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Research Article

Development of an Embedded System Based Prototype Automatic Coffee Machine and Detailed Analysis of Its Modules

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ABSTRACT

Coffee is one of the most popular beverages in the world and has an important place in many cultures. With the developing technology, coffee preparation processes have also evolved and automatic coffee machines have entered our lives. These machines provide convenience and time savings to the user, while optimizing the ideal brewing conditions of the coffee and increasing the quality of its flavour. Modern automatic coffee machines have advanced systems that can precisely control the temperature of the water, the grinding degree of the coffee bean and the brewing time. Thus, coffee lovers can have a consistent and perfect coffee experience in every cup. This article comprehensively covers the design, construction and testing process of a prototype automatic coffee machine. First, the requirements and goals determined within the scope of the project were defined, then the components suitable for these requirements were selected. During the design phase, the focus was on basic functions such as adjusting the coffee strength (amount), grinding the coffee, heating the water, brewing time and frothing the milk. The electronic control unit was designed based on Arduino Mega and the various functions of the machine were performed automatically. The user interface is implemented with an application written in the C# programming language. This user interface has established communication with Arduino Mega and aims to enable the user to easily adjust brewing settings. Finally, the performance of the developed prototype has been evaluated with various tests, and detailed analyses have been made on the reliability and user-friendly design of the system. This study presents important findings regarding the design and development process of automatic coffee machines and aims to guide future studies.

1. Introduction

The history of automatic coffee machines dates back to the beginning of the 20th century and was first developed in Italy, and over time these machines have revolutionized the coffee preparation process. Offering a great advantage in terms of ease of use, automatic coffee machines allow users to prepare a perfect cup of coffee by pressing just a few buttons [1]. These machines precisely control the water temperature, brewing time and coffee quantity, providing a consistent and quality coffee experience every time. Coffee brewing performance is one of the most distinctive features of automatic coffee machines; advanced models can perfectly prepare various types of coffee such as espresso, latte, cappuccino. In today's fast-paced lifestyle, automatic coffee machines have become a great necessity; at home, at work and even in cafes, these machines both save time and meet the expectations of users by constantly delivering high-quality coffee. These machines make the art of coffee preparation accessible, while at the same time giving coffee lovers the pleasure of serving fresh and delicious coffee every day [2].

Coffee is one of the most popular drinks in the world. From traditional to modern coffee preparation methods are constantly being changed and improved by people. In this busy society, automatic coffee machines have become widespread due to their ease of use and convenience,

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requiring only the push of a button [3]. Automatic coffee machines are machines that can make coffee from coffee grounds on their own without any additional supervision, especially for espresso coffee. In the current market, there are three types of automatic coffee machines that are tried by consumers. These are fully automatic coffee machines, semi-automatic coffee machines, and capsule coffee machines [4].

This review of the history, use and necessity of automatic coffee machines shows how technology and user expectations have evolved. In this context, there are many studies in the literature on the development, performance and consumer satisfaction of these machines. Within the scope of the literature research, various scientific articles and reports focusing on topics such as technical features, user experiences and energy efficiency of automatic coffee machines were examined. These studies provide in-depth information on how innovations in the design of coffee machines meet user needs and transform coffee consumption habits. Information on the studies conducted in the literature is provided in order.

Agustian et al. designed a coffee bean roasting machine. They used components such as a roasting machine, sensor, fan, and servo in their Arduino-based design. They conducted the tests with 250 grams of coffee. In their experiments, they showed that the coffee could be roasted to its full consistency [4].

Hadianto et al. used the fuzzy logic method to evaluate the performance of a coffee machine. The coffee machine is capable of making espresso, latte and other types of coffee and combines coffee ingredients, sugar and milk. They suggested that the water pressure in the coffee machine and the pressure exerted by the piston affect the thickness of the coffee produced and the water flow rate. They used the fuzzy inference method to determine the optimum pressure of the piston according to the weight of the coffee grounds and the type of machine. They suggested that determining the optimum pressure improves the taste of the coffee and the speed of production. In their research, they aimed to simulate the optimum pressure on the piston using the Takagi-Sugeno-Kang fuzzy logic method [5].

Sihab and Yaqin aim to design and test an automatic coffee drink machine using two Arduino Uno with I2C communication. The method uses the waterfall method, which includes analysis, design, coding and testing stages. The testing stage includes measuring coffee, milk and sugar with servo motors; while adjusting the water temperature with an electric heater. The sugar, coffee and milk ratios are set at certain intervals. These measurements are optimized to produce ideal coffee drinks. The research comprehensively covers the process of making Arduino-based automatic coffee machines [6].

