PANCAKE FLIPPER

ECE 445 DESIGN DOCUMENT - SPRING 2024

Team 54

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1 Introduction

1.1 Problem

Making pancakes at home can be frustrating for even the most patient chefs due to potential problems. Pancake flipping, in particular, is prone to issues such as tearing, folding, and burning. Achieving the perfect golden-brown outside without overcooking is a delicate balance. Deformed pancakes can also detract from their appealing texture. A more flexible solution is needed, emphasizing the necessity for pancake-making equipment that accommodates various tastes, ensuring a fun and easy cooking experience.

1.2 Solution

The proposed solution is a robotic pancake flipper equipped with a spatula, designed to automate the flipping process and ensure perfect pancakes every time. This device integrates an electric griddle and a mechanical system comprising a linear drive, a linear actuator, and servos. The electric griddle cooks the pancake, which is then moved towards the spatula by a linear actuator. The spatula, capable of side-to-side motion via a linear drive, positions itself beneath the pancake.One servo lifts the spatula and the other flips it, flipping the pancake to cook evenly on both sides. This automated system aims to eliminate common pancake-making issues by precisely controlling the cooking and flipping process, ensuring consistent and satisfactory results.

1.3 Visual Aid

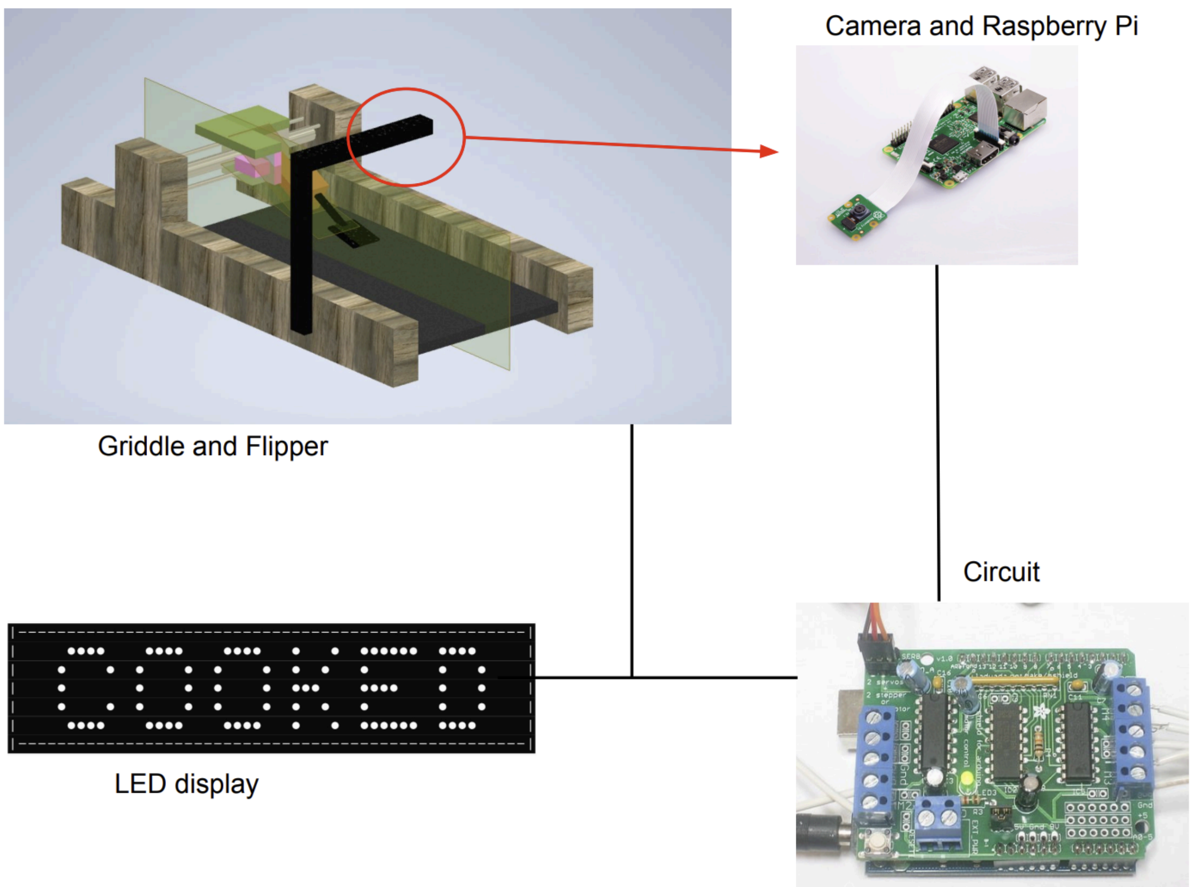

Figure 1: Preliminary CAD for pancake flipping device

1.4 High Level Requirements

To consider our project successful, the device must do the following.

Pancake Flipping Accuracy: The robotic spatula must flip pancakes with a precision that ensures minimal tearing of the pancake. Any tears must be kept under 0.5 inches**.**

Bubble Detection for Flipping Cue: The camera module should detect when there are 5 unclosing holes, with a margin of plus or minus 3 holes, as an indicator that the pancake is ready to be flipped. Upon reaching this threshold, the system will initiate the griddle's movement towards the robotic spatula for flipping.

Post-Flip Action Notification: After the pancake has been flipped and the griddle returns to its original position, the device will display a "Remove Pancake" message on the screen. This message will remain visible for 15 seconds to ensure the user has ample time to react. This 15 second period can have a 2 second margin of error.

