and tasks in support of all software life cycle processes. This practice is considered ethical in most all organizations due to necessity of continuing good coding practices.

The next standard being followed by the team is IEEE standard 1872, Standard Ontologies for Robotics and Automation (Reference 10). The primary focus of this standard practice is providing a standard methodology for the field of robotics and automation in which a common vocabulary is used. This vocabulary is crucial when presenting this product to other roboticist because this ensures that a person will grasp the core concepts utilized in this project. The standard can be seen as unethical by a few organizations that make use of custom methodologies to represent originality, but overall it is well-received by many.

2.4 Previous Work And Literature

We discovered that the most popular design for industrial scale pancake production is a conveyor belt style pancake griddle (Reference 6). The quality of the pancakes produced by these conveyor belt designs varied, most small scale ones produced low quality pancakes, distinguishable by their uneven browning and texture. It is possible for this style of machine to create higher quality pancakes, but the machine's high reliance on its physical components would require us to redesign the physical machine many times to calibrate the quality. This would be both expensive and time consuming.

The idea of autonomous robotic arms preparing food has been successfully implemented in the past for both home and restaurant applications (Reference 5). Most of these designs are modular allowing for the potential of multiple types of dishes to be produced while taking up a relatively small amount of space - unlike a belt driven system. These types of devices are typically very expensive to produce and are placed in environments specially designed to accommodate them, making them very difficult to be implemented in existing kitchens at a reasonable cost.

The aim of our project is to take the existing style of the autonomous robotic arm and utilizing the Thor robotic arm design (Reference 1-Reference 4) as a base, decrease the cost of the system and system integration into existing environments. While hobbyists have attempted to make similar systems (Reference 7) at a fraction of the cost of those produced in labs and by companies it is often at the detriment of user functionality in addition to the products ability to be easily used by users. By implementing designs similar to professionally made robotic arm cooks while providing both a modular and cost effective system introduced by hobbyists, it is feasible for this idea to cease being a science experiment and instead become a viable product. By creating a product which encapsulates the speed and efficiency of a robot with the modularity of a human chef, all while being well below the costs of similar products, our group believes that this product will stand out among the competitors as it will be able to outperform any system at a similar cost.

2.5 Proposed Design

The idea of having a robotic arm prepare food was always the initial design choice, but is was by no means the only one. In order to solve the issue with quick and high quality food preparation, a lot of potential solutions were considered. The most popular choice besides the robotic arm was a conveyor belt design. From our research it is apparent that this technology is widely used in the food industry as it is even typical to find similar systems making pancakes at hotels these days. What prevented the group from further exploring this option was that such a system typically produces a lower quality product compared to other methods. Additionally, most conveyor belt designs are only able to make one product with no alterations. The system our team desires can make several alterations to the pancakes such as changing the toppings while allowing for the ability for the system to prepare additional dishes in the future. It is for these reasons the belt system was no longer considered.

Another method the group believes could solve this problem is an innovation in food preparation systems. This could include anything from the way premade meals are packaged to how they are transported to the desired location, and even how they are prepared once they have arrived on location. The main reason why this design idea was quickly dismissed was that our team lacks the competence required for such a product and wouldn't know where to begin when designing a product like this. It was from here that an autonomous food preparation system was selected as the leading design choice.

Even after the autonomous arm was selected as the favorable design choice, several proposed designs have been considered regarding how the arm will function. A key design is whether a spatula or pointed rod will be used to maneuver the pancakes. While both designs are currently still being considered, it is likely that the spatula will be favored over the rod as it is a more diverse tool. Another proposed design involves the orientation of the arm. While initial designs showed the arm being mounted to the countertop, recent designs favor the arm being mounted to the ceiling as it will allow the robot to have a greater range of motion. So while the autonomos arm has been favored as the proposed design, there are countless design proposals constantly being applied to the subsystems.

