Multi-Purpose Automated Robotic Arm

DESIGN DOCUMENT

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List of Definitions

● 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 Automated Robotic Arm

● LED: Acronym for light-emitting diode

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1 Introduction

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 vision into a 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 and Project 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 an ever-increasing wage as well as cover medical expenses for injuries sustained in the workplace. As costs increase so does the price of the goods the consumer purchases. 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 need to 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 Operational Environment

The intended operating environment for which this product is being designed to function in is that of an industrial and home grade kitchen. This product needs to be able to withstand is intense heat produced from the oven, grill or fryer, 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. The product is likely to be used in a kitchen environment near human employees, and as such we must ensure 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 standard for sanitation, as failure to do so could lead to health concerns for the consumer, and possibly lawsuits.

1.4 Intended Users and Uses

Project mpARM aims to modernize the cooking experience in both professional and home kitchens. As a result of having two possible environments, mpARA 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 that it does not hinder the system they have already established, but instead enhances it.

Everyday people preparing food for themselves in their homes operate on a whole other 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 users behalf.

1.5 Assumptions and Limitations

Assumptions:

- The input product such as batter, sliced fruits and toppings will be similar in size shape and their location to station is consistent.
- Once the system is programed to work in certain conditions those conditions remain the same. Example would be once the robot gets use to the height of a stove top the user doesn't change it.
- 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 locations where the dish is being outputted to remains the same and unchanged

- Robot will be constantly fed required inputs such as batter and will not be required to prepare its own.

Limitations:

- The system will require users to dispense required materials such as pancake batter.
- The cost of the unit has to remain under $1500
- 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 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.

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 Month

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.

○ Expected Delivery Date: 7 Month

○ 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

○ Expected Delivery Date: 8 Month

○ 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

○ Expected Delivery Date: 9 Month

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

· Pancakes are made

○ Expected Delivery Date: 10 Month

○ 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. Specifications and Analysis

2.1 Proposed Design

Robotic Arm:
The prototype currently has several drafts which are theoretically capable of solving the problem correlating to the physical construction of pancakes in the absence of a human chef. Although all of these prototypes are based off of the THOR robotic arm designs, they differ in many ways including anything from the arm attachments being used to interact with the pancakes and corresponding ingredients to whether the robot should be installed on a countertop or be mounted 180 degrees from the countertop position to the upper cabinets. Currently, none of these prototypes have been constructed and only exist as ideas and sketches, however, plans to create the THOR arm are commencing. Since the THOR arm design is an overlapping element between all arm-based prototypes it will be relatively easy to modify the THOR arm base so as to test the variety of ideas the team has in mind.

Other elements all conceived prototypes have in common correlate to the functional and non-functional requirements as dictated by the task the robotic arm is expected to perform and environment in which the device is meant to function in. The robotic arm must first and foremost be able to perform the task of constructing a pancake from a batter state to serving the dish on a plate for human consumption. The robot will have to maneuver in small environments where hazards such as sharp objects and open flames are present without harming nearby humans who share the same space. Additionally, the robot will have to adhere to proper sanitary codes present in commercial restaurants. Lastly, the robotic arm will aesthetically be comparable to that of a kitchen appliance as opposed to some industrial piece of equipment. Our product can't look jarring in the kitchen landscape and must instead blend in like other autonomous machines which help in day to day kitchen activities. When testing our various prototypes, these requirements will need to be met in order to satisfy the customer which is why the final solution will have to encapsulate all of them.

Computer Vision:

The computer vision system is composed of an overhead camera connected to the FPGA in the embedded system. The camera will be held by a tripod so that its field of vision will contain the entirety of the griddle. There are multiple methods on how to implement the software that will determine when the pancake should be flipped and served. The first method is detecting the amount of bubbles that rise onto the surface of the pancake and determining if passes a set bubbles: pancake surface area ratio. The second method is taking the internal temperature of the pancake and seeing if it passes a researched internal temperature. The third method is not implementing any smart image processing algorithm and set a timer for each pancake in sight for both sides of the pancake. Right now, the planned approach is detecting the amount of bubbles that appear on the surface because buying a camera that reads internal temperature is too expensive and the third method is being implemented after the pancake is flipped. Each method has been researched with a variety of potential products that can be used to accomplish each method.

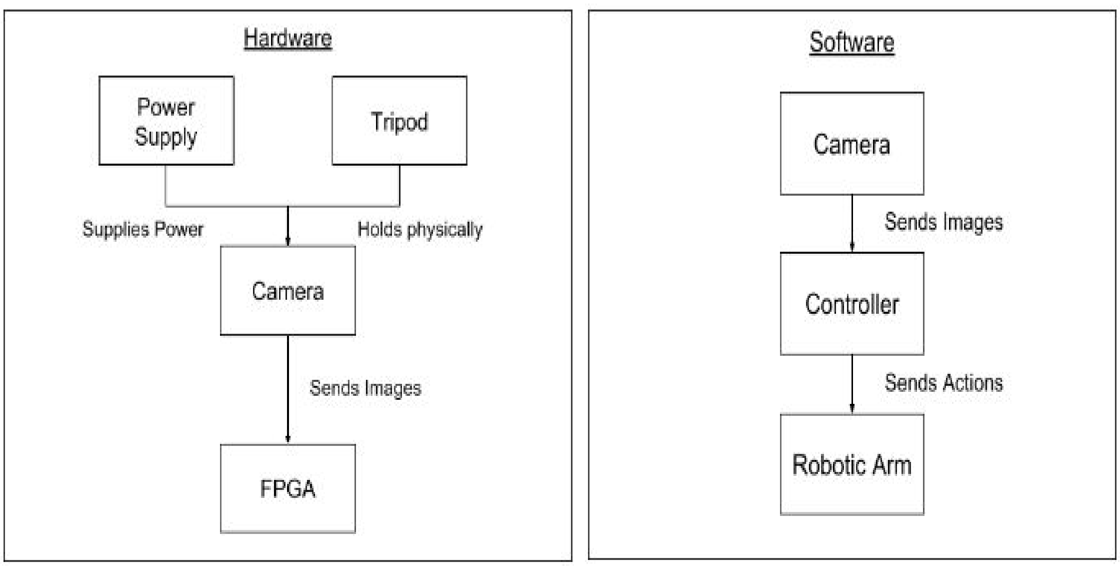


Fig. 1: Robotic arm hardware and software flowcharts

Functional Requirements

- The camera has a frame rate of 60 FPS
- The camera can see each pancake within its field of vision
- Ability to handle a minimum of 4 pancakes

Non-Functional Requirements

- The connection is reliable between the camera and the embedded system
- The image processing is scalable for increasing amount of pancakes

- Computer vision system requires little maintenance

Electrical and Mechanical Systems:

A number of possible design concepts have been considered by our team for this project. An initial consideration we addressed was whether or not a robotic arm would be an ideal solution for our requirements. A few alternatives were considered. One option was a conveyor belt system similar to what is used in factories which produce frozen pancakes. Another option was an appliance type machine which could be a modular device similar to what is currently used in homes and the hospitality industry. It was even considered that we use 3D printed food technology. Ultimately, it was decided that the robotic arm morphology satisfied the needs and desires of our client the best.