2 Design

2.1 Block Diagram

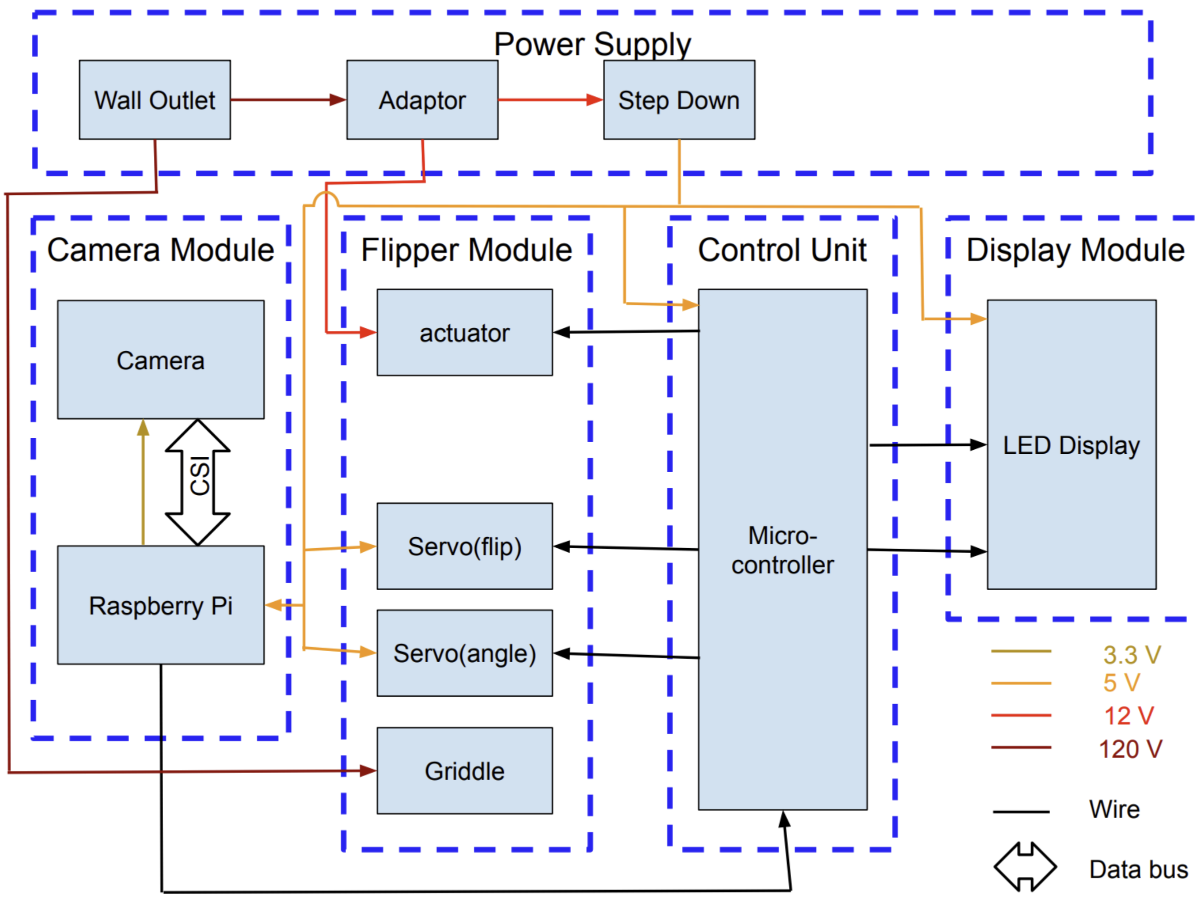

Figure 2: High-level block diagram of pancake flipping device

2.2 Subsystem Overview

This section details the components of the robotic spatula system, focusing on the functionality and interaction between subsystems to achieve seamless operation.

Power Supply: The power supply subsystem is crucial for distributing the appropriate voltages to various components of the system. It receives AC power from a wall outlet and uses an adapter to convert this into a 12V DC voltage. A regulator converts the 12V to 5V. The 5V output powers the Raspberry Pi, microcontroller, and LED display, ensuring low-voltage components operate safely. The 12V output is dedicated to higher power requirements, such as the linear actuator and servos, which are integral to the physical manipulation of the pancake. The griddle, requiring more substantial power, is directly connected to the wall outlet, bypassing the internal power supply to handle its high power consumption efficiently.

Camera Module: The camera module serves as the system's visual input, comprising a camera attached to a Raspberry Pi. This module captures real-time images of the pancake, which the Raspberry Pi analyzes using a binary AI classifier to determine the pancake's readiness for flipping based on specific criteria, such as surface bubble coverage. Once the pancake is deemed ready, the Raspberry Pi communicates this to the microcontroller with a single signal, initiating the flipping sequence. This direct communication ensures timely and coordinated action between the visual assessment and the physical flipping mechanism.

Flipper Module: The main component of the physical operation is the flipper module, which includes an actuator, and two servo motors—one for executing the flip motion and the other for adjusting the spatula's angle. The angle adjustment servo positions the spatula precisely under the pancake. The actuator then moves the griddle forward, sliding the pancake onto the spatula.

Following this, the angle servo lifts the pancake and the flipping servo flips the pancake. The movement of each component is coordinated by the microcontroller which sends individual signals to each component.

Control Unit: The control unit, powered by a microcontroller, acts as the central command center. It interprets the signal from the Raspberry Pi to commence the flipping process and orchestrates the movements of the flipper module. By moving the linear driver and activating the servos, the microcontroller ensures the pancake is flipped with precision. Additionally, it communicates with the Display Module to provide real-time updates on the system's status, enhancing user interaction.

