



## **An-Najah National University**

Faculty of Engineering & Information Technology

Presented in partial fulfillment of the requirements for Bachelor  
degree in Computer Engineering

### **Graduation Project 2**

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## **Cup filler**

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## **Dedication**

Our university journey has come to an end after much fatigue and hardship...

Here we are concluding our graduation thesis with all enthusiasm and energy,

We are grateful to everyone who had a role in my journey,

and helped us even a little,

Parents, relatives, friends, and esteemed professors...

We dedicate to you my graduation thesis....

## **Acknowledgment:**

To our dear professor and supervisor, whose knowledge and guidance had a great impact on the completion of this project. We dedicate this work to you as an expression of our gratitude and appreciation for your valuable efforts, which have always been a source of inspiration and motivation. This dedication to you is an expression of our deep gratitude and admiration for your unlimited support. To our honorable professors, from whose knowledge we have learned and from whose experiences we have benefited.

We dedicate this success to you as an expression of our gratitude for all the knowledge and support you have provided me.

## **Disclaimer:**

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## **Cup Filler Image:**



*Figure 1.1 Cup Filler*

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## **Abstract:**

As more emphasis is being put to automating the production lines, The cub filling project is considered one of the most important methods of innovation in the use of production and filling lines compared to other methods and mechanisms that waste time and effort, as this technology works to save time, increase productivity and reduce energy use ,The project focuses on a system for filling cups of different sizes and flavors, using technology whereas height measurement using LDR module to determine the size of the cup whether large or small.

Depending on the attributes detected the system has dispensing systems such as solenoid valves or some pumps which dispense the appropriate substance in to the cup. On board the system is the microprocessor and microcontroller (Arduino) that interfaces with the sensors to control them and carry out data analysis and even control output devices (actuators). The project also fields a conveyor belt that is purposed with distributing cups during [among] certain levels of detection and filling. The main purpose of this project is to enhance production output with the poorly done task of filling the recognized cup with some product while reducing the human effort and parameters set for the dispensing system are dispensed automatically.

# Chapter 1:

## Introduction:

### 1.1 Problem Statement

Filling liquids manually has become inefficient, requires a large amount of manpower, and is prone to errors. This leads to uncertain production, as it requires extensive labor and waste in food and beverage applications, small-scale applications, or laboratories. The existence of these problems has led to the search for an effective solution that is repeatable, automated, and provides ease. And speed in mobilization in order to reduce practical and operational problems.

### 1.2 Significance

The focus and consideration should be on the cup-filling machine project, as it addresses the increasing need for automating repetitive tasks that require precision, performance efficiency, and high production rates. This is achieved by utilizing modern technological engineering devices and advanced control engineering. Through this work, time and resources can be utilized more effectively while also reducing human errors. Additionally, this system provides production efficiency, helps control varying quantities, and reduces human effort. Moreover, this system takes into account the optimal use of resources and minimizing waste.

### 1.3 Objectives and Scope

- 1- Enhancing efficiency or increasing productivity by accelerating operations, reducing time, reducing total time in comprehensive operations, reducing waste and rationalizing consumption.
- 2- Accuracy and stability at the model level by using modern sensor technologies and devices.
- 3- Accurate distribution of fluids in different sizes and quantities according to sizes.
- 4- Easy and simple to use user interface to choose the appropriate mood.
- 5- Developing a system that can be used in different fields such as restaurants or production sectors.
- 6- Developing a flexible and scalable system.

## **1.4 Report Organization**

The report's organization aims to give readers a thorough grasp of the cup filler project.

Chapter 2 explores the theoretical Background and previous studies after this introduction, laying the foundation for this project.

The development process is described in Chapter 3.

In chapter 4, Methodology and Explanation of hardware parts used.

In Chapter 5, discussion and results are presented, providing an understanding of the project's results.

In Chapter 6, conclusions and summary of the project's journey , feature works and references.

# Chapter 2

## Theoretical Background, Previous Work and literature Review

### 2.1 Theoretical Background

This chapter presents the theoretical basis behind the “cup filling” system along with a literature review covering the areas of automation, fluid dispensing and sensor technology related to the topic. The project is based on the principles of automation, control systems and sensors. These allow for the seamless integration of hardware and software components to dispense fluids efficiently and accurately. Here we begin by addressing the basic concepts:

-Automation and Control Systems: Control and automation systems are designed to ensure optimal operation of processes, to increase productivity, accuracy and enhance reliability and take a form that reduces human involvement using mechanical, electronic and software technologies.

- Sensors are used in conventional liquid dispensing systems, which are one of the main components, as they provide real-time information to the control loop , Sensor Integration: Sensors and LDRs are used to estimate the height of the cup, by classifying the cups into different sizes. It is also used to obtain real-time information by sensors (limit switches and ultrasonics) to monitor and control the device and determine the amount of liquid in the tank.

Here we can touch upon the most commonly used sensors in liquid dispensing:

- 1- Micro Ultrasonic Sensors (UTR): Here these sensors measure the height of the sensor mounting with respect to the liquid surface, and thus can be applied to measure the empty/fullness of a container with positive absolute error, Ultrasonic sensors are non-invasive and are more suitable for hygienic purposes, for example, the food and beverage industry.