Once it was determined to continue with the robotic arm direction, new choices presented themselves. At one point it was intended that the pancake batter would be stored in a tank and then a small pump would pump it through a tube and then out a nozzle onto the griddle. Later, after some consultation with our advisor, it was determined to place the batter in a tank above the griddle, allowing gravity to feed the batter through a valve and thus eliminating the need for a pump. Another similar design choice was the style of griddle. A circular griddle which would spin was evaluated, as well as a shaped griddle with concave indentations to hold pancakes as they cooked, but finally it was resolved that a flat rectangular griddle would be used. Another key decision was the location to mount the camera for the computer vision. One idea was to mount the camera on the robotic arm itself, but it was found that this would be very problematic for the software implementation. It was found to be more reasonable to mount the camera on a stationary structure such as a tripod or gantry.

Furthermore, deliberation was given to non-functional aspects of this design as well. Aesthetics have been taken into account, particularly since a major appeal of the device will be its appeal to consumers and patrons. Therefore, a sleek, modern appearance is preferred, and the electrical and mechanical components conform to those ends. This design choice also makes the device easier to clean. Aside from the improved appearance and cleanliness, such a form factor improves food safety, another important consideration. It is of equal concern that this device is not a fire or electrical hazard. To these ends, wires, cables, connectors, and similar components will be kept in appropriate housings and harnessed adequately. The griddle, power supply, and other such elements have heat management accounted for in the form of heat sinks, proper venting, and heat resistant materials around them. Electrical safety has been achieved by properly grounding and insulating all of the electrical components. In addition, there are precautions taken for the effects of electromagnetic interference. Proper shielding of electronics (especially the microcontroller and other controls) ensures that electromagnetic noise and crosstalk do not cause problems.