The computer vision system has undergone multiple approaches of how to handle the problem statement of know when to flip and serve the pancakes. The main decision considered was whether to measure the internal temperature of the pancakes while cooking or determining an accurate ratio of bubbles to surface area of a given pancake to determine whether the first side of the pancake is cooked or not. Both approaches would work as intended given the current requirements of the computer vision system. The first approach would be easier to implement but the hardware required exceeds the budget set by the senior design committee. The second approach will be harder to determine an effective algorithm but is considered to be more realistic and provides an opportunity to develop and show off the software skills of the team. The proposed design to be implemented by this system is to use an overhead camera that has the griddle in its field of vision. This camera will be hardwired to the microprocessor to ensure the fast connection possible for image processing.

2.6 Technology Considerations

We decided to adapt the Thor robotic arm due to its ease of assembly and the expansive documentation that comes with it. The documentation will be an important resource for our computer interface, and coding. The 3D printed parts can be feasibly printed both in campus labs, and in the 3D printer owned by one of our group members. However, if we cannot gain access to 3D printing facilities, then our project could be halted for an unpredictable timeframe.

The computer interface will consist of a microprocessor loaded with instructions written in the C programming language. With the documentation on the Thor arm, we will be able to connect and program the microprocessor to accurately move the Thor arm. The microprocessor chosen will have the capability of handling high definition image processing required to handle computational perception code.

The technology being used for the computer vision system has not yet been used by any of the team members and will provide a significant learning code. That is why the selection of the microprocessor, FPGA, or Arduino is crucial so that the developers can begin to start the research process of how to write effective image processing code on the machine. Considerations also taking place is how much machine learning is going to be integrated into the end product. This is a giant step that the project is looking to take in the end, but will eager to start given the minimal time limit.

2.7 Safety Considerations

The primary safety concern is that of fire safety, as this design is meant to be placed in a commercial kitchen, and interfaces directly with a hot griddle. It must be ensured that the arm is able to operate safely at high temperatures, and that the wiring itself does not pose a fire risk. Additionally it must be ensured that the arm operates safely within its working environment, so that no human is injured due to to movements of the arm.

The mpARM team has considered many potential safety risks this product could present in both a home and industrial kitchen environment. Since this product is preparing food for human consumption there is the potential of improperly manufacturing food in such a way as to cause sickness or even death to those who consume the food this product makes. Safety for the operator is also being considered as they will be required to operate alongside our product in an environment with a variety of hot surfaces and sharp tools. If the right safety measures are not accounted for, potentially fatal accidents could occur in the kitchen as a direct result of the robotic arm.

Team mpARM plans to adhere to the strict regulations surrounding food preparation devices in both commercial and home kitchens. By using the regulations dictating cooking utensil regulations, the intention is to reduce the risk of customers getting sick from their food making contact with this device. Such measures will include using the appropriate materials to construct the device where food comes in contact with the robot arm. The robot arm will also need to be heat resistant where components come in contact with heat so as to prevent the machine from melting or burning.

2.8 Task Approach

Our approach divides the group members based on their area of expertise. Each member has been given a defined role, and is assigned parts of the project that fit into that role. It is our belief that this will lead each member to demonstrate the extent of their capabilities on the project. Each week the group meets and checks both individual progress on the project, and progress at a whole. As we progress further meetings are planned to facilitate to combination of the individual assignments into a complete prototype.

2.9 Possible Risks And Risk Management

This project is operating on a limited budget, and we must be wary that the more expensive components in our design do not cause us to outspend our allotted funds. We plan to carefully assess all of our purchases to reduce the chance of wasted funds, and will use cheap but reliable components wherever possible.

Our time frame is incredibly tight. With only two semesters to complete this project while managing other classwork, there is a ever present danger of falling behind schedule. We need to constantly assess our progress, and work hard to meet our time goals as we have set them.

2.10 Project Proposed Milestones and Evaluation Criteria

Key milestones for this project shall include a set of blueprints, then a series of tests on pancake recipes, electro-mechanical subsystems, a built working model, and finally a functional prototype. The tests we shall perform will be designed to show us whether or not a particular design or implementation satisfies our needs. This is relative to criteria and constraints we will define ahead of time. For example, we will develop parameters for the flavor, thickness, and batter viscosity of our pancake batter. Then we will see how that affects a batter delivery system and its contingent pump, valves, tubes, etc.