Brommer et al. aimed to identify critical environmental issues throughout the life cycle of coffee and to compare coffee preparation methods in terms of their environmental impacts. They showed that the environmental impacts of different preparation methods vary significantly depending on the power consumption of the technologies used. They found that the French press and the filter drip machine had the lowest environmental impacts, while the fully automatic and capsule machines had the highest environmental impacts due to their high power consumption and packaging waste. This study emphasizes that the energy efficiency and usage behavior of coffee machines are decisive in environmental impacts [7].

Pongsawtd et al. explain in their study how the concept of the Internet of Things (IoT) can be used to increase the efficiency of the franchise system. Traditional coffee machines have been transformed into smart coffee machines with remote monitoring and control capabilities. Smart coffee machines provide a control panel for monitoring the machine's operating status, content and components, and setting hot drink recipes. This system collects data using an Arduino board and a Raspberry Pi module. It then processes it, allowing the franchisee and the franchisee to remotely monitor the machine's performance and stock status [8].

Gomes et al. used an advanced multispectral imaging technique using reflectance and autofluorescence data to distinguish ‘special’ and ‘conventional’ green coffee beans using four machine learning algorithms. The Support Vector Machine (SVM) algorithm achieved the highest accuracy (0.96) for the test dataset. PCA (Principal Component Analysis) and SVM analysis revealed that autofluorescence data obtained from the 405/500 nm excitation/emission combination contributed significantly to the classification, with catechin, caffeine and various acids affecting the differentiation. This approach demonstrates the potential of multispectral autofluorescence imaging combined with SVM for non-destructive, real-time classification in the food industry [9].

Ogunjirin et al. detailed their project to develop a coffee roaster using local materials. This approach aimed to reduce processing costs and achieve optimum quality. The developed roaster has a roasting capacity of 25 kg and has components such as a roasting drum, an electric motor driven by a speed reducer, a frame, a cooling unit consisting of a cooling fan and a control panel. The machine can reach temperatures of 200°C, 250°C and 300°C in 5, 7 and 10 minutes respectively [10].

Tavares and Mourad analysed the environmental performance of various coffee preparation methods through a life cycle assessment (LCA). The study covers traditional espresso, French Press, AeroPress, filter coffee systems in coffee shops, home filtering and single-serving automatic machines. Energy, water consumption, waste production and environmental impact scores were calculated with 153 data collected from 40 businesses.

Single-serving softgels showed the lowest environmental impact with the lowest CO2 emissions and biodegradable waste. The results show that the ratio of coffee concentration and packaging mass is important in environmental impacts and provides valuable information for consumer preferences and public policies [11].

In their study, Andreas et al. increased the water tank capacity to 38 liters in order to increase the performance of the coffee machine and converted the single-group head to a double-group head. With these changes, the output and efficiency of the machine were significantly increased. With the Reverse Engineering Method, existing products were analyzed and redesigned, and two methods were applied by optimizing the material, technology and economic situation of the machine. As a result of the modifications, the machine reached the capacity to make 89 repetitions instead of 14 repetitions. Thus, the barista can produce 2 cups of coffee in one go [12].

A prototype coffee brewing machine was created by examining these studies in the literature in detail. The subsystems and operations in the prototype automatic coffee machine are as follows:

- A coffee amount adjustment module has been made to adjust the coffee strength. 5-stage strength level has been determined. With this module, the coffee amount is adjusted according to the strength level and sent to the grinding module.
- The coarseness level of the coffee can be adjusted in the coffee grinding module. No knife is used in the grinding process. A ceramic grinder is used. In this way, the flavor of the coffee is preserved.
- The coffee in the grinding module is poured into the drippers containing paper filters in the brewing module. After the coffee is poured, hot water is poured drop by drop onto the coffee. After the coffee is brewed, the dripper is rotated 180 degrees and the coffee paper is thrown into the waste bin. There are 4 drippers in this module.
- After the brewed coffee is filled into the glass, milk can be added as desired. The milk added to the milk tank is frothed and filled into the glass.