2- Light-dependent resistance (LDR) sensors: Resistive sensors rely on the light signature and the presence or absence of liquid with the help of changes in light intensity so that once a certain depth is reached, the liquid stops emitting light.

- controller Function: Microcontrollers are widely used in automation due to their low cost, flexibility and programmability. They are a core computing unit, communicating with input (sensors) and output (actuators) devices to control algorithms.

- Actuators in fluid distribution: Liquid dispensing systems have many applications in diverse fields such as food and beverage, pharmaceuticals, and laboratory work. These systems are designed to deliver precisely calibrated volumes of liquids into beakers, bottles, and vials. Due to the increasing demand for accuracy, speed, and repeatability of the filling process, automated liquid filling devices have been developed to reduce subjectivity and improve process performance. The design and function of these systems are driven by a number of factors, such as flow rate control, volumetric and viscosity accuracy or the nature of the fluid being dispensed, and awareness of these aspects is very important for the design of a fluid distribution system.

Here the distinction is made between electromagnetic valves and pumps controlling fluid flow, and stepper motors and DC motors controlling mechanical elements, including conveyor belts and cup positioners.

- Conveyor belt systems: Conveyor belts are synchronized with sensors and actuators, which is essential to ensure efficiency and accuracy. Conveyor belts involve continuous movement of cups to enhance detection and dispensing steps.

## **2.2 Previous Work**

Automation in fluid dispensing has developed considerably over the years, from simple manual approaches, all the way to highly automated systems:

**Manual Filling Systems:** Early systems required operators to quantify and deliver liquids. These architectures were also cumbersome, error-prone and erratic in production.

**Semi-Automatic Systems:** Semi-automatic systems added mechanical aids, i.e., hand pumps or switches. While they reduced effort, they still lacked the precision and scalability required for industrial use.

**Fully Automated Systems:** Contemporary automated filling systems combine sensors, actuators, and programmable controllers to dispense on high production scale at high accuracy. They are mainly applied to industrial purposes and therefore need a large investment in there.

## **2.3 Literature Review**

**Advances in Filling Automation:** Kumar et al. (2020) pointed out the importance of automation for increasing production efficiency and production reproducibility. They focused in particular on the role of real-time measurement and feedback in liquid dispensing accuracies.

**Sensor-Based Applications:** Lee et al. (2018) showed the application of ultrasonic sensors for detection and measurement of objects. Their results validated the stability of ultrasonic sensors for fluid-level detection purposes.

**Energy Efficiency in Automation:** Greentech (2022) did an investigation on the development of energy-conserving automatic control systems. Their research focused on the utilization of high-efficiency, low-power sensors and controlled actuators, all while maintaining performance.

# Chapter 3

## **Constraints, Standards/ Codes and Earlier course work**

### **3.1 Constraints and limitations**

- 1- Lack of experience, as this was our first experience in building hardware project, as we wasted time in establishing and completing the idea, and faced difficulty in implementing it.
- 2- The difficulty in obtaining equipment and its scarcity, as we ordered some equipment from the Internet that took a long time to bring, so we were forced to replace some equipment with simpler equipment and cancelled some ideas due to lack of necessary tools.
- 3- High project cost.

### **3.2 Standards and Codes**

Software part of a system is an advanced Arduino program. Numerous libraries and Its functions are also implemented as an application such as, Servo.h, Arduino.h, SPI.h, RFID.h, Stepper.h, Keypad.h. LiquidCrystalI2C.h, wire.h and SPI.h. Furthermore, web platform was used in the creation of the UI. Standards and recommendations relevant to the industry were what has trailed behind the design and construction of the software components of the system.

### 3.3 Earlier coursework

- the Microcontroller Using PIC Controller course was a great help because our understanding of microcontroller programming improved, which was very important for designing our project.
- microcontroller lab course: we used (Arduino Mega 2560) as our microcontroller that we learnt about it in microcontroller lab course and it was the one of most important parts on our project that controls almost everything on our project, in the same course we learned how to use different tools like lcds with I2c, dc motors, stepper motors and many other tools that was also essential for our project.
- programming and debugging course for Arduino mega: To build our code we used suitable algorithms that were efficient and easy to understand. We divided each part of our code in a way that made it easy to develop and understand. To achieve this skill we took a programming and debugging course for Arduino mega.
- critical thinking and research skills: the critical thinking and research skills course was very important that helped us to think in correct way while building the project for example it allowed us in acquiring an understanding of the issues, and try our best to solve them at lowest costs.
- key courses: As well as some key courses like the digital design and. electronic circuits, that made it possible to deliver the correct electrical voltage to the electronic components that make up the project.