2.11 Project Tracking Procedures

We will have weekly meetings which will allow us to give an update to each other and to the faculty advisor. We use Slack and email which allows us to have well-documented communication, including deadlines and timestamped confirmation of a task being completed. A timeline of the project exists for the purpose of allowing us to see where we are in relation to where we planned to be time-wise. Also, we produce a weekly report which summarizes such information. We have started these processes now and plan to continue these strategies through the end of the project.

2.12 Expected Results and Validation

The desired and expected result of this device is that upon providing it with pancake batter and powering it on, it will yield a batch of pancakes which are of a uniform and desired shape, size, and level of doneness. Our solution will have accomplished these goals at a high level if it does them consistently over a long period of time with minimal messiness.

2.13 Test Plan

Testing will commence in two realms. The first is the information realm in which we will debug and compile our code. The second is the physical realm, in which we will test the robot's electrical and mechanical systems and troubleshoot the pancake-making process. We intend that the testing process will be iterative.

Firstly, early models and prototypes of subsystems of the larger whole will be constructed. From the information gained from these things we shall progress to assembling the complete robot. In that phase the testing will include a more high-level approach. This would include fine-tuning the pancake-making process.

The first prototype was made at the HackISU event on October 12th to see if a rudimentary design could be made within 36 hours, the project given the name FlipJacks (Reference 8). FlipJacks automatically pours pancake batter, cooks pancakes, flips em, and then serves pancakes. The entire process is automated by an Arduino Uno keeping time and controlling servo motors. The pancake making process can be done in three stages: dispersal, the first side, and the second side. The dispersal stage consists of sliding a 3D printed gate to a set location to allow the flow of pancake batter from the batter containers onto a metal sheet. The first side stage consists of cooking the first side of the pancake for 10 minutes to allow the side to brown thoroughly without burning the pancake. The transition to the next stage happens by a servo flipping the piece of sheet metal 180 degrees so that any pancake being cooked is moved onto the next piece of sheet metal. After this transition is complete, the dispersal stage is repeated so that the next set of pancakes starts to cook. The second stage consists of cooking the opposite side of the pancake for 10 minutes. After the completion of this stage, the second piece of sheet metal is flipped 180 degrees and the fully cooked pancakes are dropped onto a serving platter.

For the Chem E side of the project, we found an equation of flow rate which included a viscosity equation. Using this equation we determined the size of the drill bit and gate size required to allow the batter flow as expected. We found the viscosity by its mass/volume and plugged it into the Poiseuille equation which gave the flow rate of the pancake batter given different nozzle sizes. That the process was automated up to a certain extent and was able to produce 2 pancakes every 10 minutes after the initial setup. For the mechanical side of the project, we repeatedly came up with many mechanical designs involving linkages and cantilevers, incorporating all the functions into a single structure. For the software side of the project, we programmed the Arduino effectively to run on a loop to control each servo to work as expected (Turning to certain degrees exhibiting specified rates at measured time intervals).

It is anticipated that more activities preliminary to the next prototype testing will commence before the end of this semester. It is conceivable that early testing of the robotic arm prototype could even begin before next semester begins. The second semester will be very testing-oriented. This will allow us to apply the scientific method by testing hypothesis multiple times and adjusting variables accordingly.