According to these procedures, the contribution of this study to the literature is as follows:

- How the modules in the automatic coffee machines work and what they do are explained in detail.
- Almost all of the mechanical parts used in the study were designed by us and produced on a 3D printer.
- Arduino Mega was used in the automatic coffee machine. Control was carried out with C#. Arduino Mega was used as an interface to manage the components. Control of the machine can be done in a wider area with C#.
- The prototype coffee machine can be developed in the future and transformed into a professional coffee machine.

This study consists of four main sections: introduction, materials and methods, experimental results, and discussion and conclusions. In the introduction section, the background, purpose, and research question of the study are presented so that readers can understand why the study is important and what it aims to achieve. In the materials and methods section, how the study was conducted is explained in detail; the materials, experimental setups, and methods used are described step by step. This allows other researchers to replicate the study. In the experimental results section, the obtained data and findings are presented systematically. Finally, in the discussion and conclusions section, the interpretation of the findings, comparison with the literature, and the general conclusions of the study are discussed. In addition, the limitations of the study, suggestions for future studies, and the practical or theoretical significance of the obtained results are also discussed in this section. This structure will help to present the research article systematically and understandably.

2. Material and Methods

Many materials such as Arduino Mega embedded system, various stepper motor, servo motor, connection cables, water pump, heating unit were used in the production of automatic coffee machine. Most of the mechanical parts were specially designed and produced with 3D printer. Information about the main materials used in automatic coffee machine is given.

2.1. Arduino Mega

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 chip. It has 54 digital input/output pins (15 of which are PWM capable), 16 analog inputs, 4 UARTs (hardware serial ports), a 16MHz crystal oscillator, a USB connection, a power input, ICSP pins and a reset button. It includes the basic features that a microcontroller should have. One side of the board has the same pin structure as the Arduino Uno. In this way, shields compatible with the Arduino Uno can also be used with the mega2560 [13]. Other features of the card are shown in Table 1.

Table 1. Arduino Mega properties

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (Limit)	6-20V
Digital Input/Output Pin	54 (15 of them are PWM capable)
Analog input pin	16
Maximum current that each pin can pass	20mA
Maximum current that 3.3V pin can pass	50mA
Flash Memory	256KM (8KB bootloader)
SRAM	8KB
EEPROM	4KB
Clock Speed	16MHz
Length*Width	101.52 mm * 53.3 mm

2.2. XD-37GB520 DC motor

The XD-37GB520 DC motor is a high torque and low speed DC motor used in various applications. The most distinctive feature of this motor is that it comes with an integrated gearbox, which increases torque while reducing rotation speed. It usually works at voltages such as 12V or 24V and is offered with different gear ratios, so it can be customized according to specific needs. The XD-37GB520 stands out with its high efficiency and durability, making it an ideal choice for robotic systems, automation projects, electric toys, model vehicles and other industrial applications. Thanks to its compact design and powerful performance, this motor is often preferred in projects that require precise control [14]. XD-37GB520 model DC motor was used in the coffee grinding module. Various coffee grinding tests were performed with the selected motor to test its power adequacy and as a result, it was decided that it was sufficient for the project.

2.3. Nema 17 step motor

NEMA 17 stepper motor is a type of motor that has a flange size of 1.7 x 1.7 inches (43.2 x 43.2 mm) and is commonly used in applications that require precise motion control. The "NEMA" standard specifies the dimensions of the motor, and NEMA 17 is especially preferred in areas such as 3D printers, CNC machines, robotic projects, and automation systems. These motors typically have a step angle of 1.8 degrees (200 steps/revolution), although models with smaller step angles are also available. NEMA 17 stepper motors are ideal for applications that require high torque, typically providing torque between 20 and 60 Ncm. They mostly operate in the 2-12V range and draw 1-2A. Due to their durability, reliable performance, and precise control capabilities, NEMA 17 stepper motors are widely used in both hobbyist projects and industrial applications [15]. Nema 17 stepper motor is used to rotate the helix in the first module to adjust the coffee strength.

2.4. L298N motor driver

L298N motor driver is a popular motor driver integrated circuit with dual H-bridge structure, and is generally used to control DC motors and stepper motors. This driver allows two DC motors to be controlled independently or together, and can perform forward-reverse motion, speed control and stop operations for each motor. L298N can operate in a wide voltage range from 4.8V to 46V and provide a maximum current of 2A per channel. Equipped with an integrated heat sink, it ensures efficient operation even at high currents. Easily integrated with microcontrollers, L298N is widely used in robotic projects, automation systems and various hobby applications. Thanks to its robust structure and flexible use, it is a reliable and cost-effective solution for motor control needs [16]. It is the driver card used in the motors used in automatic coffee machines.