Display Module: An integral part of user interaction, the LED display module offers real-time status updates concerning the pancake's cooking and flipping stages. While the specifics of the displayed messages ("Place Batter," "Pancake Cooking," "Flipping," "Cooked") will be refined throughout the project's development, this module ensures the user is informed of the current state of operation, facilitating a user-friendly interface that complements the automated process. The display module receives two signals from the control unit. It decodes the two signals to decide which message to display.

2.3 Functional Overview & Block Diagram Requirements

2.3.1 Power Supply Subsystem

This subsystem contains an adaptor that converts AC to DC and supplies the linear actuator, the Raspberry Pi, and microcontroller. The power lines must be capable of handling the current without significant voltage drop over the length of the wire. Connectors should provide secure, stable connections to prevent power disruption.

Requirements	Verification
Adaptor supplies at least 3A at 12 V +/- 0.2V for the linear actuator and at least 1.5A at 5V +/- 0.1V for the Raspberry Pi and microcontroller.	Use a multimeter to measure the output voltage of the adaptor under a load simulating the linear actuator's consumption and the output voltage of the adaptor under a load simulating the combined consumption of the Raspberry Pi and microcontroller.
The power lines must be capable of handling the current without significant voltage drop over the length of the wire.	Perform a voltage drop test by measuring the voltage at the beginning and end of the power lines under maximum expected load.

Table 1: Requirements and verification of power supply subsystem

2.3.2 Camera Module Subsystem

We are using Raspberry Pi to process the camera feed in real-time and run the binary AI classifier to determine pancake readiness. Our camera will capture images at a resolution sufficient for the AI classifier to determine the cooking status.

Requirements	Verification
Raspberry Pi requires a stable 5V power supply and must interface with the camera using the Camera Serial Interface (CSI). The Pi must process the camera feed in real-time and run the binary AI classifier to determine pancake readiness.	Use a multimeter to measure the voltage at the Raspberry Pi's power input while it is running. Verify the physical connection between the Raspberry Pi and the camera module through the CSI port. Test the interface by capturing a series of test images or video to confirm successful communication and data transfer.
Camera needs to capture images at a resolution sufficient for the AI classifier to determine the cooking status accurately.	Determine the minimum resolution required by the AI classifier for accurate cooking status determination. Test the camera by capturing images at this resolution and running them through the classifier to verify accuracy.

Table 2: Requirements and verification of camera module subsystem

2.3.3 Flipper Module Subsystem

This subsystem contains an actuator and a linear driver and they must provide precise control of the spatula's position. We will also be using two servos, one is the flip servo and the other is the angle servo. They must provide precise torques for the system to run accurately.

Requirements	Verification
Actuator and linear driver must provide precise control of the spatula's position with a positional accuracy of +/- 5 mm and must operate at 12V.	Perform multiple operations to ensure the actuator maintains the specified positional accuracy of +/- 1mm. Verify the operation voltage of the actuator and linear driver is consistently at 12V using a multimeter.
Servos are required to rotate accurately within a 1-degree precision and operate on a 5V power supply. The torque needed for the flip servo is approximately 0.3 Nm, while the angle servo requires about 1.5 Nm. The flip servo must achieve a 180-degree rotation, and the angle servo should reach 90 degrees.	Use a protractor or an angle measurement tool to verify that the servo can achieve rotations with 1-degree precision. Confirm the servos operate at a stable 5V supply voltage using a multimeter. Test each servo by applying a load equivalent to the required torque specification and measure the actual torque output to ensure it meets the 0.3 Nm for the flip servo and 1.5 Nm for the angle servo. Measure the rotation angle using a protractor or digital angle finder to ensure the flip servo reaches a full 180-degree rotation and the angle servo achieves a 90-degree rotation.

The mass of the flip servo must be under 0.12 kg	The specification on the mass for the flip servo will be checked before purchasing. The mass can be verified using a scale.

Table 3: Requirements and verification of flipper module subsystem

2.2.4 Control Unit Subsystem

The control unit subsystem contains a microcontroller that handles multiple input/output operators with the camera module, flipper module, and display module simultaneously. We will ensure that the microcontroller provides timely flipping.

Requirements	Verification
Microcontroller requires a 5V power source and must be capable of handling multiple input/output operations	Use a multimeter to confirm the microcontroller is receiving a stable 5V power supply. Conduct a stress test by simultaneously triggering various input and output tasks programmed into the microcontroller and observe if it can manage without errors or resets.
Microcontroller must process Raspberry Pi signals and control the Flipper Module within 100 milliseconds to ensure timely	Implement a test script on the Raspberry Pi that sends signals to the microcontroller, simulating the commands to flip. Measure the response time from signal

flipping.	reception to the initiation of the Flipper Module's action using a logic analyzer or timing software.
Must include digital I/O for controlling the Flipper Module and a serial or I2C connection to the Display Module.	Physically inspect the microcontroller to confirm the presence of the required digital I/O pins and either a serial or I2C interface for connections.

Table 4: Requirements and verification of control unit subsystem

2.2.5 Display Module Subsystem

The display module subsystem contains a LED display that presents information legibly in various lighting conditions. It will receive data from the microcontroller to display the pancake and griddle status. The display will update the user with real time status.

Requirements	Verification
The LED display must operate on a 5V supply and be able to present information legibly in various lighting conditions.	Use a multimeter to verify that the LED display operates with a 5V power supply. Place the LED display in environments with differing light levels (e.g., bright sunlight, dim light) and confirm that the information displayed remains clear and readable from a reasonable distance.

Must receive data from the microcontroller via I2C or a similar protocol to display the pancake and griddle status.	Send test data from the microcontroller to the display, representing various pancake and griddle statuses. Verify that the display accurately reflects the sent data and correctly represents the status information.
The display should update within 500 milliseconds of receiving new data.	Simulate real operation by continuously sending updated status data from the microcontroller to the LED display. Measure the time interval between sending the data and the display update using a stopwatch or a software tool capable of timing the update latency.