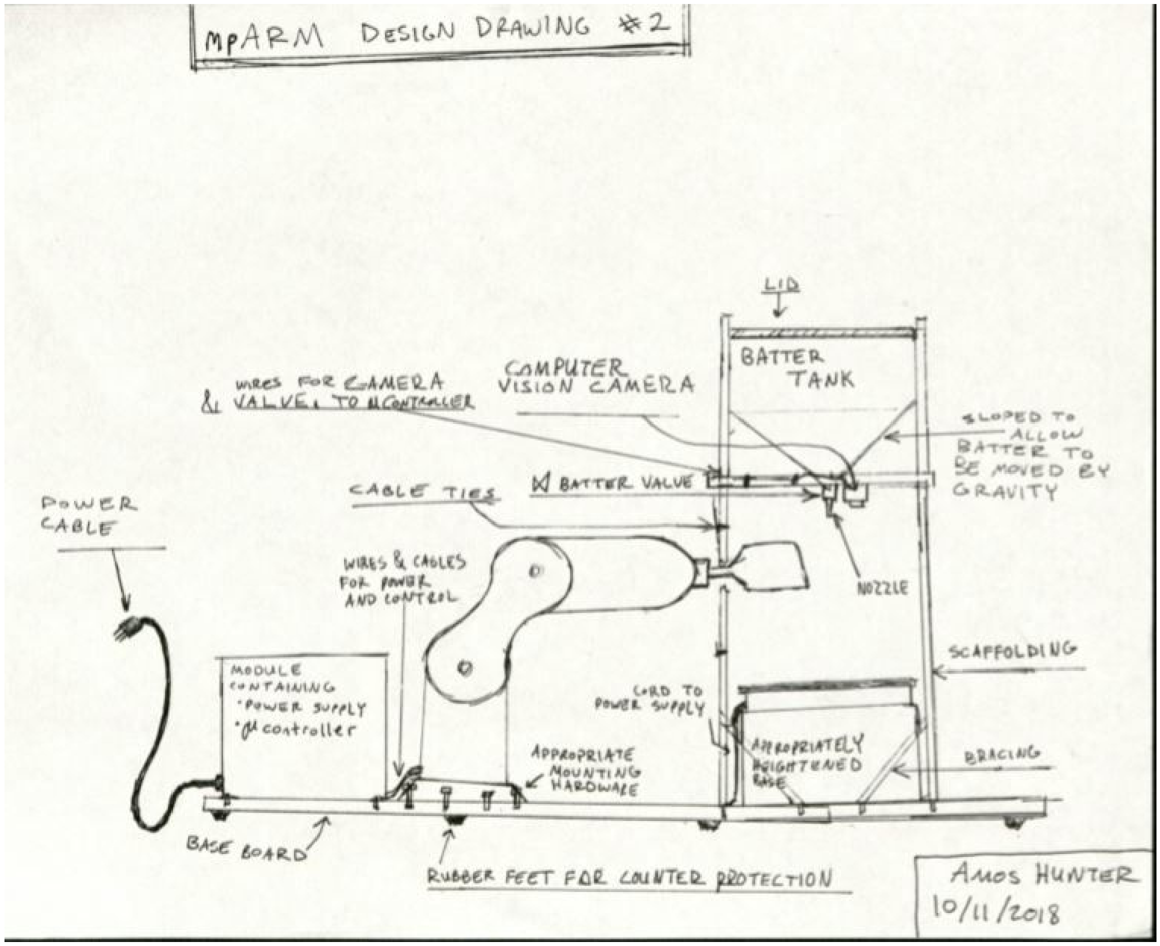


Fig. 2 Electro-mechanical overview

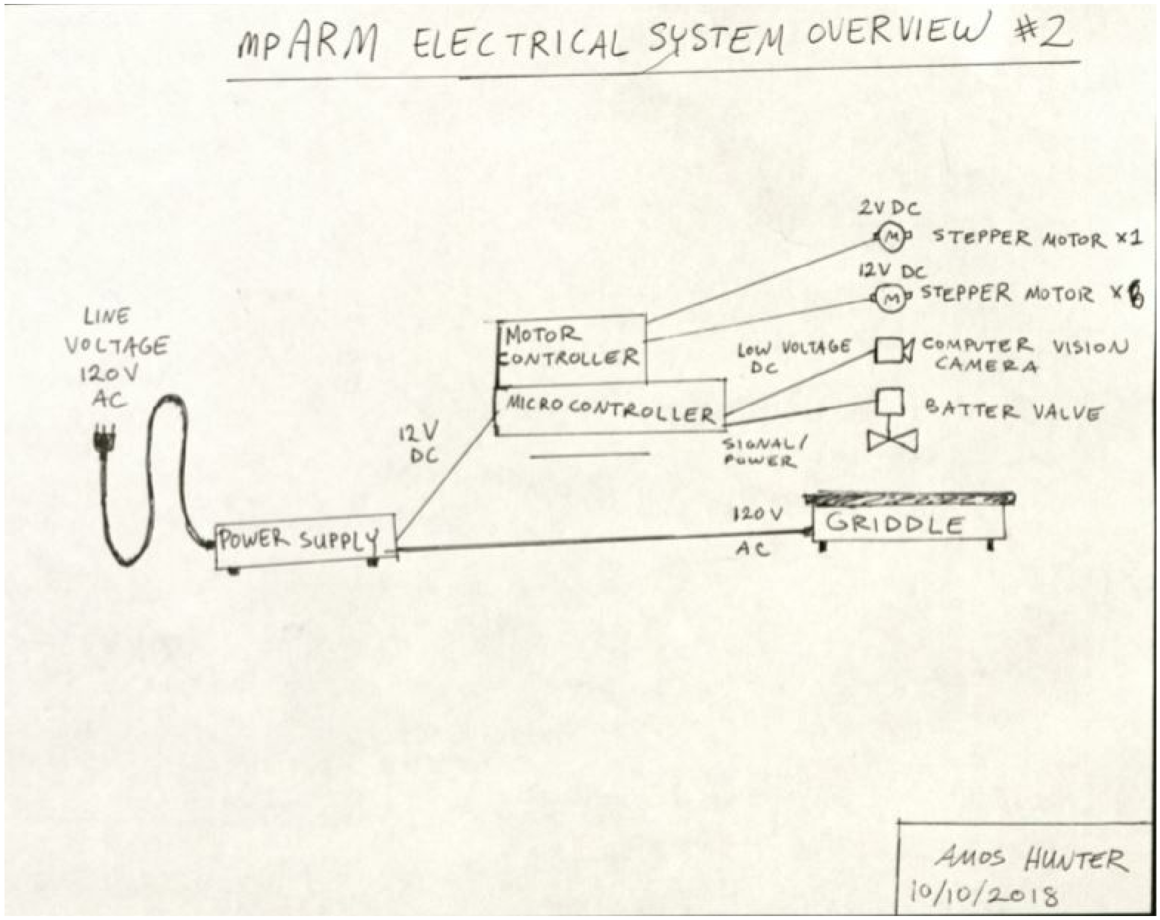


Fig. 3 Electrical system overview

Embedded Systems:

We have came up with multiple designs and done a lot of research on a FPGA that could handle all the inputs and outputs that will be needed in a timely manner, But at this point in the project we have been unable to test any of these because we don't have the means to yet.

This project functional requirements would be that the inputs are dealt with correctly and outputted correctly and that there is enough input ports for all the components that need to be interfaced with the FPGA. That is the same with the output ports. There needs to be enough so that the components that need information sent to them, will have information sent to them. The non-functional requirements would be the speed, but if it gets to slow it will be bad because pancakes will burn. Also receiving all the inputs correctly (which will make it run slower), because it there is 60 fps losing a couple of frames won't matter in the grand scheme.

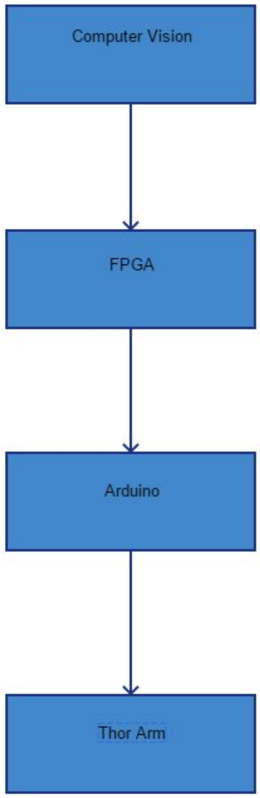


Fig.4 Inputs and Outputs of FPGA

2.2 Design Analysis

Robotic Arm:

Despite how early along Senior Design is, the group has accomplished a great many feats surrounding the mechanism which will prepare the pancakes. One of the most noteworthy accomplishments is the decision of a robotic arm. Initially, many ideas surrounding how the pancakes were going to be produced were suggested. Everything from conveyor belts to pre-packaged goods were suggested, but a robotic chef was the chosen method. Unfortunately, only sketches and models have been constructed thus far, and as a result no idea has been tested. In the next month however, our team will construct a basic robotic arm in which the various designs may be implemented and later tested. Until such time there will be nothing to record relating to test results or observations regarding the systems strengths and weaknesses.

Computer Vision:

The proposed hardware design for the computer vision system works because it meets all the functional and non-functional requirements set by the potential users. The software design of the system is what needs to be tested to effectively determine what the most efficient algorithm design is. The analysis will be re-evaluated when the prototyping is starting. The current strengths of using method one is that advances my current engineering and mathematical skills and is a reliable technique of ensuring the pancakes will be flipped on time. The weakness of the method is that there will be a large learning curve. Brett plans to overcome this challenge by working with his mentor, Alexander Stoytchev.