2.5. SG90 servo motor

The SG90 servo motor is a micro servo motor that is especially popular for hobby projects and small-scale robotic applications due to its small and lightweight structure. It generally operates in the range of 4.8V to 6V and can produce 1.8 kg/cm torque, making it effective in a variety of low-torque applications. The SG90 has a rotation angle of up to 180 degrees and provides precise position control with a PWM (Pulse Width Modulation) signal. This motor is lightweight yet durable thanks to its plastic gears and is frequently preferred in educational projects and hobby models due to its low cost. It is used in a variety of applications such as RC (radio-controlled) vehicles, robot arms, automatic doors and sensor guidance systems. The SG90's easy installation and use make it an ideal choice for both beginners and experienced users [17]. SG90 servo motor is used to throw the paper filters inside the drippers into the waste container in the automatic coffee machine. It can throw the paper filters by rotating the drippers 180 degrees.

2.6. Water pump

A 6-12V water pump is a type of pump that is usually low voltage and is used in a variety of hobby, home and garden applications. These pumps are notable for their small size and low energy consumption and are typically used in applications such as water transfer, aquariums, plant watering systems and small fountains. These water pumps, which can operate in the 6 to 12 volt range, provide safe and efficient water flow. They are usually equipped with brushless motor technology, providing long-lasting and low-maintenance performance. They are popular for their easy installation and use, as well as their low cost and durability. These pumps can generate enough pressure to move water to a certain height or distance, making them a versatile and practical solution [18]. In the automatic coffee machine, the water pump is used to draw water into the kettle and to transfer milk from the milk tank to the glass.

3. Development of Automatic Coffee Machine and Experimental Results

Four different modules were used in the development of the automatic coffee machine. These modules were created and assembled in a way that is compatible with each other. All modules are controlled by a single embedded system. The embedded system used is Arduino Mega and the analog and digital inputs and outputs are sufficient to control all components. Arduino Mega control is implemented with C# software. Arduino Mega triggers the components according to the commands sent to Arduino Mega from C#. The reason why only Arduino Mega is not used is to both visualize the control of the automatic coffee machine and to ensure code independence. Basic level codes were written to Arduino Mega and all durations and hierarchical operations were implemented via C#. In this section, all modules that make up the automatic coffee machine will be explained in order. The systems and modules that make up the automatic coffee machine are shown in Figure 1.