Table 5: Requirements and verification of display module subsystem

Each of these subsystems must meet their respective requirements to ensure the robotic pancake flipper operates as intended, fulfilling the high-level requirement of providing a reliable, automated pancake-cooking experience.

2.4 Hardware Design

2.4.1 Operating Voltage and Regulation

To ensure the optimal operation of our project's various components, it is crucial to supply regulated voltage to our devices. Our design approach involves using a 12V power supply directly from the wall, from which we will step down the voltage to 5V for the components requiring lower voltage.

For the Raspberry Pi Zero 2 W and Pi Camera, both require a 5V supply to function properly. The Raspberry Pi Zero 2 W has a maximum current requirement of 580mA, while the Pi Camera needs up to 250mA. To accommodate these components, we will utilize a step-down voltage regulator to convert the 12V supply to a stable 5V, ensuring compatibility and maximizing performance.

The microcontroller operates at a higher 5V input voltage in our setup, drawing up to 500mA. This arrangement allows for direct compatibility with our chosen 12V wall power supply, simplifying the power management system by eliminating the need for voltage conversion for this component.

The Lift Servo and Flip Servo are designed to operate at 5V, with substantial current requirements of 1900mA and 1800mA, respectively. These significant current demands necessitate a robust power supply system that can deliver high currents at 5V while maintaining stable voltage levels, ensuring efficient and reliable servo operation. It can be noted that the servos are capable of operating at up to 6.8 volts to meet the advertised torque, however it would unnecessarily add complexity to our design so we will operate them at 5V.

The Linear Actuator requires a 12V supply and draws 3A of current. This component, along with the microcontroller, can be powered directly from our 12V wall supply, simplifying the design by reducing the number of components requiring voltage regulation.

Our project incorporates two primary voltage rails: a 12V rail for the microcontroller and Linear Actuator, and a stepped-down 5V rail for the Raspberry Pi Zero 2 W, Pi Camera, and servos. The total current requirement for the 5V components sums to 5030mA, indicating the need for a power supply capable of meeting these demands efficiently. For the 12V components, the microcontroller draws 500mA, and the Linear Actuator 3A, emphasizing the importance of a reliable 12V power source.

To manage the voltage regulation efficiently, we will employ a high-efficiency step-down (buck) regulator to convert the 12V supply from the wall to 5V for the necessary components. This method ensures minimal power loss and maximizes the efficiency of our power distribution system.

Our design strategy focuses on simplicity, efficiency, and reliability. By minimizing unnecessary voltage conversions and optimizing for the specific voltage requirements of our components, we aim to reduce power loss/heat and ensure stable operation across all devices.

	Voltage	Current (Max)
Microcontroller	5V	500mA
Raspberry Pi Zero 2 W	5V	580mA
Pi Camera	5V	250mA
Lift Servo	5V	1900mA
Flip Servo	5V	1800mA
Total		5030mA
Linear Actuator	12V	3A
Total		3000mA

Table 6: Voltage and amperes for parts

2.4.2 Transistor Motor Control System

For the effective management and control of a DC motor requiring a 12V 3A setup in our project, we've opted to utilize the TIP120 NPN Darlington transistor and the 1N5406 GP rectifier. Their availability at the UIUC ECE student center and their suitability for our specific power requirements influenced this decision.

The TIP120 transistor, with its capability to handle loads up to 60V and a continuous current of 5A, is an ideal choice for our application. It offers a peak current handling capacity of 8A, which comfortably accommodates our motor's 3A requirement. The transistor's high DC current gain (hFE) of approximately 1000 is beneficial for achieving the desired amplification without necessitating excessive input power. Additionally, its base current requirement of 120mA for full saturation makes it compatible with the control signals from our microcontroller unit, facilitating straightforward integration into our circuit

To complement the TIP120, the 1N5406 GP rectifier has been selected for its robust voltage and current handling capabilities, offering protection against the back EMF generated by the DC motor. This ensures the longevity and reliability of our motor control system by safeguarding the transistor and other circuit components from potential damage due to sudden voltage spikes.

In the implementation phase, particular attention will be paid to the thermal management of the TIP120, considering its operation within a high-power environment. The TO-220 package of the TIP120 facilitates efficient heat dissipation, but the inclusion of a heatsink may be considered to enhance thermal performance further, ensuring the system's stability under prolonged operation. Additionally, the circuit design will incorporate a base resistor to limit the base current to the TIP120, preventing overdrive and potential damage to the transistor.

The integration of these components into our motor control system is conducted with precision, ensuring that the electrical characteristics of the TIP120 and the 1N5406 align with the operational requirements of our motor. By doing so, we aim to achieve a balance between performance, efficiency, and reliability, enabling the controlled and safe operation of the DC motor within the scope of our project's objectives.characteristics and ensuring their compatibility with our system's requirements, we achieve a robust and efficient control mechanism capable of handling demanding applications with ease.