Electrical and Mechanical Systems:

A number of previous designs and ideas have been evaluated for the electrical and mechanical systems of the multi-purpose arm. The evaluation process has consisted of considering pros and cons to proposed solutions, some prototyping in the form of drawings and sketches. We arrived at our present design (see Figs. 2 and 3) through these means and also through consultation with out faculty advisor. We observe that while we presently have a good design on paper, further testing is needed with physical prototypes. It is obvious that further refinements could be necessitated by our findings from doing so.

Specifically, it may be advantageous to mount the THOR arm from above rather than from below the griddle, to take advantage of the degrees of freedom of the design better. Also, we intend that an oscilloscope and multimeter be used to test the circuit performance of our project. This is especially to address issues relating to signal noise, proper power delivery, and proper connections being made.

Key strengths to this design of the electrical and mechanical systems are safety and simplicity. It is both convenient and safe to have all electrical grounds connected to one common conductor. It is also much more simple from the client's perspective to have only one cord to plug into the wall and know that the machine is powered and grounded. The cable management techniques and the principle of keeping as many electrical connections and components inside of a housing also works toward that purpose. For the user, operation is as simple as plugging it in, filling it with pancake batter, and selecting the specifications of their pancakes. From our perspective, construction of this apparatus is relatively simple as well. Most of the electrical components are available for purchase from vendors and need very little modification. The situation is similar for much of the hardware. This simplicity is aided by the modularity of the major components of our system (it is not necessary to build a power supply or griddle from scratch, for instance).

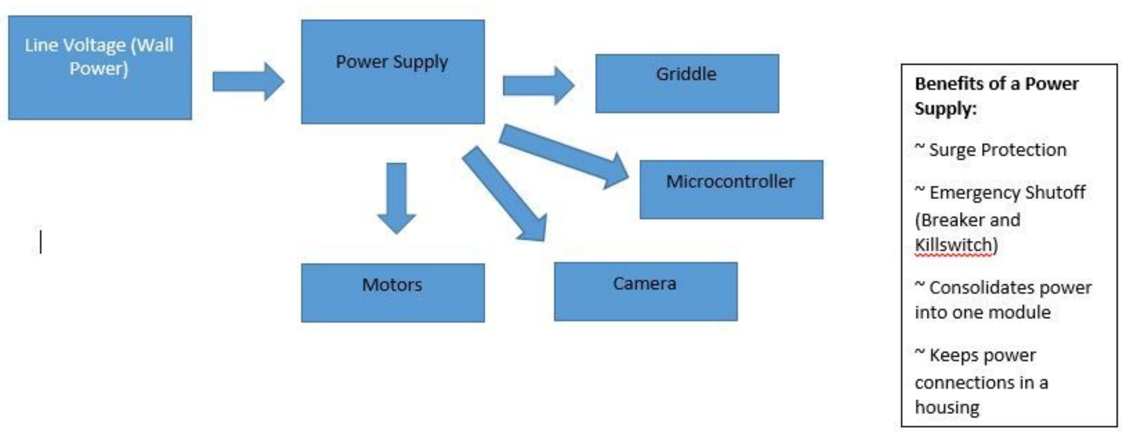


Fig. Basic power flow, showing the advantages of a commercially-available power supply

With all of that said, there are indeed certain disadvantages. The flip side to using pre-made electrical components is that matching the characteristics and dimensions to our purposes can be a complex task. Most components come in standardised ratings for voltage, power consumption, etc. so care must be taken to combine everything into a coherent system. The same may be said for the physical dimensions of components. A particular concern is the power supply, because as can be seen from Fig. 3, there are a variety of DC and AC electrical sources that must be available. This may require some additional power conversion. Indeed there are other potential issues for this proposed but as the project progresses those shall be dealt with in turn. A chief advantage the proposed design has is that it is easy to modify, as the modularity of major elements allows for the addition, subtraction, and modification of almost every component.

Embedded Systems:

For the design for the embedded systems, there has been a lot of research on chips that will be powerful enough to handle the systems that our design has and that will integrate with the components that we are going to be using for this project. Since that it is so early in the making of our project and things are likely to change it is hard to get a firm grasp on what we will be needed for the project and we are unable at the moment to test anything.

3 Testing and Implementation

3.1 Interface Specifications

Robotic Arm:

For the physical testing of the robotic arm, there are only a finite amount of hardware and software which will be required to test the devices performance. Various components will need to be connected to the robotic arm in addition to a simple segment of code to test the motions in which the arm is capable of performing in addition to the amount of weight it can realistically maneuver. Being able to visually capture the capabilities of the robotic arm when operating will be key in testing the functionality of the device.

Computer Vision:

The computer vision system will require interfacing between the camera and the FPGA. Testing needs to be done to ensure that image processing can be read from the camera every 0.5 secs at a maximum and be analyzed by the FPGA.

Electrical and Mechanical Systems:

The user will interface with this machine in two main ways. The first is to add batter to the batter tank above the griddle and then to clean said tank when done. The user needs only to lift the lid of the tank to add batter. The lid is included to prevent contaminants from entering the batter and prevent spillage from the device. The tank is removable from the stand which holds it, so that it may be cleaned. Ordinary soap and water works fine for cleaning the tank and nozzle. The second way in which a user interfaces with this machine is the pancake controls. Simplicity and ease is emphasized by this design. A large rocker switch with indicator LED turns the machine on and off. The griddle power is controlled separately by a similar switch. Griddle temperature is adjusted by a large ergonomic knob attached to a potentiometer. The controls are clearly and appropriately labelled for easy identification. We test that these things meet our requirements by asking people who are not a part of our group and who are not familiar with our project to interact with the controls and batter system. Then we observe their reactions and listen to their opinions regarding the experience.

