An-Najah National University

Faculty of Engineering & Information Technology

Computer Engineering Department

Graduation Project 2

CoffeeLine

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Acknowledgment

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we would also to thank our families, who gave us the continues support and shared their knowledge, which helped us complete and finish this project.

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With sincere appreciation,
Karam Zaidan
Ameed Salameh

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Abstract

This project aims to design and build a smart automated filling machine that can fill and package four different products: coffee, cardamom, tea, and cappuccino, with two available sizes. The system allows the user to choose the product type and the required weight (for example, 0.5 kg). After the selection, the machine automatically fills the container with the correct amount and seals it with a lid. The main idea of the project is to create a small automated production line that can work efficiently and accurately without human interference. The project focuses on using microcontrollers to control mechanical parts and perform industrial processes on a smaller scale. The system uses both Arduino and ESP32 microcontrollers. The Arduino is responsible for controlling the motors, sensors, and the filling process. The ESP32 works as the main controller that communicates with the Arduino to manage system operations and coordinate tasks. A load cell with an HX711 module is used to measure the weight accurately, and the system works in a Local Mode, all processes are done locally through an LCD screen and keypad, where the user can select the product and the desired weight

Chapter 1

Introduction

1.1 General background

With the rapid advancement of embedded systems and Internet of Things (IoT) technologies, smart solutions have become increasingly important in everyday control systems. Modern control applications are no longer limited to manual operation; instead, they rely on automation and microcontrollers to improve efficiency, reduce human error, and enhance system reliability. This has created a growing need for intelligent systems that are easy to control and capable of operating efficiently.

1.2 Objectives

The main objective of this project is to design and build a smart hardware system capable of automatically and accurately filling coffee with cardamom, tea, and Nescafe into containers or packages using the ESP32 microcontroller. The system allows users to select the type of product, ingredient amounts, and optional additions, while monitoring stock levels and providing alerts when supplies are low. The project aims to reduce human intervention, enhance the speed and efficiency of the filling process, and deliver a reliable and user-friendly experience.

1.3 Significance

The significance of this project lies in providing an innovative solution for fast and accurate filling of coffee with cardamom, tea, and Nescafe into containers, while reducing reliance on human intervention. By employing smart control techniques and automatic stock monitoring, the system enhances operational efficiency, minimizes errors, and ensures high-quality final products. The project represents a practical step toward integrating smart technology into food production lines and improving performance and productivity.

1.4 Organization of the report

This report is organized into several sections to present the CoffeeLine project clearly and systematically. The report begins with an introduction that provides the background and objectives of the project. The second section describes the project's scope and boundaries. The third section explains the methodology and procedures followed during the implementation of the project. The fourth section presents the results and practical observations, including any challenges encountered and how they were addressed. The fifth section discusses the significance and potential impact of the project. Finally, the sixth section summarizes the key conclusions and provides recommendations for future development. Appendices are also included to provide additional information and supporting data related to the project.

Chapter 2

Theoretical Background and Previous Work

2.1 Historical Context

The idea of beverage and food product packaging in containers has been around for decades, initially relying on traditional manual methods for preparation and filling. Workers used to fill coffee, tea, or Nescafe into containers by hand, which was time-consuming and prone to errors or contamination. As the industry developed and demand for ready-to-use products increased, the need for automated solutions capable of fast and precise filling became apparent.

In recent decades, food production lines have undergone significant transformation through the use of microcontrollers, smart sensors, and automated control systems, improving product quality, increasing efficiency, and reducing reliance on human intervention.

The **CoffeeLine** project represents a practical step within this context, combining smart control, stock monitoring, and automated filling of coffee with cardamom, tea, and Nescafe into containers in a precise and user-friendly manner.

2.2 Existing Literature

Over the past two decades, automated filling systems for powdered products such as coffee, Nescafé, tea, and spices have gained increasing attention. These systems aim to improve filling accuracy, enhance production efficiency, and reduce human involvement.

Early filling systems were mainly semi-automatic, requiring manual container handling and using simple mechanisms with limited accuracy. With technological advancements, modern systems began integrating load cells for accurate weight measurement, motors for precise movement, and sensors such as IR and ultrasonic sensors for container detection and material level monitoring.

Recent projects focus on small-scale automated systems controlled by microcontrollers like Arduino and ESP platforms, often supported by user interfaces such as LCDs, keypads, and mobile applications. Despite these developments, challenges related to calibration accuracy and system stability still remain.

2.3 Evolution of Agricultural Technology and Related Work

Automated filling systems for powdered products have developed from manual and semi-automatic processes into more advanced systems that use sensors, motors, and microcontrollers. Early solutions required human intervention for container positioning and filling control, while modern systems focus on improving accuracy and efficiency through automation.