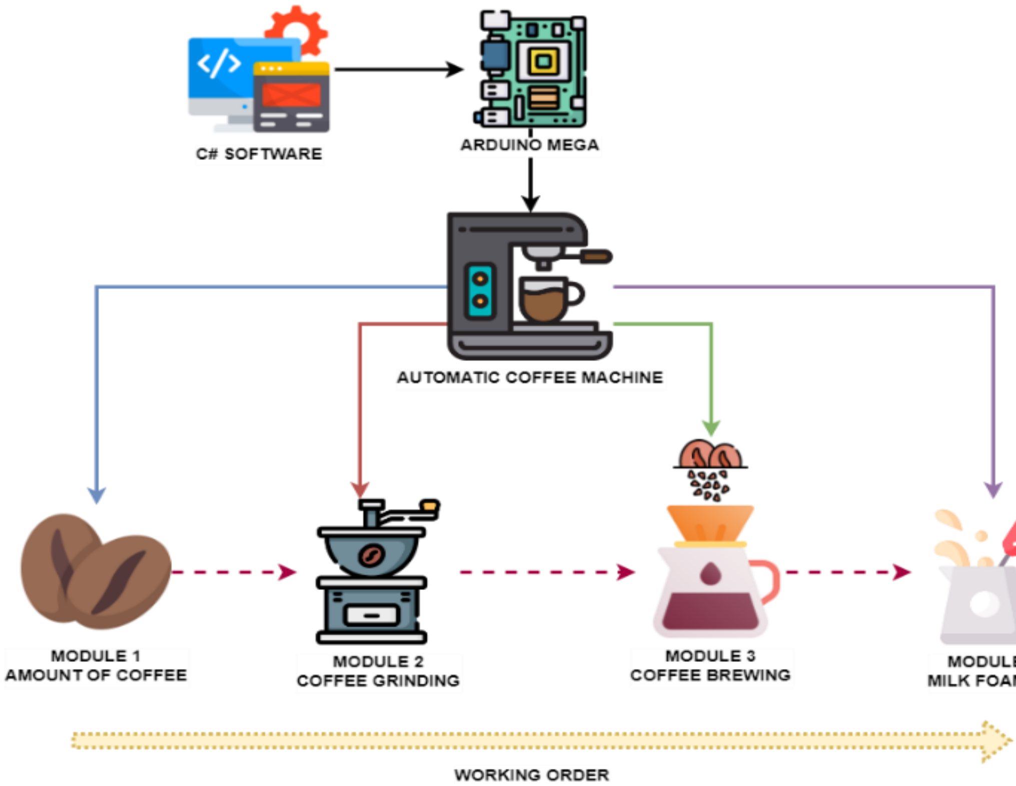


Figure 2. Automatic coffee machine modules

3.1. Coffee strength adjustment module

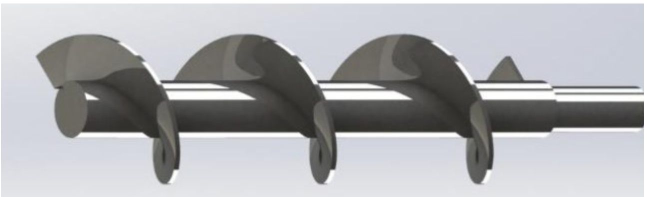
All mechanical parts in the coffee strength adjustment module are designed originally. There is a 150-gram capacity coffee bean container. A helix was produced so that the coffee beans in the container could be transported to the coffee grinding module. The helix was connected to a Nema 17 stepper motor with the help of a ball. Many tests were performed while deciding on this motor. Since coffee beans have a matte texture and do not have a standard shape, they can be caught in the helix. Therefore, this problem was overcome by using a powerful motor. A certain amount of coffee is sent to the coffee grinding module according to the helix rotation time. In order to adjust the coffee strength, the helix rotation time is adjusted according to the coffee weight. Although there is no general standard regarding coffee weights, it has been seen as a result of research that very hard coffees are between 16-18 grams and very soft coffees are between 5-7 grams. Since there are 5 levels, the lower and upper levels of these limits were selected because the scale could be better. In short, 5 grams of beans are used in the lightest coffee. The heaviest coffee uses 18 grams of beans. The values in the table were tested ten times each time and the average of these values was taken. The coffee grams corresponding to the rotation time of the helix are shown in Table 2.

Table 2. Times and weights used in coffee strength adjustment

Strength degree	Duration(Saniye)	Weight (Gram)
Very soft	1	5
Soft	2	10
Medium	2.5	12.5
Strength	3	15
Very strength	3.5	17.5

The 5-stage strength level in Table 1 has been determined. The motor is connected to Arduino Mega with L298N driver. The codes written for this module on Arduino Mega work with commands coming from C#. If desired, the time can be adjusted via C# without the need for re-coding on Arduino Mega. Only the seconds information indicating the weight of coffee to be ground is sent to Arduino Mega from the C# program. Figure 2 shows the design of the mechanical parts of the strength level adjustment module. The real image is shown in Figure 3.

(a) Coffee bean container



(b) Helix

Figure 2. Coffee strength adjustment module design

Figure 3. Coffee strength adjustment module

3.2. Coffee grinding module

The grinder and bean container are the basic components of automatic coffee machines, which are responsible for turning whole coffee beans into powder before brewing. The quality of the grinder determines the uniformity of the coffee grounds and affects the flavor and aroma of the brew. Automatic coffee machines can use burr grinders, which crush the beans between two grinding surfaces, or blade grinders, where rotating blades chop the beans. Although blade grinders are cheaper, they produce irregular powder particles, which leads to longer extraction times and lower quality coffee. Burr grinders provide a consistent coffee grind by offering multiple levels of grind fineness. Automatic coffee machines equipped with burr grinders also allow for the grinding time to be adjusted, allowing the coffee strength to be customized according to personal preferences. In the coffee grinding module, coffee beans coming from the coffee strength adjustment module are ground. Coffee grinding is done using traditional methods. Coffee beans trapped between ceramic discs are ground. After grinding, the filter coffee coarseness can be adjusted manually. A standard shot size was determined by determining the ideal size according to the amount of coffee coming from the coffee strength adjustment module through trials (drinking trials). A standard rotation time was determined in this module.