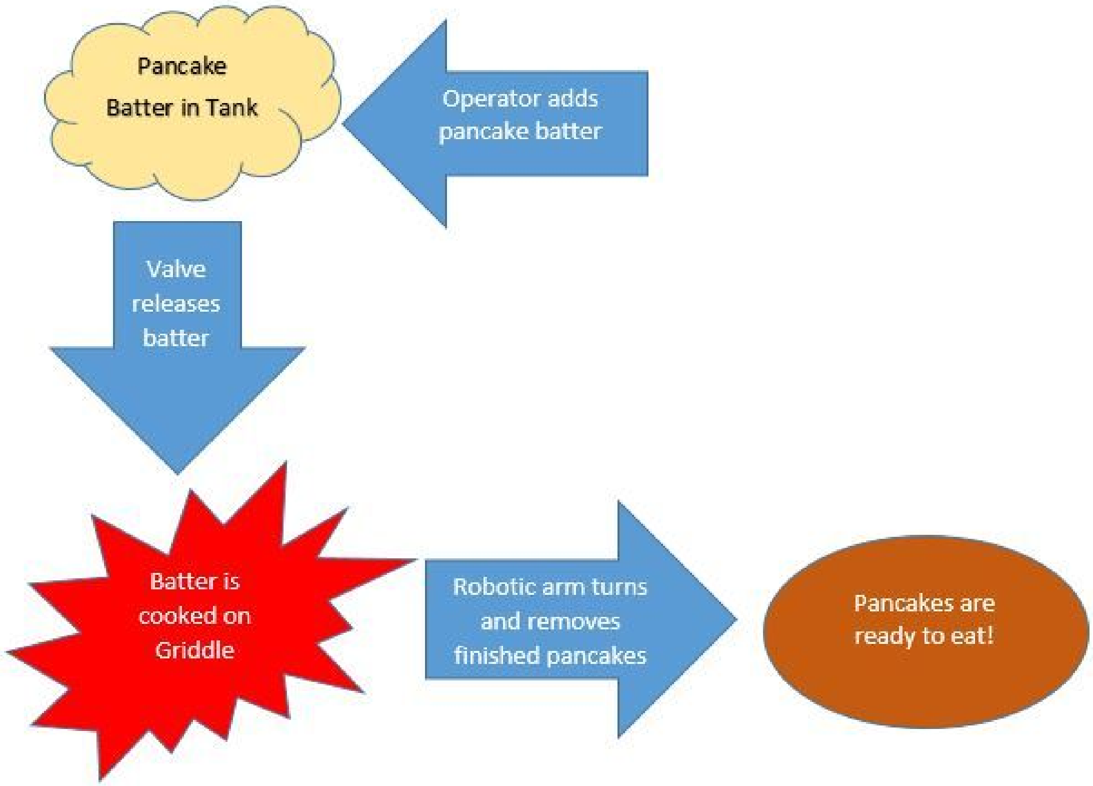


Fig. Product flow through system

Embedded Systems:

For the testing for the FPGA will be mainly be through the program we use for the programing and writing of the code on the chip. The programing of the FPGA will need to be tested because it will have to be able to take inputs from a component and do calculations and if the way the FPGA takes the input is wrong then the output to the arm will be wrong. The software that will be coded on the chip will also need to be tested so that the calculations will be correct and precise.

3.2 Hardware and software

Robotic Arm:

In order to properly test the robotic arm before it can be implemented into the final design, several components will be required to test the functionality of the arm. Most of the required components are already owned by members of the team or can be cheaply purchased through an online vendor.

Hardware used for testing:

- Power Supply
- Arduino
- Motor Shield

- Electronic Scale
- FPGA

Software used for testing:

- Arduino IDE
- Vivado (used for programing and testing FPGA)

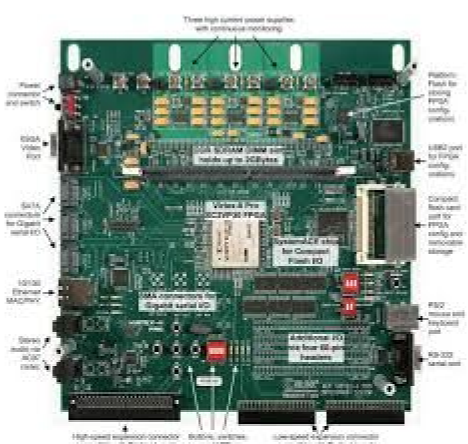
Hardware Descriptions

The power supply provides power to the motors which are used to power the robotic arm. While for testing purposes it would be ideal to have a variable power supply it is not required and a power supply capable of 9 to 12 VDC would be sufficient depending on the size of the motors.

The Arduino microcontroller will be used to program a series of movements for the arm to follow in order to test the capabilities of the device.

The motor controller will allow for the signals created by the Arduino microcontroller to drive the motors as the Arduino all by itself does not have enough power to drive the motors which control the robotic arm by itself.

The electronic scale is a great way to measure the weight which will be subjected to the robotic arm.



The FPGA is good for processing incoming inputs and outputs what the arm should do.

Software Descriptions:

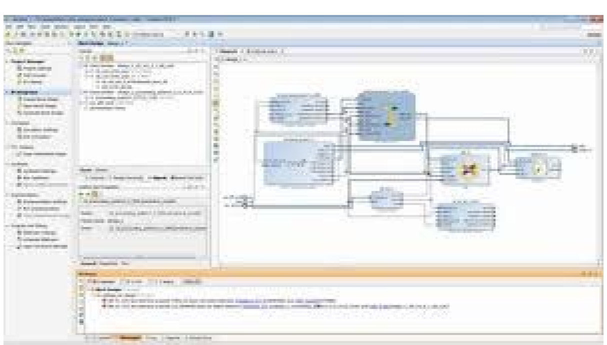
The Arduino IDE (Integrated Development Environment) is a software that allows the team to program commands to the Arduino microcontroller. This is how we will program the robot to perform a series of motions to test the physical abilities of the robotic arm.

Computer Vision:

The computer vision system will require a GoPro hero 4 to accurately transmit high-def data at a high frame rate per second.

The software being tested will be hosted on the FPGA and will need to utilize image processing to send commands to the arm.

Vidado



(Not for project just an example)

This program allows you to design and and program the FPGA with the hardware it will be using.

Electrical and Mechanical Systems:

Hardware Used for Testing:

~ power supply (see above)

~ solderless breadboard

~ jumper wires

~ plywood

~ capacitors

~ rocker switches with indicator LEDs

~ meter stick

~ calipers

The power supply is described in the above section.

A solderless breadboard is a convenient way to prototype circuits without permanently assembling components.