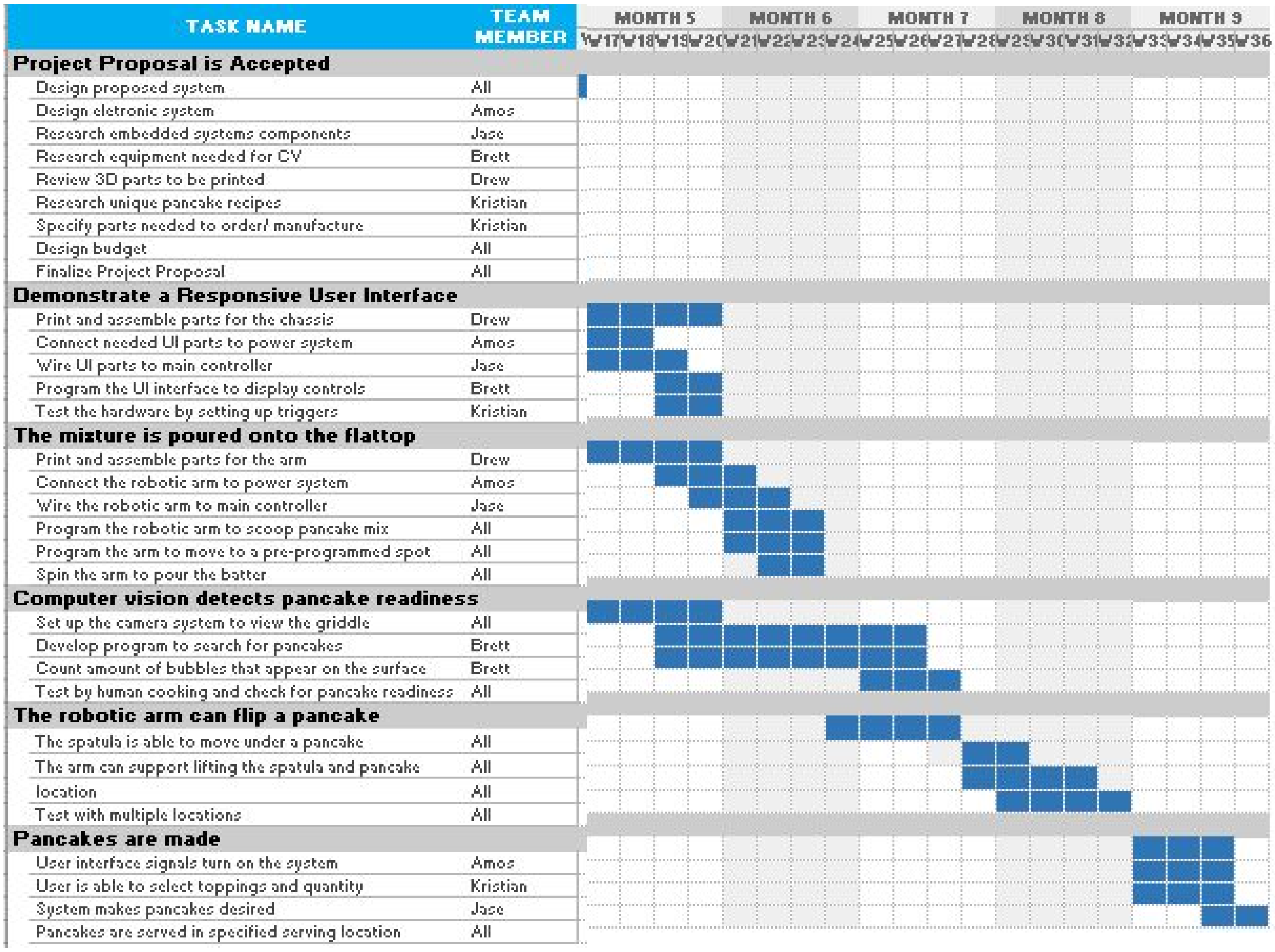
3. Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

A realistic, well-planned schedule is an essential component of every successful project. Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity. The planning process and the beginning of the 3D printing will initiate during the first semester. Each person will be required to document what parts they will require to complete their section of the mechanical system. The 3D printing will require reserving space and time in the Design building. The larger parts of the arm will take upwards of 20 hours to print one section. The second semester will consist of assembling the mechanical system, developing the software and embedded system programs, and finally testing each part multiple times.

The following Gantt chart will show the subtasks and time needed to complete each of the deliverables on the left hand side. The planned time for each of subtasks was made by selecting team members based off their given role and when they would be available to start the next task. As the team approaches the planned subtasks, the tasks are subject to change as we deem necessary in order to accommodate any problems encountered or tasks completed early.