Because while the amount of coffee should be parallel to the extraction time, sometimes this parallelism can be disrupted. It has been determined that the reason for this is the position of the coffee beans falling into the grinder. The XD-37GB520 DC motor with a gear unit is used in the coffee extraction module. While determining the use of this motor, dozens of motors were tested and it was determined that the most ideal motor was the XD-37GB520 DC motor. All mechanical parts were designed in accordance with the project and produced on a 3D printer. The design of the coffee grinding module is given in Figure 4. The real image of the coffee grinding module is shown in Figure 5.

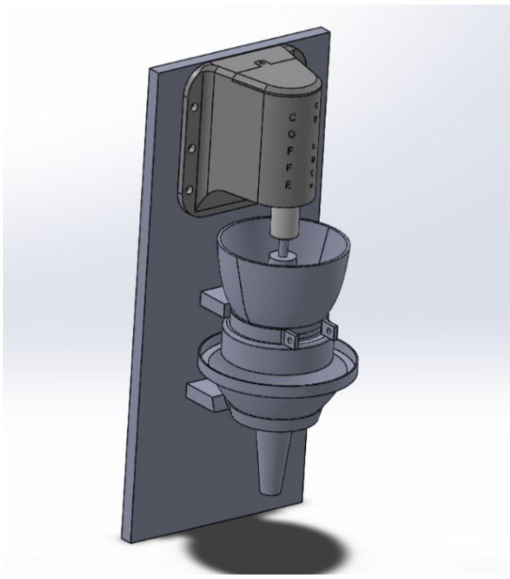


Figure 4. Coffee grinding module design

Figure 5. Coffee grinding module

3.3. Coffee brewing module

Automatic coffee machines prepare coffee by brewing pre-ground coffee. Brewed coffee is different from other coffee drinks such as espresso and filter coffee because it is prepared using pre-ground coffee instead of freshly ground coffee. The brewing unit is at the center of coffee preparation in automatic coffee machines. This unit prepares coffee according to the solid-liquid extraction technique and is very important in producing aromatic coffee drinks. The brewing unit has two basic components: the brewing basket and the brewing chamber. Pre-ground coffee is filled into the brewing basket and placed directly on the brewing chamber. Hot water is applied to the brewing basket to extract the aromas of the coffee grounds and the brewed coffee is collected in the brewing chamber.

There are drippers in the brewing module into which the ground coffees coming from the coffee grinding module will fall. There are filter papers that are manually placed inside the drippers each time. The water heating system works with the relay triggered by the Arduino Mega to brew the ground coffee that falls on the filter paper. The hot water in the water heating system drips in drops onto the coffees in the paper filter and ensures that it is brewed. The hot water system was purchased ready and used. After the brewing is finished, there is an SG90 servo motor under each dripper so that the paper filter can be thrown into the waste bin. After the brewing, the filled dripper is rotated 180 degrees and thrown into the paper waste bin. Then it returns to its original position. There are 4 drippers that work with the same logic. A MG996R model 360-degree rotating servo motor is used for the rotation of the drippers. The real image of the coffee brewing module is shown in Figure 6.

