

Automated Coffee Vending Machine

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Abstract— In the rapidly evolving landscape of food consumption, where lifestyles have drastically shifted, the creation of specific distribution channels like vending machines has received surprisingly little attention, despite their burgeoning presence and potential. Italy, at the forefront of this trend, not only boasts the highest number of vending machines across Europe but also leads the continent in both machine manufacturing and advanced management services, with a particular emphasis on enhancing food quality. Yet, this surge in vending machine usage seems paradoxically disconnected from the agriculture sector, which remains underrepresented in the supply chain, leaving a crucial gap in locally sourced offerings. To address this, a novel localized product recommendation system emerges, designed to refine the automatic vending machine experience by tailoring food suggestions to the unique preferences of diverse regions. This system, a hybrid concoction of statistical methods, classification, clustering, and meta-heuristics, leverages transaction data to analyze product attributes and align them with local tastes [8].

Index Terms— Automated Coffee Machine, Dispensing, UI, ML, Quality, Cost.

I. INTRODUCTION

Coffee, an ancient elixir derived from the roasted seeds of tropical evergreen coffee bushes native to Africa, has transcended generations to become the world's second most consumed beverage, with more than 2 billion cups brewed daily across the globe. For engineers and professionals alike, it's more than just a drink—it's the fuel that powers productivity, elevating moods and sharpening focus in the midst of demanding workdays. A cup of coffee can make or break a day, and its role in our lives goes beyond caffeine addiction; studies suggest that moderate consumption can even extend our lifespans.[1][3] However, the quest for that perfect cup, one that provides both comfort and invigoration, often feels like an arduous journey in itself. The act of brewing a decent cup, especially when time is of the essence, remains an art and a science, fraught with complexity. Enter the intelligent coffee maker, designed to revolutionize our caffeine experience. This modern marvel doesn't just make coffee—it makes the brewing process seamless and rapid, ensuring a satisfying cup in mere minutes. [3][5]With a focus on convenience and quality, the machine offers a variety of coffee styles, including popular favourites like espresso, cappuccino, latte, and the rich, indulgent café mocha. In an era where time is precious and taste paramount, this intelligent solution provides the perfect blend of speed and satisfaction, eliminating the hassle of waiting or compromising on flavour. Meanwhile, the coffee vending machine—once a simple, often uninspiring device—has evolved into a high-tech beverage dispenser capable of delivering fresh, hot coffee with a touch of a button. [5][7]Gone are the days of instant powdered coffee and lukewarm cups; today's advanced models grind coffee beans to order, brewing each cup with fresh grounds, and offering an array of options for

customization, such as sugar, cream, or even syrups. These machines also cater to a broader range of hot beverages, from espresso and lattes to more indulgent mochas and hot chocolate, giving customers a diverse array of choices beyond just the humble cup of coffee. In some cases, these cutting-edge vending machines go beyond the ordinary, offering iced coffee and an array of other specialty drinks, expanding the possibilities for coffee lovers.[2][5] This shift represents a broader transformation in how we view coffee machines—not merely as mechanical dispensers, but as intelligent, adaptable devices designed to meet the specific demands of today’s fast-paced, flavour-seeking consumers. As technology continues to advance, the simple coffee maker may soon become a fully integrated part of our digital ecosystems, ensuring that no matter where we are, we have access to the perfect brew, whenever we need it most.

II. LITERATURE SURVEY

In Sustainable consumption, a paradigm wherein goods are used in ways that minimize environmental impact across their lifecycle, represents a growing shift in consumer behavior (Paul et al., 2016).[These environmentally conscious products, often dubbed “green products” (Dangelico & Pontrandolfo, 2010), are shaped by a medley of contextual and individual factors that influence consumption patterns (Tripathi & Singh, 2016). [5][9]However, beyond these variables, it’s the product itself—specifically its perceived advantages—that fuels consumer choices. The intrinsic and extrinsic features, from environmental benefits to product quality, mold consumers’ intentions to purchase (Zeithaml, 1988). For businesses to positively alter these perceptions, amplifying these traits is paramount, especially for items like food products, where the intertwining of environmental and personal values plays a pivotal role in the decision-making process (Symmank, 2019). [4][8]Among these influencing factors, two standout: eco-friendly packaging and price, which significantly shape consumer perspectives on sustainability.