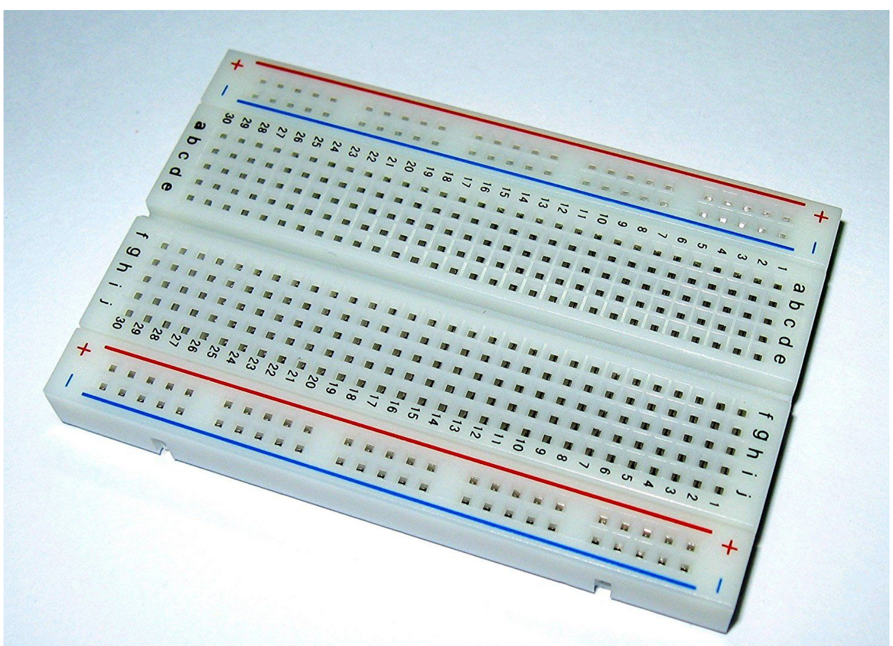


Fig. A solderless breadboard

Jumper wires make it easy to connect and disconnect electrical components, especially on a breadboard.

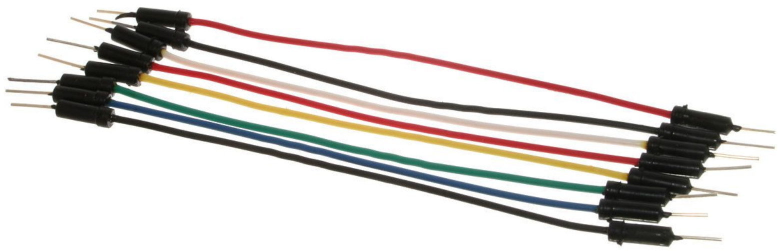


Fig. Some jumper wires

A piece of plywood provides a durable base for building prototypes on top of and also for testing and troubleshooting the finished product.

Fig. A sheet of plywood

Capacitors are commonly used electronic components which store charge. In testing our electrical system, we use these for switch debouncing.

Fig. Some capacitors

Rocker switches with built in LEDs can turn elements of our system on and off, while indicating the state of the switch as they do so. If the switch is on, an LED is lit, making it clear to a user which way is on or off. They are called rocker switches because they rock back and forth.

Fig. Some Rocker switches with LEDs

A meter stick is useful to us for measuring components and verifying that they meet the dimensional requirements we have for them. It measures distance using the metric system.

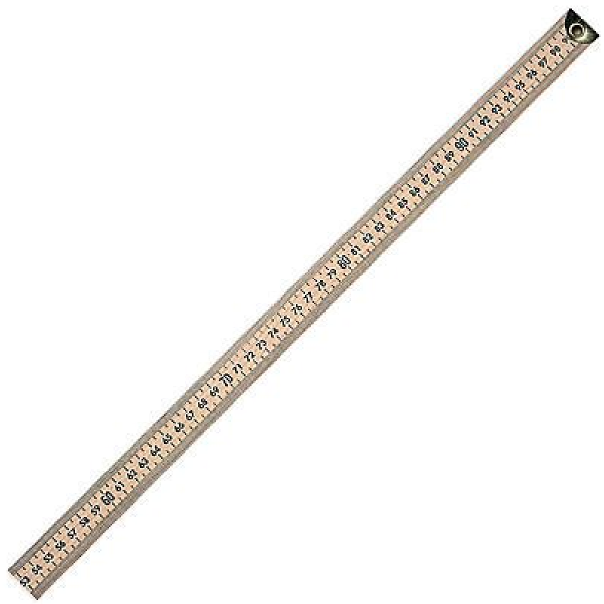


Fig. A meter stick

Calipers are very helpful for measuring the distance between two points, especially things such as inner and outer diameters and very small distances. Whereas the meter stick finds usefulness in measuring the larger components of the mpARM, the calipers are just right for the smaller components.

Fig. A pair of calipers

There are not software considerations for the purely electromechanical elements of our design, other than that the electromechanical systems must be operational to fully test the software.

3.3 Functional Testing

Robotic Arm:

The robotic arm portion is being tested on its mobility, ability to maneuver in a precise and fluid way, and the weight it can carry. For testing the range of motion the robotic arm can produce, human commands transmitted through the Arduino microcontroller directs the position of the motors controlling the robotic arm. By having the motors operating at only a fraction of their potential speed, the team is able to reliably determine the capabilities of the robot. This test does not require the documentation of the max range values the arm is able to perform, instead team members observe whether or not the arm is capable of performing the same degrees of motion used to make and plate a pancake. The next test is designed to test how fluid the robotic arm can perform actions. By playing with the Arduino IDE and how the program interacts with the motor controllers which in turn affect the motion of the motors controlling the robotic arm, team members are able to determine not only how smooth the robot can perform any desired task in addition to the speed at which the task is completed. The final test involves whether the prototypes in addition to the pancake being cooked can be supported by the robotic arm. Luckily, the robotic arm we are constructing has supporting documentation which includes the maximum payload the arm is capable of carrying. By measuring the weight of the prototypes being added to the robotic arm and by knowing the weight of a pancake the team is able to test if the arm is capable of the additional features the team is opting to add on.

Computer Vision:

The software program for the computer vision system will be tested by holding a camera connected to a laptop and verify whether the algorithm detects when a pancake should be flipped. The code will then go through integration testing on the FPGA by manually executing the code. After sufficiently satisfied with the result, the code will undergo system testing by verifying that the code is constantly used automatically by the running program. Once completed, the entire mpARA system will go through acceptance testing by doing small user testing cases and checking if the results are as expected.