Recent projects commonly use load cells for weight measurement, stepper and DC motors for precise movement, and microcontrollers such as Arduino and ESP platforms for system control and user interaction. These technologies help reduce human error and improve consistency in the filling process.

However, challenges such as calibration accuracy, electrical noise, and system stability still exist. Our project addresses these challenges by integrating automated container movement, real-time weight monitoring, and a simple user interface, making it suitable for small-scale automated production applications.

Chapter 3

Methodology

In this chapter, we provide a comprehensive explanation of the materials, methods, and standards employed in the design and development of the CoffeeLine smart system for filling coffee with cardamom, tea, and Nescafe into containers. The methodology encompasses the systematic integration of hardware components, software, and control systems, each playing a crucial role in ensuring accurate filling, precise quantity control, and stock monitoring.

Detailed descriptions of sensor and mechanical component selection, communication protocols, and software architecture are included to demonstrate how these elements work together seamlessly to achieve the project's objectives efficiently. Additionally, the interaction between the user interface and the automated system is explained to ensure a smooth and reliable user experience.

3.1 Standards and Specifications

Our design adheres to engineering standards to ensure reliability and compatibility. Notably, the IEEE 802.11 standard is employed for communication protocols, focusing on seamless con-nectivity and efficient data exchange within the system. Additionally, the design rigorously complies with safety standards, enhancing overall safety and user well-being.

3.2 Hardware Components

3.2.1 Microcontrollers

Arduino Mega 2560

The Arduino Mega 2560 microcontroller board, built around the ATmega2560 chip, offers a robust set of features for various applications. It includes 54 digital input/output pins, 15 of which can be used for pulse-width modulation (PWM) outputs. The board also provides 16 analog inputs, 4 hardware serial ports (UARTs), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This extensive feature set makes it an ideal choice for our project needs. Given the large number of devices that need to interface with the microcontroller, the Arduino Uno was deemed insufficient, leading us to select the Arduino Mega 2560 as the central microcontroller for our project.

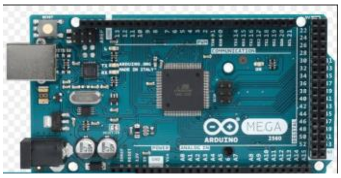

Figure 3.1: Arduino Mega 2560 Microcontroller Board

The project utilizes both the **ESP32-DevKitC ESP32-WROOM-32U Core Board** and the **Arduino Mega** microcontrollers, which play essential roles in enabling smooth communication between the system components. The ESP32 acts as a control interface, allowing users to select the product type and desired weight through a mobile app or local interface. Once a command is received, the Arduino Mega executes the corresponding task—such as activating the filling, weighing, or lid-sealing mechanisms—ensuring accurate and efficient operation throughout the production line.

Figure 3.2: ESP32-DevKitC ESP32-WROOM-32U Core Board

3.2.2 Motors and drivers

Stepper motor

Figure 3.3: Stepper Motor

Stepper motors are commonly used in systems that require precise control of position and movement. They operate by rotating in fixed steps, which allows accurate control of speed and direction without the need for complex feedback mechanisms.

In this project, a stepper motor is used to control the dispensing mechanism for filling coffee with cardamom, tea, and Nescafe into containers. The motor ensures accurate and consistent portioning during the filling process. It was chosen for its high precision, reliability, and suitability for continuous automated operation.

The **NEMA 17 stepper motor** is used for precise control of the filling and lid-pressing mechanisms in our automated production line. Known for its high torque and accuracy, it allows smooth and consistent movement of the conveyor belts and lid platform. Paired with the **DIV268N driver**, which supports microstepping and includes over-current and overheat protection, this setup ensures reliable and precise operation for positioning containers and pressing lids accurately during the filling process.

Figure 3.4: DIV268N driver

DC Motor

Figure 3.5: DC Motor

Figure 3.6: H-Bridge

The DC motor is used to move the pressing plate responsible for sealing the lid onto the container.

It is controlled through an H-bridge circuit, which allows the motor to rotate in both directions, enable precise up-and-down movement of the pressing mechanism during the lid sealing process

3.2.3 Sensors

In our project, the ultrasonic sensor was primarily used to monitor the level of raw materials inside the product container such as coffee, tea, Nescafé, cardamom. It provides real-time level information that is displayed in the website, allowing the user to monitor the available amount of each product.

And we used IR Sensor, The IR sensor is used to detect the presence of the container at the lid pressing position When the sensor detects a container in front of it, it triggers the lid pressing mechanism to operate, ensuring that the pressing process occurs only when a container is correctly positioned.