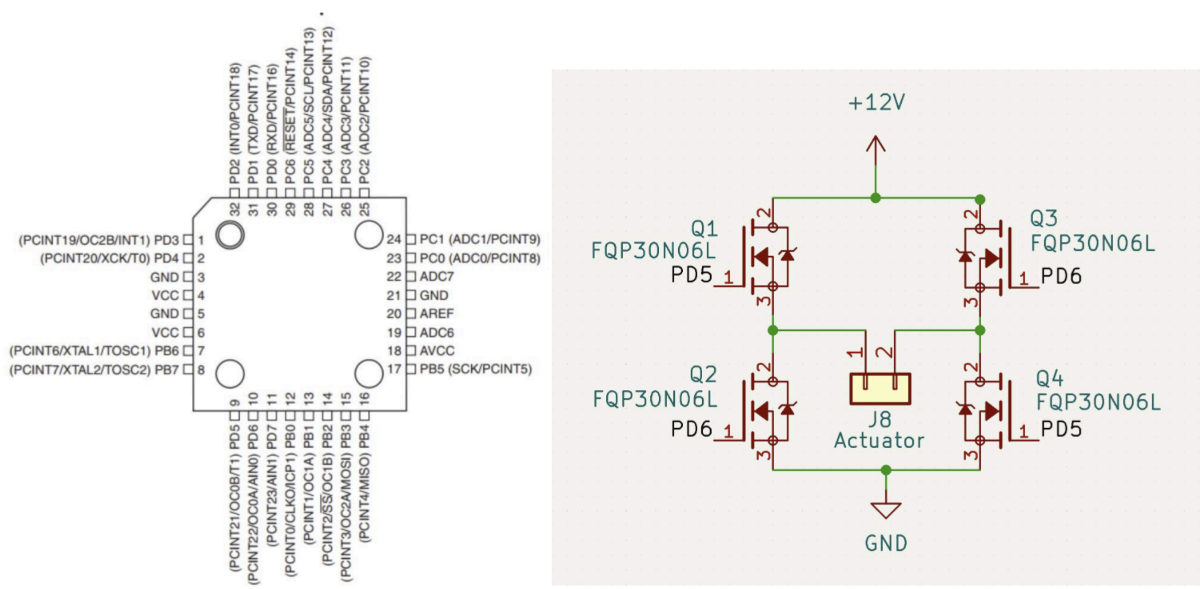

Figure 3: Schematic of linear actuator and microcontroller (ATmega328) using h-bridge

2.5 Software Design

2.5.1 Video Acquisition and Labeling

To build a robust image classifier, we will record multiple videos of pancakes cooking, capturing diverse lighting conditions and pancake types. Frames extracted from these videos will be meticulously labeled as "ready to flip" or "not ready." This manual labeling, based on bubble formation and browning, provides the crucial ground truth data for training the model.

Frame Extraction: Extract individual frames from the videos at a suitable frame rate (e.g., 10 frames per second) to obtain a larger set of images.

Manual Labeling: Here's where manual flipping comes in. We will meticulously label each frame:

"Ready to flip": Mark frames where the pancake exhibits enough bubbles and browning to indicate readiness for flipping.

"Not ready": Label all other frames where the pancake is undercooked or lacks sufficient visual cues.

Annotation Tool: Use a labeling tool like LabelImg to create bounding boxes (if necessary) and assign the correct labels to each image.

2.5.2 Model Training Refinements

Our videos offer a wealth of training examples and allow us to employ data augmentation techniques. Cropping, rotation, and changes in brightness and contrast will simulate diverse real-world scenarios, enhancing our model's robustness. For efficient training, we will use transfer learning, fine-tuning a pre-trained image classification model on our pancake-specific dataset.

Data Augmentation: With videos, we can easily increase the size and diversity of the training dataset by applying transformations like:

Cropping to focus on the pancake area.

Rotation to simulate different pancake orientations.

Brightness and contrast adjustments to account for lighting variations.

Adding noise to improve robustness.

Transfer Learning: Since we may have a limited dataset initially, start with a pre-trained model like MobileNetV2. Fine-tune it on your pancake images to leverage the knowledge it has learned on general image classification tasks.

2.5.3 Algorithm

The algorithm is as follows:
Step 1: Gather Pancake Cooking Data
- Record videos of pancakes cooking under different conditions.
- Extract frames from these videos.

Step 2: Label the Frames
- Watch each frame and decide if the pancake is "ready to flip" or "not ready."
- Mark each frame accordingly.

Step 3: Prepare Data for Training
- Resize and normalize each frame to a standard size.
- Augment the dataset by making variations like rotating images, adjusting brightness, etc.

Step 4: Choose a Model
- Select a pre-trained model suitable for image classification tasks (e.g., MobileNetV2).

Step 5: Train the Model
- Initialize the selected model with pre-trained weights.
- Add additional layers on top for our specific classification task.
- Split the labeled data into training and validation sets.

- Train the model using the labeled frames, using techniques like transfer learning.
- Monitor the model's performance on the validation set during training.

Step 6: Evaluate the Model
- Once training is complete, assess the model's performance using a separate test set.
- Check metrics like accuracy, precision, and recall to see how well it classifies pancakes.

Step 7: Deployment
- Deploy the trained model for real-world use, where it can classify pancake readiness in new images or videos.

Step 8: Continuous Improvement
- Gather feedback on the model's performance in real-world scenarios.
- Periodically retrain the model with additional data or fine-tune hyperparameters to improve its accuracy.

2.5.4 Inference and Communication

During operation, our Python script will capture real-time camera frames, apply preprocessing consistent with the training data, and feed them to the classifier. We will carefully calibrate the decision threshold to control when a "ready to flip" signal is sent to the microcontroller, ensuring a reliable flipping action

Video Preprocessing: In the Python inference script, extract frames from the camera feed in real-time. Apply the same preprocessing techniques (cropping, resizing, normalization) as during training.

Decision Threshold: Experiment with the prediction threshold. We might want a higher threshold (e.g., 0.9) to increase confidence that the pancake is truly ready before triggering the flipping action.

Communication Consistency: Ensure the signal sent to the microcontroller is unambiguous and easily interpretable (e.g., a simple "1" to initiate flipping and "0" otherwise).

2.5.5 Microcontroller

Communication and Signal Handling: The microcontroller will establish a communication channel with the Raspberry Pi using either serial, I2C, or digital I/O pins. It will continuously monitor for the "ready to flip" signal, initiating the pre-programmed flipping process upon receipt.