Electrical and Mechanical Systems:

The electrical system is tested with a multimeter and oscilloscope to ensure that the expected electrical behavior is found at each node in the circuitry. This includes voltage level, power consumption, and signal integrity. This would prevent issues such as short circuits, interference, and other undesirable effects. The interactions between the electrical and mechanical systems is tested by a few key evaluations. Firstly, wires and cables must not be loose and in the way of the moving parts, nor should their harnessing impede the motion of the arm. Secondly, it must be demonstrated that the motors work properly. This can be shown by observing the motors move or not according to the appropriate signal. Thermal dissipation must be kept in check to avoid overheating. Precautions are taken to account for this, such as heat sinks and proper ventilation, but by feeling the heat with one's hand it can be determined if it is a significant issue. A thermometer may be needed to get a more accurate determination of this.

Embedded Systems:

The functional testing will be if the FPGA can handle all the inputs and output them correctly, the FPGA having enough power to handle the components that we are using and testing of the code to be able to know what to do when the image comes in from the computer vision.

3.4 Non-Functional Testing

Robotic Arm:

The nonfunctional testing surrounding the construction of the robotic arm is purely aesthetic. The arm must be easily incorporated into existing kitchens in an easy and efficient way without ruining the current kitchen setup. Testing is done by meeting with several individuals unrelated to the team and getting their input on the device. Specifically the are being asked whether this product would fit in their current cooking setup and if they see the robotic arm as another appliance for their kitchens. This is an important test as clients will need to feel that our product is not intrusive to their space, but rather enhances it. Having a survey group to understand whether this was accomplished is vital to the products success.

Computer Vision:

The computer vision system will need to be reliable enough to constantly send images of the griddle. This would be tested by doing duration tests of how long the camera can continuously run while the FPGA processes the data at the same rate. The process needs to be scalable to relay detailed information about multiple pancakes within the set field of vision. This will be tested by starting with one pancake and adding additional pancakes until the embedded system does not receive enough details of each pancake to be successful. Once completed, the computer vision system should require little to no maintenance after the final testing stage is done.

Electrical and Mechanical Systems:

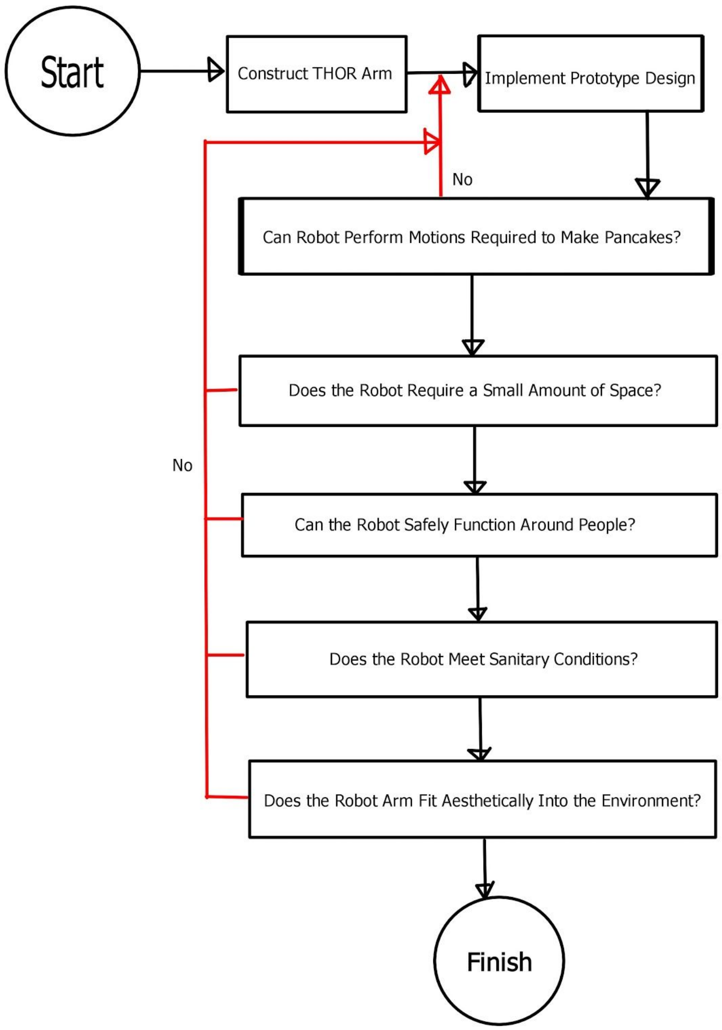
We test that the overall appearance is aesthetically pleasing to many people. In addition we survey the user experience with the controls and operating the machine. Further, we test that people find it easy to clean. This is done by finding a group of self-selected volunteers and asking them to respond to a series of questions after allowing them to interact with the machine.

Embedded Systems:

The big test for this is that it can do everything fast enough so that pancakes don't get burnt and everything run smoothly so that every output is correct.

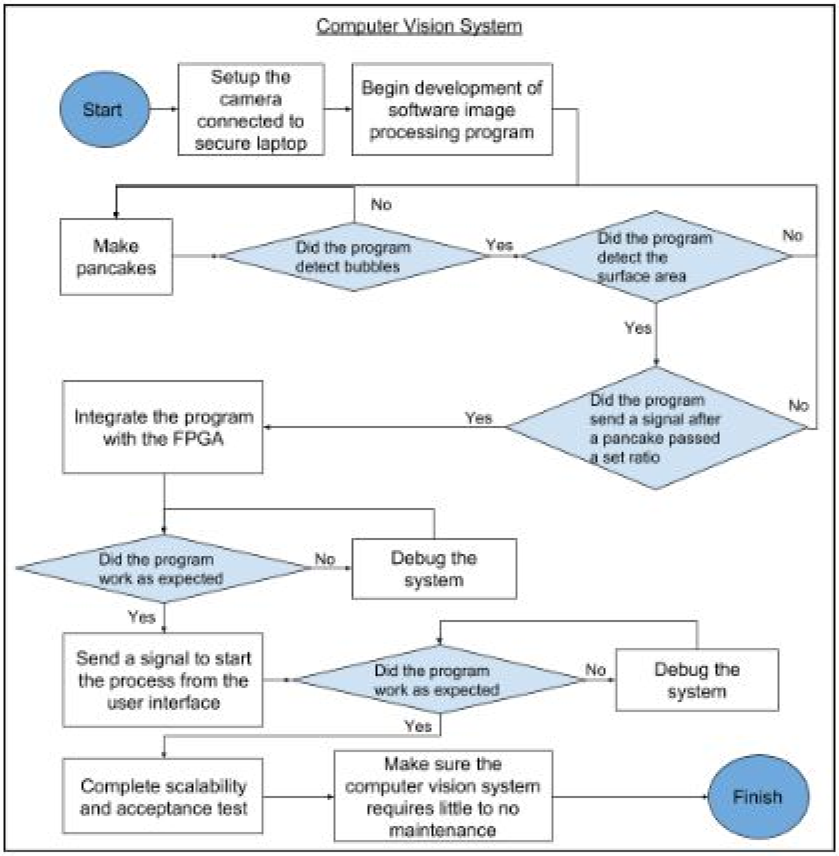
3.5 Process

Robot Arm:



The methods used to test whether or not the robot is capable of producing a pancake and if the robot met the aesthetic requirement were discussed in a previous section the the documentation and will not discussed here. Determining the amount of space the robot is allowed to function in has not been currently defined. The team is currently constructing a maximum amount of space in which the robot will be required to function in. A box with the volume of the desired space is then constructed and so long as the robot doesn't make contact with the box while operating it passes the space test. A test determining how safe the product is around people is a harder test to develop. The team is currently observing the function of the robotic arm and examining the potentially harmful effects the robots process might have on humans within the vicinity. For future tests having simulated humans interacting in the same environment will be implemented and observed. Any harmful tendencies the robot shows in the process will be fixed. When it comes to determining if the robot meets sanitation requirements, the team is reviewing the sanitary codes of restaurants and making sure the robot meets all of said requirements as a kitchen appliance.

Computer Vision:



Electrical and Mechanical Systems:

Testing methodology for this section of the machine proceeds as follows:

1. The functional aspects are tested first, being that they are fundamental to the project.
    a. Electrical components are tested first, since they move the mechanical parts it is natural that they should have precedence.
        i. Electrical safety (including shock and fire hazards) is addressed once the basic circuitry is in place.
        ii. Proper electrical characteristics are tested for each component to verify that each is functional before going into a larger circuit. A power supply and multimeter is used for this.
            1. If a component does not function as needed, it is exchanged for a different one which is tested in the same fashion. This is repeated until a satisfactory component is found.
        iii. The components are assembled into the circuits dictated by the schematic using a breadboard, power supply, jumper wires, and necessary discrete components.
        iv. Testing with an oscilloscope and multimeter is conducted to verify the desired circuit behavior is observed.
            1. If changes are needed, the circuit is adjusted accordingly until the functionality being tested is achieved.

b. The mechanical pieces are tested.
   i. Each component is assessed for appropriate durability.
   ii. Each component is tested for proper dimensions.
      1. For many components, this may be done by simply ensuring that they fit together with certain other components. For others, it may involve taking measurements with a meter stick or calipers.
c. The entire system is assembled and troubleshot at a holistic level.
   i. Th overall functionality may be assessed by evaluating the pancakes produced by the machine. Namely;
      1. Does the machine move according to the programming it is given?
      2. Does the machine allow batter onto the griddle?
      3. Does the machine heat the griddle adequately (not too much and not too little)?
      4. Does the machine allow the batter to cook into a pancake (neither prematurely ending cooking nor overcooking the pancake)?
      5. Does the machine flip the pancake?
      6. Does the machine exit the pancake once it is done cooking?

2. The non-functional aspects are tested. While important, the implications of aesthetics, user-friendliness, and ease of cleaning are determined by the situation created by implementing the functionality of the mpARM.
   a. With a functional prototype, people from outside our group are invited to assess the overall appearance, ease of use, and ease of cleaning of the machine. It is desirable that they should give feedback to questions such as:
      i. Would you eat pancakes made by this machine?
      ii. Would you consider having this machine in your home or business?
      iii. Do the controls feel intuitive?
      iv. Do you feel that this machine is easy to clean and care for?
      v. Is this machine easy to use?
      vi. If this were a commercially available product, would you consider purchasing one and why?
      vii. Do you feel that this machine has a nice appearance? Why or why not?

Embedded Systems (Flow Chart):

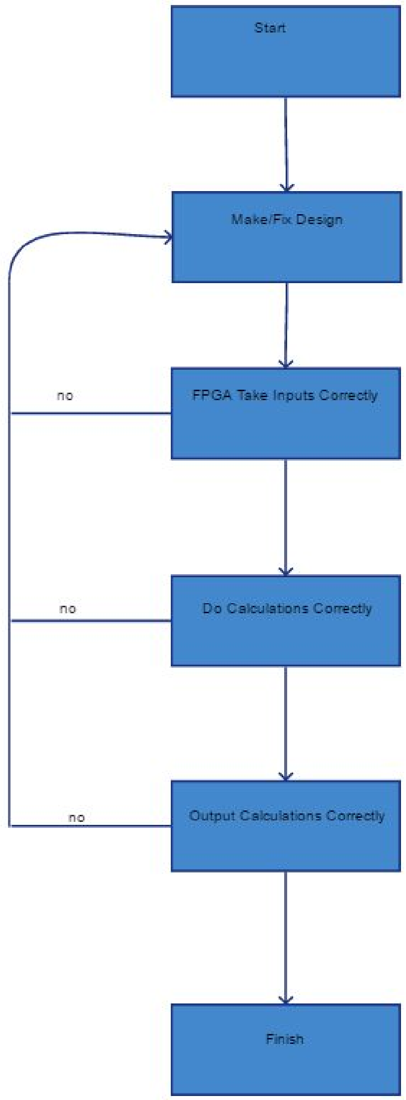


Fig 5. Testing when able to

3.6 Results

Robotic Arm:

There have been no results for testing the robotic arm as thus far into the course physical construction of the project is limiting as ,ost constructing is reserved for later into the first semester and the majority of the second semester.

Computer Vision:

There have been no results for the computer vision system because the software and hardware of the embedded system has not yet been concluded.

Electrical and Mechanical Systems:

The physical testing has not yet proceeded. However, ideas have been theoretically tested to arrive at the present design. This is in terms of feasibility, safety, and other practical matters.

Embedded Systems:

There hasn't been any results yet because it is early in the course.

4. Closing Material

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

http://thorrobot.org/

4.3 Appendices

Not yet established