TASK NAME	TEAM MEMBER	MONTH 1				MONTH 2				MONTH 3				MONTH 4			
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Project Proposal is Accepted																	
Design proposed system	All	■	■	■	■	■											
Design eletronic system	Amos			■	■	■	■	■	■								
Research embedded systems components	Jase			■	■	■	■	■	■								
Research equipment needed for CV	Brett			■	■	■	■	■	■								
Review 3D parts to be printed	Drew			■	■	■	■	■	■								
Research unique pancake recipes	Kristian			■	■	■	■	■	■								
Specify parts needed to order/ manufacture	Kristian						■	■	■	■	■	■	■				
Design budget	All						■	■	■	■	■	■	■				
Finalize Project Proposal	All													■	■	■	■
Demonstrate a Responsive User Interface																	
Print and assemble parts for the chassis	Drew										■	■	■	■	■	■	■
Connect needed UI parts to power system	Amos																■
Wire UI parts to main controller	Jase																
Program the UI interface to display controls	Brett																
Test the hardware by setting up triggers	Kristian																
The mixture is poured onto the flattop																	
Print and assemble parts for the arm	Drew										■	■	■	■	■	■	■
Connect the robotic arm to power system	Amos																
Wire the robotic arm to main controller	Jase																
Program the robotic arm to scoop pancake mix	All																
Program the arm to move to a pre-programmed spot	All																
Spin the arm to pour the batter	All																
Computer vision detects pancake readiness																	
Set up the camera system to view the griddle	All																
Develop program to search for pancakes	Brett																
Count amount of bubbles that appear on the surface	Brett																
Test by human cooking and check for pancake readiness	All																
The robotic arm can flip a pancake																	
The spatula is able to move under a pancake	All																
The arm can support lifting the spatula and pancake	All																
location	All																
Test with multiple locations	All																
Pancakes are made																	
User interface signals turn on the system	Amos																
User is able to select toppings and quantity	Kristian																
System makes pancakes desired	Jase																
Pancakes are served in specified serving location	All																



3.2 Feasibility Assessment

This project seems quite feasible, although there certainly may be difficulties. We foresee potential challenges with budget, access to 3D printing time, and having to learn new programs in time to be efficient in them. The main challenge facing this project after the completion of the second semester is marketing this product to potential consumers in the restaurant area. However, if we are not able to meet our non-functional requirements as defined by the team members such as reliability, performance, and efficiency, the product will have a low demand. Most restaurants already employ cooks that can efficiently make pancakes as fast as their hands can move. That is why the purpose of this project has been shifted to showing the engineering skills of the team, add to the atmosphere of a given restaurant, and provide high quality pancakes consistently. This is the point our team must demonstrate effectively for this project to maintain being a feasible investment of time and resources.

3.3 Personnel Effort Requirements

Each member will include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just a number of hours per week for the number of weeks that the task is active. Trello or another way to track the tasks that are completed or being worked on throughout the project may be used.

3.4 Other Resource Requirements

- 3D Printer
- electric griddle
- stepper motors for arm
- servo motor for hand
- microchips (FPGA)
- solder
- wire
- motor modulation

3.5 Financial Requirements

The total financial resources that are required for this project is our budget of $1,000 and whatever we contribute as a group if necessary. This will be used to cover the cost of materials and parts.

4 Closure Materials

4.1 Conclusion

In conclusion, the team is making headway in developing a mechanism able to optimize efficiency and consistency of modern day cooking and save the consumer time. The mpARA will be able to make pancakes at the touch of button and on completion serve the food on a platter. This product is implementable in modern day smart homes and will increase Smart City's reputation and market value. As the project continues the team will gain insight in the project progress.When building the product, a comprehensive list of resources used to develop this project will be compiled. This list will grow into the second semester. In the end we hope to develop a device which both solves the increase in restaurant costs while providing everyday consumers with the ability to elevate themselves from the pains of cooking and instead focus their time on more meaningful tasks.

4.2 References

Reference 1: http://thorrobot.org/

Reference 2: https://www.thingiverse.com/thing:1743075

Reference 3: https://github.com/AngelLM/Thor

Reference 4: https://hackaday.io/project/12989-thor

Reference 5: http://time.com/3819525/robot-chef-moley-robotics/

Reference 6: https://www.youtube.com/watch?v=CNsnSSsBu44

Reference 7: https://www.youtube.com/watch?v=qJnvUReDUWE

Reference 8: https://devpost.com/software/flipjacks

Reference 9: https://ieeexplore.ieee.org/document/4578383

Reference 10: https://ieeexplore.ieee.org/document/7084073

4.3 Appendices

Not yet established