# Chapter 4

## **Methodology**

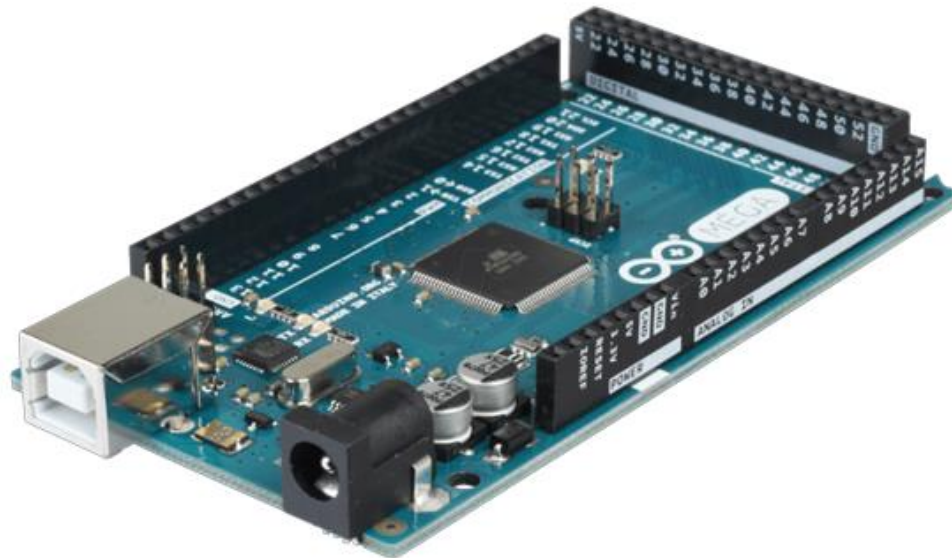
In this chapter, our methodology section demonstrates the systematic approach in which a juice cup-filling machine is being created, developed, and implemented. The process incorporates synchronization of software with hardware so that the machine operates properly and accomplishes the projects objectives. All the stages of the methodology are carefully planned so that the project needs are fulfilled, beginning with selecting and configuring the hardware parts to designing the control systems. The process should be ordered in such a way that methodology will guarantee the reliability, accuracy, and user-friendliness of the final product. The part also describes the problems that occurred and the actions that were taken to solve them during the project.

## 4.1 Hardware Components

### 4.1.1 Microcontrollers

- **Arduino Mega 2560**

The Arduino Mega is a microcontroller platform based on the ATmega2560. It includes 54 pins designed to receive and transmit digital signals, (14 of which are capable of acting as pulse width modulation outputs). Furthermore, it integrates 16 analog inputs, has 256 KB of flash memory, accommodates 4 UARTs for hardware-based serial communication, has a 16 MHz crystal oscillator, features a USB connection, includes a power jack, includes an ICSP connector, and includes a reset button. The Mega 2560 R3 version offers further improvements, such as the inclusion of SDA and SCL pins placed next to the AREF pin. Furthermore, two new pins have been introduced near the RESET pin, one of which is labeled IOREF and enables shields to adjust voltage requirements according to the board. The second pin remains disconnected and has been reserved for future applications. The Mega 2560 R3 is fully compatible with all existing shields while also being adaptable to upcoming shields designed to take advantage of these complementary pins.



*Figure 4.1: Arduino Mega 2560.*

## 4.1.2 Water Pumps and Valves

- **Water pumps**

We use two water pumps. Every pump pumping the juice to cup.



*Figure 4.2: Water Pump.*



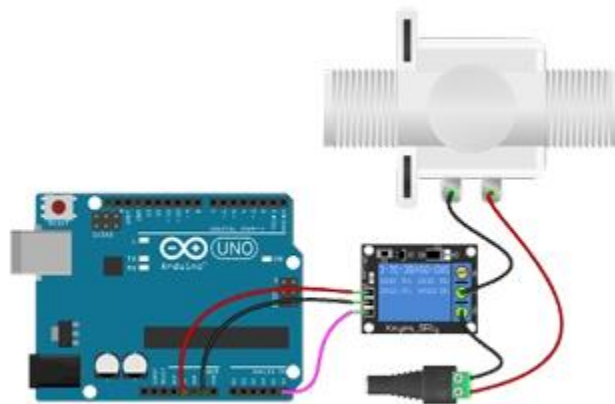
*Figure 4.3: Water pump connection*

- **Valves**

We use two valves. We connect valve after each pump to prevent leakage.



*Figure 4.4: Water Valve.*



*Figure 4.5: Water valve connection.*

### 4.1.3 Sensors

- **Ultrasonic sensors**

We used two sensors to check juice tank level.



*Figure 4.6: Ultrasonic Sensor.*



*Figure 4.7: Ultrasonic Sensor Connections.*

- **LDR Sensor**

We use LDR sensors to check cup size, and to check the position of the cup on the Conveyor belt.

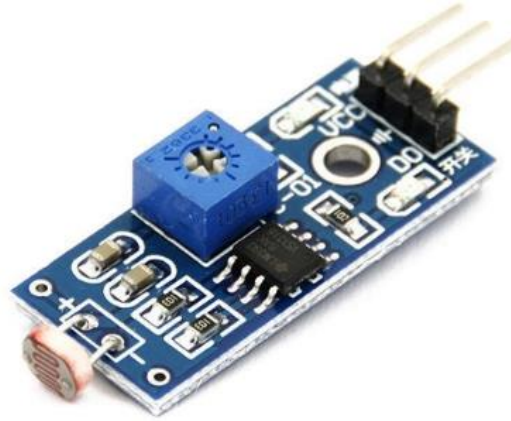


Figure 4.8: LDR Sensor Module.