Servo Control: We will use the Arduino's Servo library to precisely control the angle servo (for lifting the spatula) and the flip servo (for the flipping itself). Thorough calibration of the servo positions within our mechanical setup is vital for reliable and accurate flipping.

Linear Actuator Control: Our approach will utilize either digital I/O pins for direct control or a dedicated motor driver board, depending on the specific linear actuator chosen. The microcontroller will control the actuator's movement, extending the griddle under the pancake and retracting it after the flip.

Sequence Flow with Safety: The core of the microcontroller logic resides in its main loop() function. It will await the "ready to flip" signal from the Raspberry Pi. Upon receipt, it seamlessly orchestrates the sequence: moving the griddle forward, lifting the pancake, flipping, and ultimately returning components to their starting positions. We will implement safety mechanisms like timeouts and limit switches to prevent damage if unexpected issues occur.

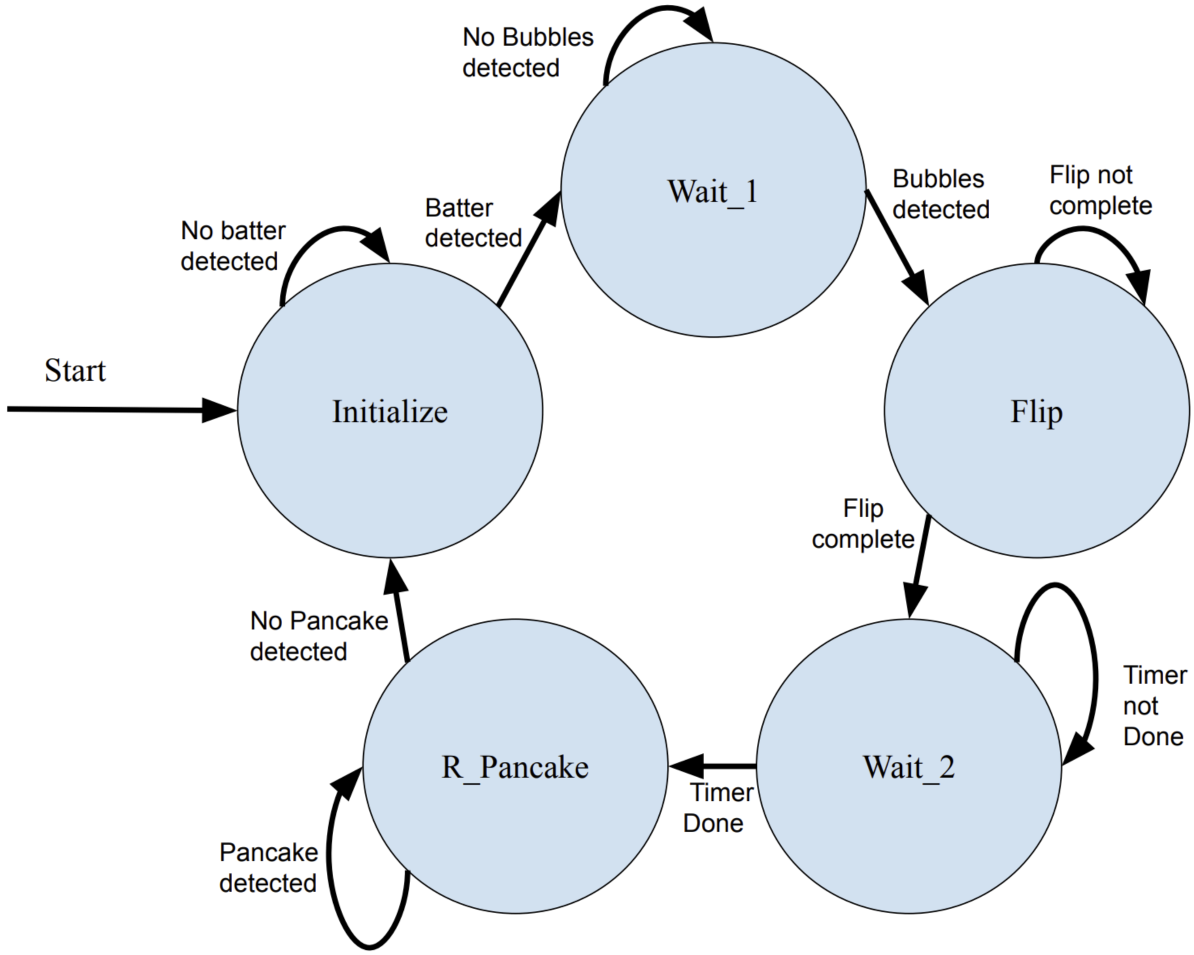

Figure 4: State diagram for microcontroller program

The following describes what each state does.

Initialize: The Initialize state resets the positioning of the flipper module and displays the "Pour Batter" message until the camera detects that batter has been placed. After 30 seconds, the microcontroller transitions to the Wait_1 state.

Wait_1: The Wait_1 state waits for the signal from the raspberry pi that indicates that the pancake is ready to be flipped to be high and displays the "Cooking" message. Once the signal is high, the microcontroller transitions to the Flip state.

Flip: In the flip state, the microcontroller moves the servos and actuator to execute the flip of the pancake. It brings in the griddle towards the spatula, lifts the spatula, and flips it. Then the griddle is slid back to the original position. Next, the spatula is unflipped and returned to its original position. Once all these steps are complete, the microcontroller moves on to the Wait_2 state.