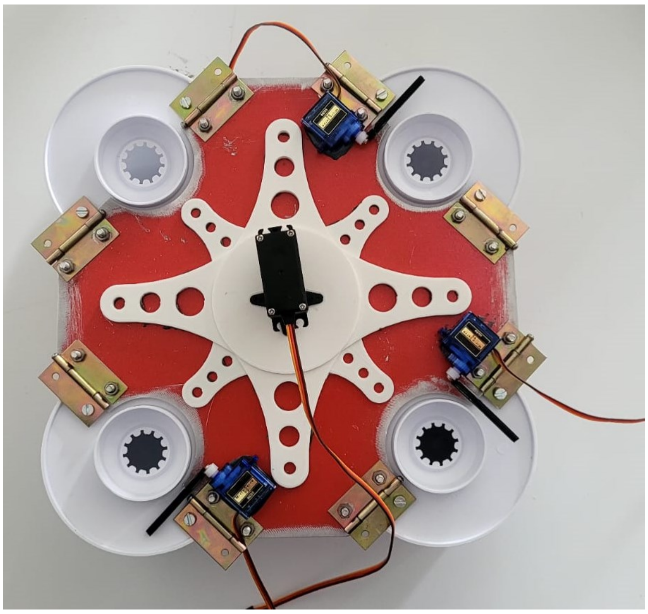


Figure 6. Rear view of the coffee brewing module

3.4. Milk Foaming module

The milk frothing system is one of the useful additional parts options for the automatic coffee machine. This system allows the automatic coffee machine to prepare cappuccino coffee drinks. Without this system, for each cappuccino cup, a customer has to order espresso and steamed milk separately, and the customer has to froth the steamed milk himself. Since frothing steamed milk requires skill and practice for the customer, not correcting this problem makes the entire coffee machine even more difficult to use for inexperienced customers and also makes it unusable for customers who are not skilled. The last module, the milk frothing module, uses a DC motor, milk frothing tank and milk frothing mixer tip. Optionally, the milk poured into the frothing tank can be turned into foam after the motor operates for 30 seconds. After 30 seconds, the milk in the milk tank is poured into the cup with the help of a pump. The pump is connected to the relay controlled by the Arduino Mega. The milk frothing module is shown in Figure 7.

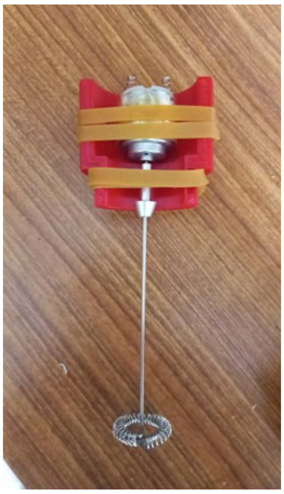


Figure 7. Milk frothing module

3.5. Arduino Mega embedded system and C# software

Arduino Mega is used as an interface for ease of use and coding flexibility. Basic control codings were made and necessary variable values were taken from C# application. In the coffee strength adjustment module, second information is sent to Arduino Mega from C# application. According to the incoming second information, the spiral period and coffee amount are adjusted. In the coffee grinding module, second information is sent to Arduino Mega from C# application. According to the incoming second information, the motor rotates and the coffee is ground. In the coffee brewing module, a trigger variable is sent from C# for the plate where the drippers are located to rotate. There is a 90-degree rotation code for the plate in the codes on Arduino Mega. Then, with the command from C#, the water heating module works by triggering the relay controlled by Arduino Mega. After the coffee brewing process, after the dripper holder plate rotates 90 degrees, the servo belonging to the dripper rotates 180 degrees and throws the paper filter into the waste bin. After this stage, the milk is frothed and poured into the glass with the help of a pump. The interface of the C# application used in performing these operations is shown in Figure 8.

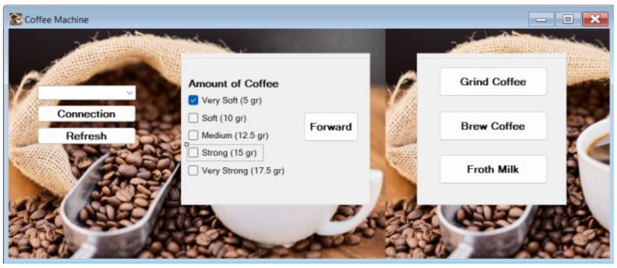
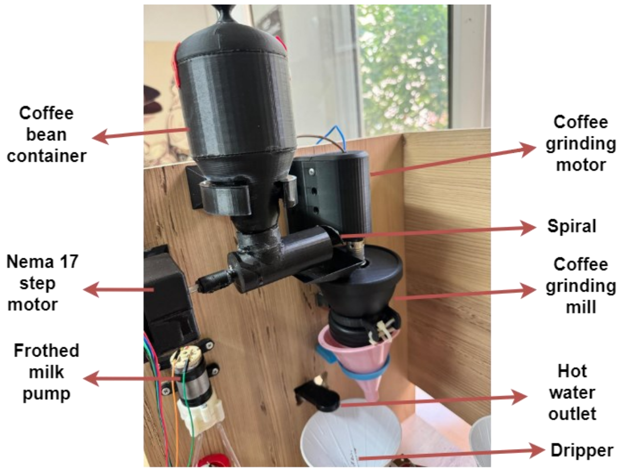
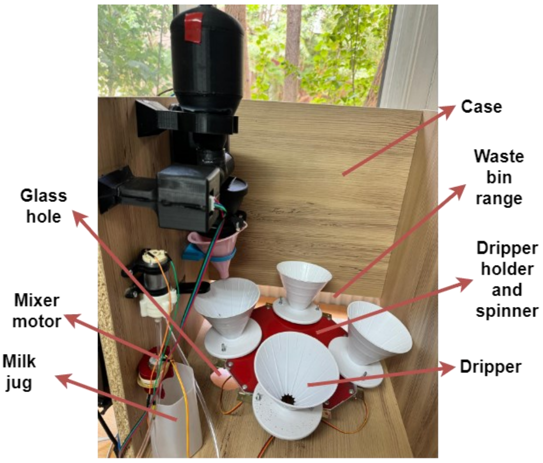