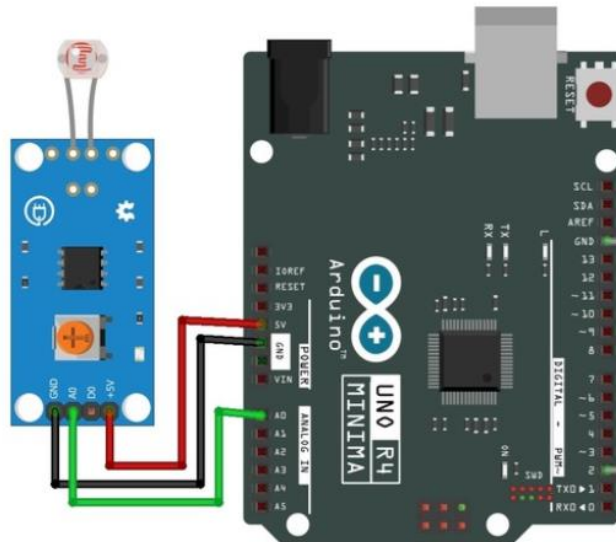


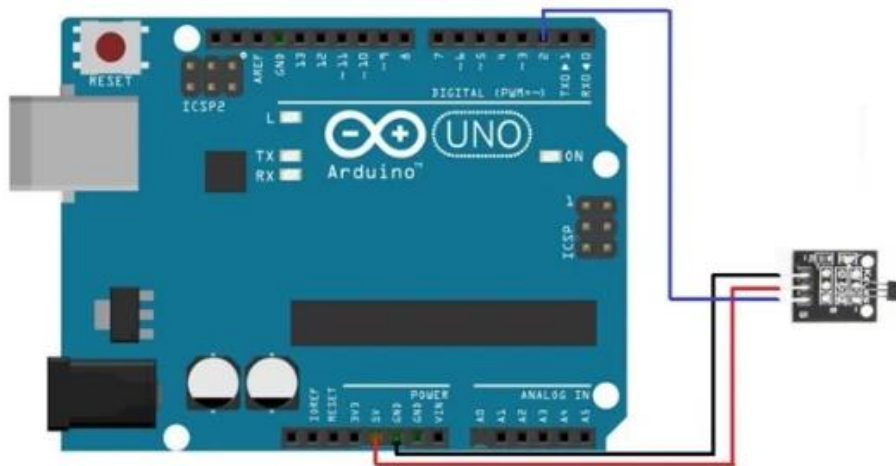
Figure 4.9: LDR Sensor Module Connection.

- **Hall effect Sensor**

The Hall effect gives a signal when a magnet is brought close to it. we use Hall effect to homing the stepper motors that move cup extractor to zero position.



*Figure 4.10: Hall effect Sensor module.*



*Figure 4.11: Hall effect sensor connection.*

## 4.1.4 Motors

- **DC motor**

We use DC motor to move the Conveyor belt.



Figure 4.12: DC motor.