Wait_2: In the Wait_2 state, the microcontroller waits for a period of time that is still yet to be determined. This is to allow the other side to cook. The “Cooking” message is still displayed and has been displayed since the Wait_1 state. Once the microcontroller is finished waiting, it moves to the R_Pancake state.

R_Pancake: In this state, the “Remove Pancake” message is displayed until the camera no longer detects a pancake on the griddle. After 30 seconds, the microcontroller returns to the Initialize state.

Note: when the camera detects batter in the Initialize state, detects bubbles in the Wait_1 state, or detects a pancake in the R_Pancake state, the raspberry pi will set its output signal to the microcontroller to high for 15 seconds.

2.6 Commercial Component Selection

2.6.1 Angle Servo Motor

For the servo motor that lifts the spatula and pancake, we chose to use the ZOSKAY 35kg high Torque Coreless Motor. The ZOSKAY 35kg high Torque Coreless Motor has a torque of 29 kg-cm at 5V or about 2.84 N-m which meets the torque requirement of 1.5 N-m set previously. Another major requirement of the angle servo motor is that it must have a range of motion of at least 90 degrees. The ZOSKAY 35kg high Torque Coreless Motor has a range of motion of 180 degrees. With the torque and range of motion requirements met, we are confident that the chosen servo motor will perform the lift as required.

2.6.2 Adapter and Regulator

For the adapter we are using the TOBWOLF 3 Prong DC 12V 8A Power Supply Adapter. We need 12V and 3A to power the linear actuator. We need the remaining power for the other components that require 5V. In order to step down the voltage to 5V, we will use the following voltage regulator: UCTRONICS DC 9V 12V 24V to DC 5V 5A Buck Converter Module.

2.7 Tolerance Analysis:

One of the critical aspects that poses a risk to the successful completion of the robotic pancake flipper project is the torque of the angle servo within the Flipper Module. The servo is responsible for adjusting the angle of the spatula. Not having enough torque could result in not being able to successfully flip the pancake or damaging the device itself.

Servo (Flip)

Variable	**Description**	**Value**
m_p	Mass of pancake	≤ 0.12 kg
r_p	Radius of pancake	≤ 0.10 m

m_s	Mass of spatula	≤ 0.11 kg
l_s	Length of spatula	≤ 0.30 m
m_f	Mass of flipping servo	≤ 0.12 kg
g	Acceleration of gravity	9.81 m/s^2

Table 7: List of variables for torque calculation

Assuming the worst case where all the weight is distributed the furthest away from the axis of rotation of the angle servo ($l_s + r_p$), the torque needed to perform the lift can be calculated using the following formula.

$$\tau = (m_p + m_s + m_f)*g*(l_s + r_p)$$

$$= (0.12 + 0.11 + 0.12)*9.81*(0.30+0.10)$$

$$= 1.37 \text{ Nm}$$

The torque requirement for the angle servo is set at 1.5 Nm. If the torque requirement and the requirement for the mass of the flip servo to be under 0.12 kg are met, the angle servo should be able to lift the pancake.

Incorporating the specific power requirements of 12V 3A for the linear actuators, servos, and 5V 5A for the Raspberry Pi, microcontroller, and LED display into our thermal analysis adds a layer of precision to our approach, ensuring that we account for the actual operational demands of the robotic pancake flipper system.

Detailed Thermal Analysis with Specific Power Requirements

Given the system's power requirements of 12V 3A for certain components and 5V 5A for others, we can further refine our thermal analysis to anticipate the heat generation and manage the thermal load effectively.

12V 3A Components: The components operating at 12V and drawing 3A of current will have a power consumption of P=V×I=12V×3A=36WP=V×I=12V×3A=36W. This substantial power draw necessitates efficient heat dissipation mechanisms, especially for the linear actuators and servos, which perform high-power mechanical operations that can generate significant heat.

5V 5A Components: Similarly, the components requiring 5V and drawing 5A consume P=V×I=5V×5A=25WP=V×I=5V×5A=25W. The Raspberry Pi and microcontroller, which are critical for processing and control tasks, fall into this category. Although these devices are less likely to generate as much heat as mechanical components, their continuous operation can still lead to elevated temperatures, requiring careful thermal management.

Applying Thermal Management Strategies

With these specific power requirements in mind, the project will implement targeted thermal management strategies:

For 12V 3A Components:
Implementing larger heatsinks with higher thermal dissipation capacity to manage the 36W power consumption. Active cooling solutions, such as small, efficient fans, may also be considered to enhance airflow around these components, particularly in enclosed spaces where

heat may accumulate.

Using thermal interface materials (TIMs) to improve the thermal contact between the components and their heatsinks, ensuring efficient heat transfer.

For 5V 5A Components:

While passive cooling may suffice for these components, monitoring their temperature in real-time using embedded sensors will allow for dynamic thermal management. If temperatures approach critical thresholds, the system can throttle processing power or activate additional cooling measures.

Ensuring adequate ventilation in the design of the device's housing to allow for effective ambient cooling, preventing hot air from stagnating around these components.

Integration and Safety Measures

Incorporating voltage regulation mechanisms that can respond to fluctuations in power demand will help stabilize the thermal environment within the device, preventing scenarios where voltage drops lead to excessive current and, consequently, heat generation.

Furthermore, integrating safety mechanisms like thermal fuses or shutdown protocols triggered by temperature sensors ensures the system can protect itself and the user from overheating risks. This proactive approach to managing the thermal output based on the specific power requirements of 12V 3A and 5V 5A components enhances the system's safety, reliability, and performance.

2.8 Cost Analysis

The total cost for parts as seen in the table below is $215.72. 6% sales tax adds another $12.94. We can expect a salary of $40/hr×2.5hr×60 = $6000 per team member. We need to multiply this amount with the number of team members, $6000× 3 = $18,000 in labor cost. This comes out to be a total cost of $18,215.72.