Figure 3.7: Ultrasonic Sensor

Figure 3.8: IR Sensor

3.2.4 Power devices

Power Supply (12V 29Ah)
For our automated filling and packaging line, we used a 12V 29Ah power supply to provide stable and reliable power for all motors, sensors, and electronic components. This power supply was chosen for its high capacity and consistent output, ensuring smooth operation of the conveyor belts, filling mechanism, and lid-pressing system throughout the production process.

Figure 3.9: Power Supply

3.2.5 Other Devices

In our project, we used rubber belt is used to move the container holder smoothly along the production line. It provides controlled linear movement between different stations, such as filling and lid pressing. Ensuring stable and accurate positioning of the containers.

Figure 3.10: rubber belt

In our project, we used load cell and HX711 module to measure the weight of each container in real-time during the filling process. It ensures that each container receives as close as possible to the selected weight, improving accuracy and reducing product waste. The weight data appears on the lcd for monitoring and verification.

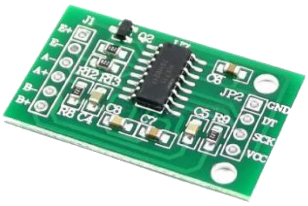

Figure 3.11: HX711

Figure 3.12: load Cell

The keypad is used to enter user commands such as product selection and weight setting. The LCD display shows system status and real-time information, allowing easy monitoring and control of the filling process.

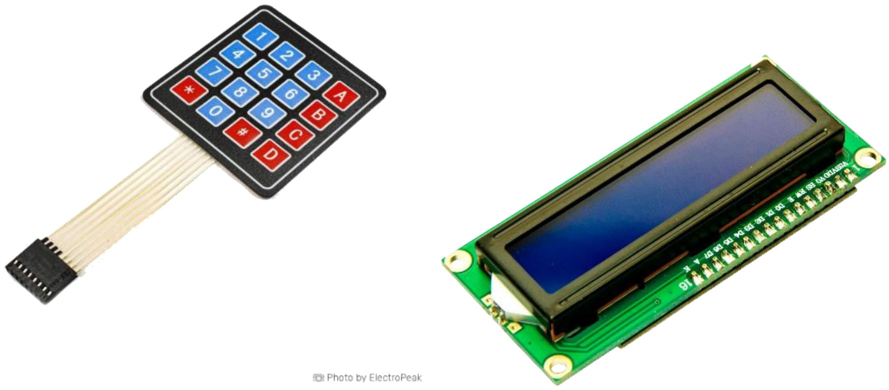

Figure 3.12: LCD and Keypad

Wires We used 3 types of wires female-to-female, male-to-female wires for various connections, and wires.

Figure 3.13: Wires

Connectors We also used wire collectors to organize and manage the wiring system efficiently. These collectors ensured that the wires were neatly arranged, reducing clutter and preventing tangling, which helped maintain a clean and functional setup for the robot's electrical components.

Figure 3.14: Connectors

The raw material containers are used to store powdered products such as coffee, cappuccino, and other similar materials before the filling process. These containers are designed to keep the materials organized and easily accessible for the system.

Figure 3.15: Containers

3.3 Experimental Procedures

 Container Linear Movement
In our project, the movement of containers along the production line is achieved using a rubber belt drive linear motion system powered by stepper motors. This system allows smooth and controlled forward and backward motion, ensuring accurate positioning of containers at each station such as filling and lid pressing.

 Product Selection and Weight Control
The system allows the user to select the desired product type and target weight either through a keypad and LCD interface or via a mobile application. This flexibility enables easy control of the filling process and improves user interaction with the system.

 Automatic Filling Process
During operation, the selected powdered product is dispensed into the container automatically. A load cell continuously measures the container weight in real time, allowing the system to stop filling when the target weight is approximately reached.

 Weight Measurement and Monitoring
The load cell combined with the HX711 module provides real-time weight readings during the filling process. The measured weight is displayed on the LCD screen and within the application, allowing the user to monitor filling accuracy.

 Lid Detection and Pressing Mechanism
An IR sensor is used to detect the presence of the container at the lid pressing station. Once the container is detected, a DC motor controlled via an H-bridge activates the pressing mechanism to seal the lid securely onto the container.

 Raw Material Level Monitoring
Ultrasonic sensors are used to measure the powder level inside the raw material containers. The measured levels are sent to the application, providing the user with live feedback on the available quantity of each product.

 Microcontroller Coordination
The Arduino microcontroller handles motors, sensors, and real-time operations, while the ESP32 enables communication with the mobile application. This coordination ensures smooth system operation and allows both local and remote control.