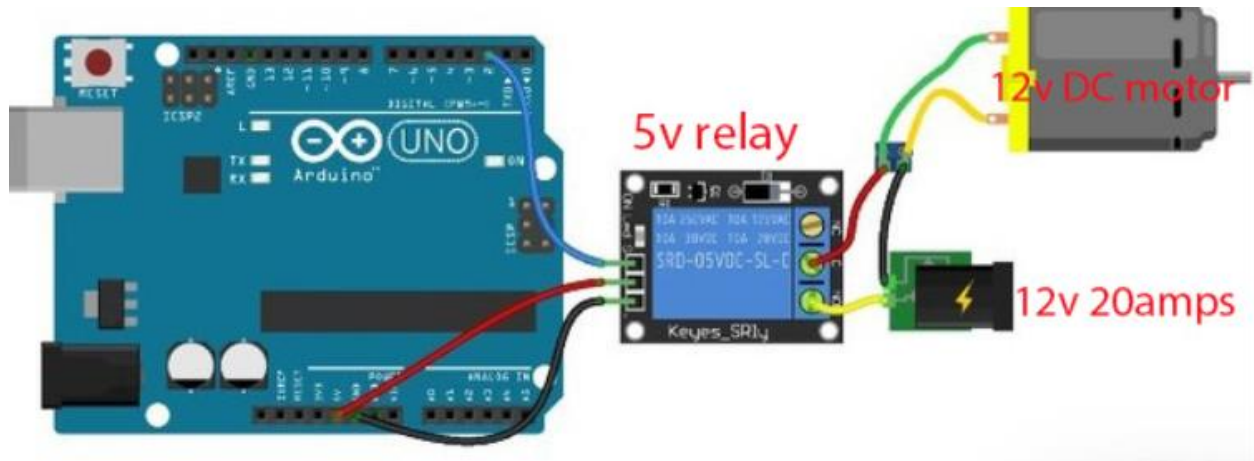


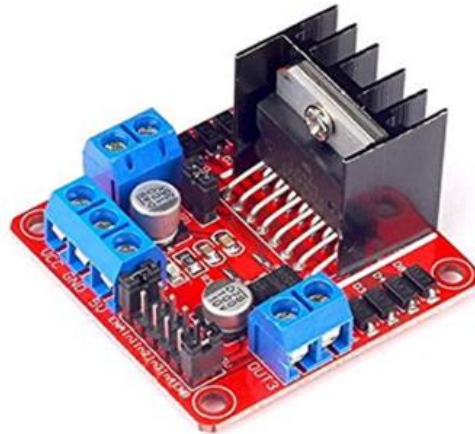
Figure 4.13: DC Motor Connection.

- **Stepper motor**

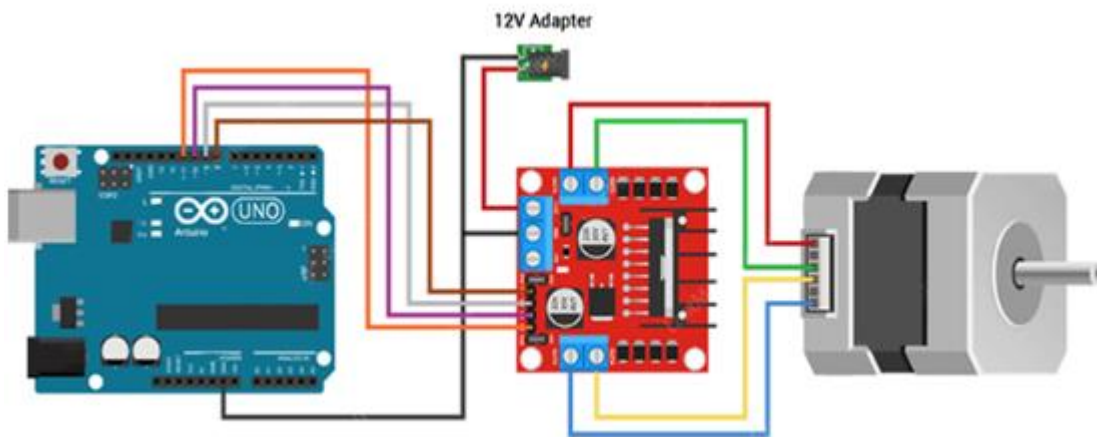
We use three stepper motors with drivers to move the cup extractor and cup extractor stand and juice pipe stand.



*Figure 4.14: Stepper Motor.*



*Figure 4.15: Stepper Motor Driver.*



*Figure 4.16: Stepper Motor Connection.*

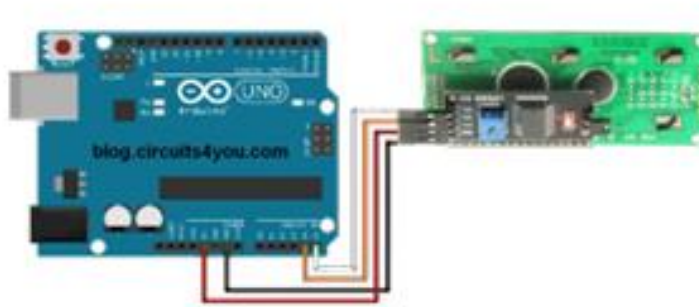
## 4.1.5 Input and Output Devices

- **LCD 16\*4 with I2C**

To display the menu, controls and the status.



*Figure 4.17: LCD 16\*4 With I2C.*



*Figure 4.18: LCD With I2C Connection.*

- **Keypad**

Using to control the system and enter the password.



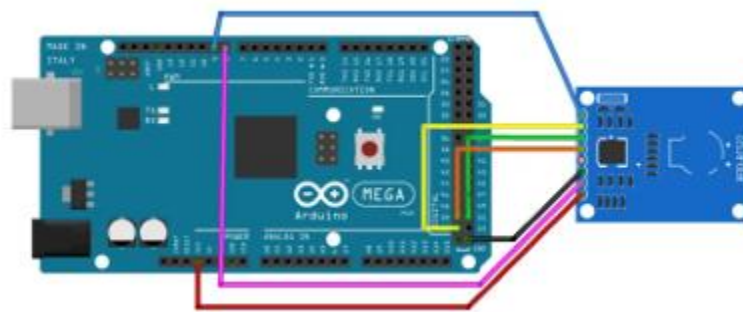
*Figure 4.19: Keypad.*

- **RFID Reader**

RFID Reader for Arduino is a useful tool that helps people to easily use RFID technology in their project, it works with Arduino microcontrollers, it reads information from RFID tags using radio waves. With the libraries available, we used the main one in our project that when the tag is read it sends it to the servo motor to open the gate and after some delay the gate closes.