Description	**Manufacturer**	**Quantity**	**Extended Price**	**Link**
BELLA Electric Griddle with Crumb Tray	BELLA	1	$27.99	Link
IC MCU 8BIT 48KB FLASH 48TQFP	Microchip Technology	1	$1.74	Link
ATMEGA328P-PU MCU	Microchip Technology	1	$3.18	Link
Rasp Pi Camera Module 5MP 1080p	ARM	1	$8.54	Link
Raspberry Pi Zero W	Raspberry Pi	1	$24.99	Link

ZOSKAY 35kg high Torque Coreless Motor servo	35	1	$28.99	Link
Miuzei 20KG Servo Motor High Torque RC Servo	Miuzei	1	$13.59	Link
ECO-WORTHY Heavy Duty 330lbs Solar Tracker Linear Actuator	ECO-WORTHY	1	$42.99	Link
TOBWOLF 3 Prong DC 12V 8A Power Supply Adapter	TOBWOLF	1	$12.74	Link
UCTRONICS DC 9V 12V 24V to DC 5V 5A Buck Converter	UCTRONICS	1	$14.99	Link

Module				
AZERONE Led matrix pixel 4MM Pitch led panels digital led module	AZERONE	1	$35.98	Link

Table 8: Cost of device parts

2.9 Schedule

Week	Task	Person
February 18th - February 24th	Buy parts	All
February 25th - March 2nd	Test Servos and linear actuator	Jason and James
	Assemble and test power supply module	James
	Begin prototyping PCB and Flipper module	Jason
	Test Camera and Raspberry Pi	David
March 3rd - March 9th	Prototype and test PCB and Flipper module	Jason
	Prototype and test LED module	James
	Collect pancake data	David
	Begin programming Raspberry Pi	David
March 10th - March 16th	Continue programming Raspberry Pi	David
	Begin PCB design	Jason and James
March 17th - March 23th	Program Raspberry Pi	David
	Finish and order PCB design	Jason and James
March 24th - March 30th	Integrate and test all modules	All
	Revise and reorder PCB	All
March 31st - April 6th	Integration tests	All
	Revise and reorder PCB	All
April 7th - April 13th	Finalize assembly	All
	Integration tests	All
April 14th - April 20th	Fix remaining bugs	All
April 21th - April 27th	Demo	All
April 28th - May 4th	Presentation	All

Table 9: Schedule

2.10 Risk Analysis

There is a possibility that the camera may not detect the bubbles and will not send the proper signal to the microcontroller to initiate the flipping process. This poses a risk that the pancake will burn and potentially catch on fire. This risk must be addressed. To ensure that the pancake is not being cooked indefinitely, a five minute timer will be initiated in the microcontroller once the device is in the cooking regime (after the batter has been placed on to the griddle). If the bubbles are not detected within the five minutes, the signals to initiate the flipping process will be sent from the microcontroller to the linear actuator and servos.

3 Ethics and Safety

Ethical Considerations

The development and deployment of a robotic pancake flipper raise several ethical considerations that necessitate careful attention. These include concerns regarding user safety, data privacy (especially relevant if the device is connected to the internet or a smartphone), and the potential impact on employment within commercial settings. Addressing these issues is crucial to ensure the project aligns with the IEEE Code of Ethics, which advocates for prioritizing the welfare, health, and safety of the public, as well as the ACM Code of Ethics and Professional Conduct. Both codes emphasize the importance of:

- **Avoiding Real or Perceived Conflicts of Interest**, ensuring that any decisions or actions taken in the course of the project prioritize the public interest and welfare above personal or commercial gains.
- **Maintaining Privacy and Confidentiality**, especially in the handling of data collected or transmitted by the device, to protect users' personal information in accordance with IEEE's guidance on professional conduct.
- **Mitigating Negative Societal Impacts**, including addressing concerns related to job displacement in commercial environments by engaging with stakeholders to understand and, where possible, alleviate these impacts.

Safety Issues and Regulatory Compliance

Safety and compliance with regulatory standards are paramount to the ethical deployment of the robotic pancake flipper:

- **Physical Safety**: Design features such as guards around hot or moving parts, automatic shut-off mechanisms, and clear safety warnings are essential. The project will aim for compliance with UL (Underwriters Laboratories) and CE (Conformité Européenne) standards, reflecting the IEEE's commitment to minimizing the risk of harm and ensuring the safety and health of the public.
- **Regulatory Standards**: Adherence to FDA regulations for kitchen appliances will be ensured, particularly concerning the safety and non-toxicity of materials in contact with food, aligning with the IEEE's ethical principle of safeguarding public welfare.
- **Campus Policy**: The development process will comply with campus policies on laboratory safety and electronic device use, ensuring a safe environment for all project participants.

Mitigation of Safety Concerns

To address potential safety concerns:

- **Design Review and Testing**: The project will implement regular safety reviews and rigorous testing, consistent with the IEEE's emphasis on identifying and mitigating potential hazards to prevent harm.
- **Training and Documentation**: Comprehensive user manuals, safety warnings, and maintenance routines will be provided, aligning with the IEEE's ethical principle of making stakeholders aware of safety measures and maintenance practices to prevent accidents and injuries.

Avoiding Ethical Breaches

The project team commits to regular evaluations of practices, policies, and behaviors to identify and address potential ethical risks proactively. This includes thorough documentation of the project's processes, limitations, algorithms, and decision-making AI, ensuring transparency and accountability in line with IEEE ethical standards. As the project evolves, ongoing reassessment of ethical considerations will be conducted, taking into account feedback from teaching assistants, technological advances, and any new ethical dilemmas that may arise.

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