Figure 8. C# application

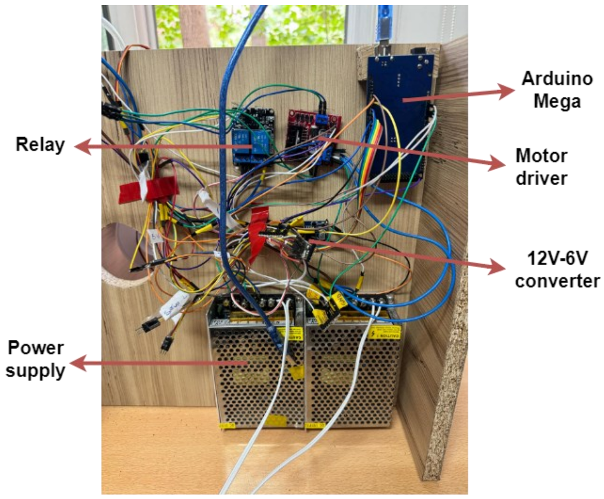
In the interface shown in Figure 8, firstly the Arduino Mega connection is established. Then the coffee degree is determined. Then the coffee grinding process, coffee brewing process and milk frothing processes are carried out. If desired, these processes can be carried out hierarchically. In order to perform the tests, the operation button of each module was used separately. The real images of the coffee machine and the components of the modules on it are shown in Figure 9 (a, b, c). The water heater is shown in Figure 10.



(a)



(b)



(c)

Figure 9. (a) Coffee strength adjustment module and coffee grinding module, (b) Total view of the coffee machine, (c) Electronic parts of the coffee machine

Figure 10. Water heating module

4. Conclusions

Automatic coffee machines have become increasingly popular in recent years due to their ease of use, convenience, and consistent brewing quality. They offer a range of customizable options, including coffee strength, aroma level, temperature, and milk frothing, allowing users to recreate their favorite specialty drinks at home. They are designed for home or workplace use, but larger units can also be used in coffee shops or restaurants. With this motivation, a prototype automatic coffee machine was built in this study. This machine has four modules. The coffee strength adjustment module, coffee grinding module, coffee brewing module, and friction frothing module make up the automatic coffee machine. The operating conditions of each module were tested repeatedly. Possible errors were detected and necessary modifications were made. The prototype automatic coffee machine was controlled with Arduino Mega. A flexible control software was implemented to develop the automatic coffee machine by connecting Arduino Mega to C# application. Instead of re-coding on Arduino Mega, changes can be made entirely through C#.

The prototype automatic coffee machine developed in this study includes various modules that allow users to personalize their coffee experience, while it has some limitations and areas that need to be developed in the future. Firstly, the hardware components and sensors used in the prototype may not be as precise as commercial products, so the measurement accuracy and consistency of the coffee preparation process may be limited. This is especially evident in fine-tuning settings such as the strength level and aroma level. Furthermore, the connection between the C# application used and the Arduino Mega, although flexible, is a system that does not have the capacity to collect and analyze data on a larger scale. This provides a limited infrastructure to collect user feedback and optimize the machine's performance.

In the future, upgrading this system with a more advanced microcontroller or single-board computer could allow for the implementation of more complex control algorithms and user interfaces. At the same time, the accuracy of the coffee preparation process could be increased by using more advanced sensors and components. For example, more precise control could be provided for parameters such as water temperature, coffee bean grinding degree and milk frothing process. In addition, the integration of a machine learning algorithm that records and learns users' preferences could provide a personalized coffee preparation experience by better understanding users' habits and tastes. Adding an internet connection could provide additional features such as remote access and control, software updates and online recipes. Finally, reviewing the aesthetic and ergonomic design of the machine could improve the user experience and increase the marketability of the product. These suggestions could be taken into account during the process of converting the prototype into a commercial product and could offer users a richer, more flexible and more satisfying coffee experience.

Declaration of Ethical Standards

The article does not contain any studies with human or animal subjects.

Credit Authorship Contribution Statement

All authors contributed to the design and study of the article. ASA, literature research and reparation of the draft; YST, analysis of data and result, arranged the materials, methods and data.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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