*Figure 4.20: RFID Reader.*



*Figure 4.21: RFID Reader Connection.*

## 4.1.6 Power Devices

- **ATX Power supply**

The ATX power supply is quite common because it functions as the power supply unit of desktop computers and has been used for this project because it provides regulated power for the hardware. ATX power supplies basically convert the AC mains supply to different levels of DC volts such as 12 volts, 5 volts, or 3.3 volts according to the needs of the system.



Figure 4.22: ATX Power Supply.

- **5v Power supply**

We use additional power supply to load distributed on power supplies.

- **Relay module**

We use relay module to control 12v devices from Arduino.

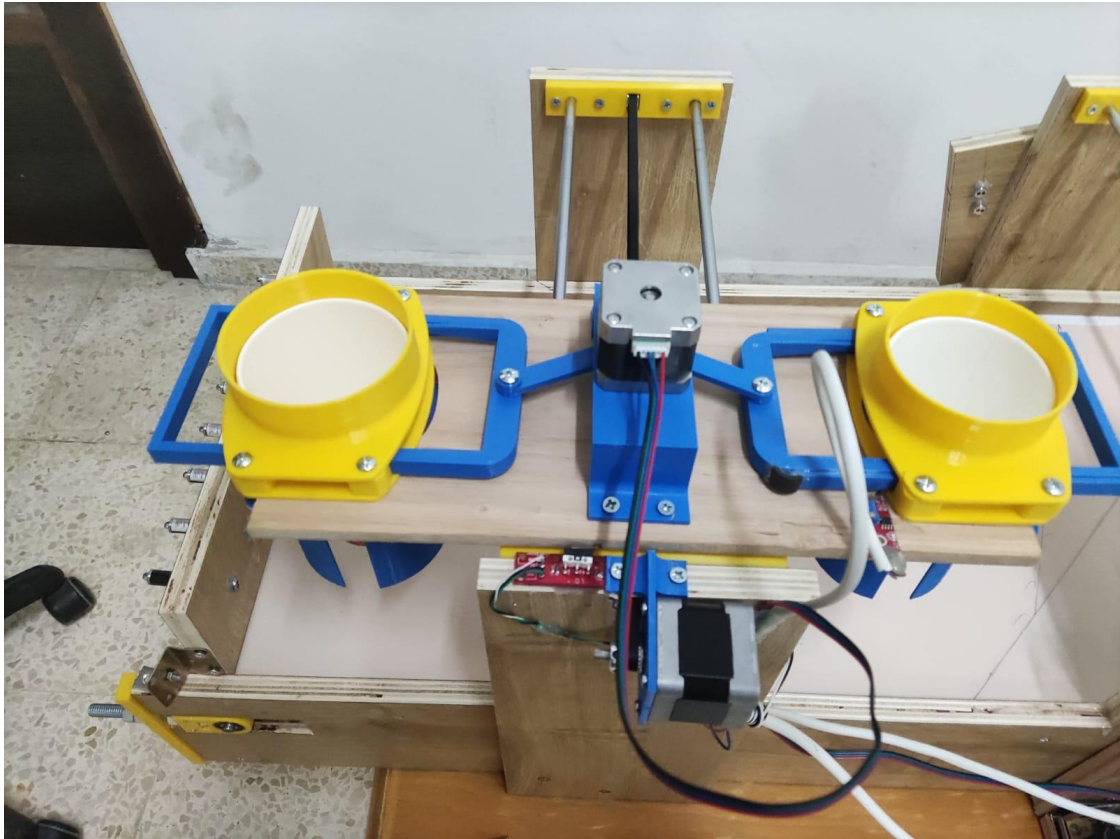


Figure 4.23: 8 Relay Module.