Chapter 4

Discussion

4.1 Mechanical Challenges

Box Stability on Conveyor

One of the main challenges was ensuring that boxes remained stable on the rubber belt conveyor during movement. Uneven motion or vibration could cause tipping or misalignment at filling and lid-pressing stations. We resolved this by adjusting belt tension and adding guide rails to keep boxes aligned.

Powder Flow Consistency

Filling powdered products sometimes led to uneven flow, forming a small pile in the container instead of a flat surface. This could affect lid placement and weight accuracy. To improve this, we designed the system to allow a gentle vibration at the filling station to level the powder.

Lid Pressing Mechanism

Ensuring the lids were pressed evenly onto boxes was challenging due to slight variations in box height. We calibrated the DC motor and H-bridge control to deliver uniform pressing force, and used a single IR sensor to detect the box position accurately before activating the press.

4.2 Electrical Challenges

- Electrical Leakage Issue

An electrical leakage issue occurred during the testing phase, which affected the stability and overall operation of the system. This problem was addressed by improving electrical insulation and reorganizing the wiring, ensuring safe and stable system operation.

- Power Supply Distribution

Supplying power to motors, sensors, and microcontrollers simultaneously presented a significant challenge. Motor operation caused voltage drops that affected system stability. This required better power distribution planning and separation between motor power lines and logic control circuits.

- Signal Noise and Load Cell Instability

The load cell combined with the HX711 module was highly sensitive to electrical noise. Interference from motors and power lines caused fluctuations in weight readings, affecting measurement accuracy. Several filtering and isolation techniques were applied; however, achieving complete stability remained a challenge.

Chapter 5

Conclusion and Future Work

5.1 Summary

This project focused on designing and implementing a small automated production line for filling and packaging powdered products such as coffee, tea, cappuccino, and cardamom with selectable weights.
The system was developed using a combination of mechanical components and microcontrollers to perform filling, weighing, and lid pressing operations automatically.
The system relies on an Arduino microcontroller to control motors, sensors, and the filling process, while the ESP32 enables user interaction through a keypad, LCD, and mobile application.
A load cell with an HX711 module was used to measure the weight of the containers during filling, and IR and ultrasonic sensors were employed to detect container presence and monitor raw material levels.
This project demonstrates a practical implementation of industrial automation concepts on a small scale, highlighting the integration of mechanical design, electronics, and control systems.

5.2 Conclusion

In conclusion, the automated filling and packaging system successfully demonstrates the feasibility of building a compact and efficient production line with minimal human intervention.

The system is capable of handling multiple products, selecting different weights, measuring weight in real time, and sealing containers automatically.

Despite some challenges related to weighing accuracy, electrical noise, and material flow, the system achieved its primary objectives and operated reliably during testing.

This project provides valuable hands-on experience in automation, sensor integration, and system coordination, and serves as a strong foundation for future improvements and real-world applications.

5.3 Recommendations

•Improve Load Cell Calibration
More advanced calibration techniques and signal filtering are recommended to enhance weighing accuracy.

• Separate Power Lines
Motor power and control logic power should be fully isolated to reduce electrical noise and improve system stability.

• Enhance Material Flow
Adding vibration mechanisms to material containers can prevent powder compaction and improve filling consistency.

• Strengthen Mechanical Structure
Using stronger materials or metal frames can increase durability and reduce vibration.

• Better Cable Management
Organized wiring and proper insulation are essential to avoid electrical leakage and interference.

• Extended Testing
Testing the system with different materials and weight ranges can improve reliability and performance.

5.4 What We Have Learned

• System Integration

We learned how to integrate mechanical, electrical, and control components into a single automated system.

• Microcontroller Coordination

The project improved our understanding of communication between Arduino and ESP32 for system control.

• Weight Measurement Techniques

We gained experience in using load cells and HX711 modules for real-time weight measurement.

• Motor Control

We developed skills in controlling DC motors, stepper motors, and drivers for precise motion.

• Problem Solving

Troubleshooting electrical noise, calibration issues, and mechanical misalignment enhanced our practical engineering skills.

• Industrial Automation Concepts

The project strengthened our understanding of small-scale production line automation.

5.5 Future Work

• Scalability
Expand the system to handle larger production volumes and additional product types.

• Automatic Lid Feeding
Implement an automated system for feeding lids instead of manual placement.

• Small Container Handling
Add mechanisms to automatically handle small-sized containers similar to large ones.

• Vibration System
Introduce a vibration unit to level powdered materials inside containers after filling.

• Improved Accuracy
Use higher-quality load cells and advanced filtering algorithms to improve weight precision.

• Full Mobile Control
Enhance the mobile application to allow full system control and monitoring.