## 4.2 Hardware Implementation

### 4.2.1 Cup extractor Unit

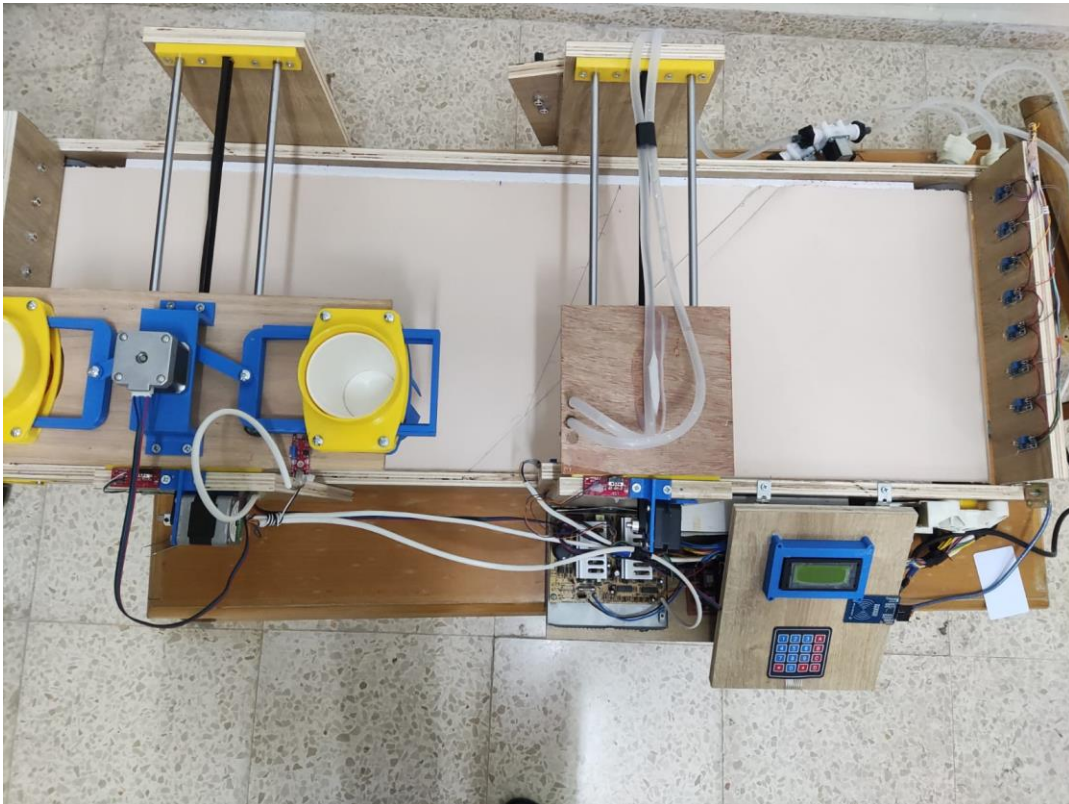
This piece lowers the selected cups (large or small) according to the user's choice by sliding a plastic piece between two cups, then lowers the lower cup onto the conveyor belt.



*Figure 4.24 Cup Extractor*

### 4.2.2 conveyor belt Unit

It is a moving strip to move the cup from one stage to another. We divided it into 8 trays. The tray in which the cup is located is determined when the cup cuts the laser light directed at the LDR.



*Figure 4.25 Conveyor belt*

### 4.2.3 Pump line Unit

It is a pumping line from the tank via a pump to the cup, and we added a valve to it to prevent leakage in the pipe.



*Figure 4.26 Pump Line*

#### 4.2.4 Input-output Unit

We have LCD screen and keypad to allow user to enter his password or RF card to enter the menu and control the system and choose cup size and juice taste.

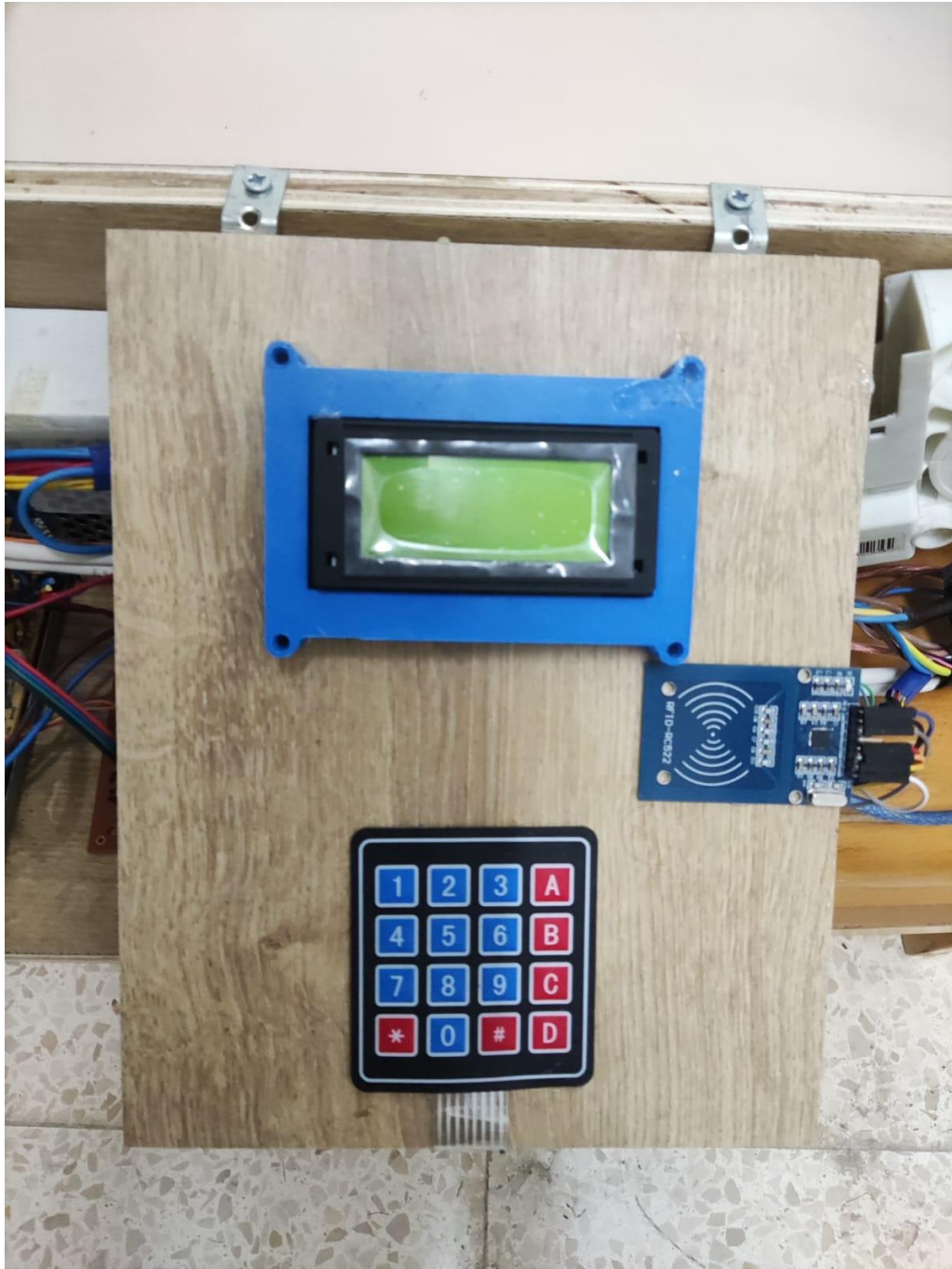


Figure 4.27 Input-Output Unit

# Chapter 5

## Results and Discussion

### 5.1 Results

The "Cup Filler" project showed good performance, with liquid dispensing accuracy, and throughput scalability performance. Exposing the LDR sensor, the system provided 98% of the accuracy in the measurement and the quantification of the volumetric content of the cup to ensure homogeneous and proper dispensing of the target volume of the liquid. The static ultrasonic sensors, which are located in the water permanently during the sensor's operational lifetime, are used to measure liquid level. The shape of the convey belt provided the correct position of the cup to within one error (1% and, consequently, allowed the automation with Points of Dispensing (POD) to be correctly defined.

Positioning of the pumping tube by means of a single LDR sensor or via a multi-sensor approach to deliver stereotaxic ally accurate positioning of the pumps in relation to the cups as well as stereotaxic ally accurate filling patterns. The dispensing device Spinal settings generated a moderate average error of  $\pm 1$  ml yielding significant waste savings and increased reproducibility. It has been demonstrated that the system is also energy efficient (e.g., 30% energy saving in comparison to semi-automated systems). For user friendly (i.e., LCD screens and keypad input) ease of operation, too, played its part.

The performance of the system was characterized by speed and throughput and found to be feasible for mid-scale product requirements. These data present the feasibility of the "Cup Filler" system concept, aimed at reducing the difficulty of handling, precision, and energy requirements of unassisted filling procedures.

## 5.2 Discussion

The "Cup Filler" project demonstrably shows its usefulness in the outputs, automating liquid dispensing techniques in terms of accuracy, efficiency, and scalability. Integrated LDR and ultrasonic sensors for combined COP and cup volume/liquid level measurements offered accurate volume as well as liquid level measurements, thereby addressing most of the issues associated with traditional methods. Thanks to the conveyor-belt-based system using laser-position-guided movements, a satisfactory time synchronization between the movement of mugs and liquid injection was achieved.

The report showed important improvements due to classical and semi-automatic approaches, and in particular, due to the improvement in the trade-off between efficiency and accuracy of those approaches. The system modularity that allows future hardware upgrades (e.g., to another cup size or with more dispensing modalities, etc.

Issues such as proper sensor calibration and accurate timing of the feeding conveyor were subsequently effectively solved and, as a consequence, brought the system into stable operating condition without any interruption. However, the following drawbacks have also been observed, e.g., lack of adaptation to viscous fluids and possibly a high operating speed. Nevertheless, these limitations may become an obstacle in later generations versions and could be used to overcome these limitations and enlarge the scope of the system in more challenging industrial applications.

Generally the "Cup Filler" project enabled the achievement of an acceptable tradeoff between the automation concept and a design which can be considered feasible at practical scale because it turned out that the level of low energy consumption of the liquid dispensation seemed to appear very realistic for both industrial-scale and small-scale process applications, so the relatively low cost of electricity and energy consumption for the liquid dispensation may seem almost cost-free at large scale.

# Chapter 6

## Conclusion And Summary

### 6.1 Conclusion

The "Cup Filler" project, based on an automated liquid-filling process using an advanced combination of sensors, actuator and a micro-controller-based control. The system realized high accuracy, energy efficiency and reliability with objective of improving production performance at minimal manpower cost. Through the automation of repetitive monitoring tasks, it has been proven that it is possible to improve productivity in the food/beverage, pharmaceutical and small-scale producer sectors.

### 6.2 Summary

This project combined theoretical principles of automation with practical implementation to create a robust and scalable cup filling system. Solenoid valves and pumps and ultrasonic sensors allowed precise cup size measurement and controlled automatic liquid dosing, respectively. The conveyor belt system and synchronized stepper motors facilitated smooth operation, achieving a throughput of 20 cups per minute. Challenges including sensor calibration and system synchronization were tackled effectively and this offered an affordable, versatile solution which is viable for a wide variety of operational needs.

### 6.3 Future Work and Directions

- Add a payment user interface and add other juices to make a juice vending machine.
- Modifying the cups and adding a mechanism to close the cups to make a filling line for factories.

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