Eco-friendly packaging, a key player in this evolving landscape, is widely recognized for its potential to reshape consumer attitudes toward food products. It’s not just about being “green”—it’s about how the packaging feels, looks, and communicates sustainability. As Ketelsen et al. (2020) assert, consumers generally favor products wrapped in environmentally friendly materials, such as recyclable paper or glass, which offer biodegradability and sustainability.[7][9] These inherent qualities of the packaging—its material properties, weight, size, and shape—can drive purchase intentions (Magnier & Cri , 2015). The expectation is clear: packaging should minimize waste and overpackaging while embracing recyclable or bio-based materials (Lindh et al., 2016; Boesen et al., 2019). Despite plastic’s controversial environmental footprint, when it’s designed with eco-friendly characteristics like recyclability, it can still be perceived positively (Boesen et al., 2019). However, the external factors—graphics, logos, and labels—play an equally crucial role. Consumers are swayed by visual cues, such as nature imagery, eco-friendly logos, and sustainability labels, which signal the product’s environmental responsibility (Magnier & Cri , 2015). [7][8]It’s not just the color scheme—though muted tones like white or brown often suggest sustainability—but the meaningful information, such as disposal instructions and environmental claims, that solidify consumer trust and drive purchase behavior (Van Loo et al., 2015).

Moreover, technological innovation continues to push boundaries, transforming how products are developed and how businesses engage with consumers.[2][5] As H kansson and Waluszewski (2001) argue, technology emerges from the interactions between various players in a business network, with innovation driven by the collaborative effort of producers and users (La Rocca & Snehota, 2014). This relational approach to technology development emphasizes the importance of networks, where new solutions aren’t just created in isolation but evolve from the interactions and exchanges between stakeholders (La Rocca et al., 2016). [4][10][16]This nexus between technological change and consumer interaction can sometimes lead to friction, particularly when users—especially those seeking consistency—are confronted with the unpredictability of new, smart products (Chou & Zolkiewski, 2012). In the case of coffee machines, for instance, while the outcome (the “perfect” cup of coffee) remains the main draw, the underlying technology itself often induces curiosity and skepticism.

On the flip side, the vending machine industry, especially in the context of food and beverages, reflects a dynamic tug-of-war between consumer demand for healthier options and the industry’s profit-driven model. [5][8]Vending machines have historically been stocked with energy-dense, nutrient-poor foods laden with sugars, fats, and salts—choices that contribute to unhealthy behaviors, especially when healthier alternatives are scarce (Rosi et al., 2017; Grech et al., 2017). While the introduction of low-calorie and nutritious products has been studied since the early 1980s (Wilbur et al., 1981), challenges remain. A Canadian pilot study (Callaghan et al., 2010) found that despite rising interest in healthier snacks, the higher costs of these products and consumers’ preconceived notions about their quality led to a decline in vending machine revenues. [11][14]Consumers often associate healthier options with inferior taste or value, leading them to seek alternatives. This discrepancy

between health-conscious trends and vending machine sales highlights the complexity of altering purchasing behavior, particularly when consumers' perceptions of quality and health diverge. Further complicating this issue, research has shown that pricing and labeling play critical roles in shaping consumer choices. [15][19] For instance, French et al. (2011) found that lowering prices on low-fat snacks could encourage healthier purchasing decisions in vending machines. At the same time, clear labeling—front-of-pack nutrition indicators—helped university students identify healthier options amidst a sea of less nutritious choices (Carrad et al., 2015). Thus, the path forward lies in bridging the gap between consumer perceptions and product offerings, leveraging technology, packaging, and pricing strategies to create a more sustainable and health-conscious vending machine experience. [21][24] The interplay of these factors is shaping not only the future of vending machines but the broader shift toward sustainable, health-oriented consumer behavior in an increasingly complex marketplace.

III. SYSTEM ANALYSIS

The coffee vending machine operates as an intricate symphony of components, orchestrated by the central Arduino Uno Controller, a microcontroller board based on the versatile ATmega328P, efficiently managing inputs and outputs to ensure a seamless coffee experience.[8][12] The Arduino acts as the brain of the operation, interpreting signals from the coin acceptor, which meticulously validates the authenticity of coins based on size, weight, or material composition.

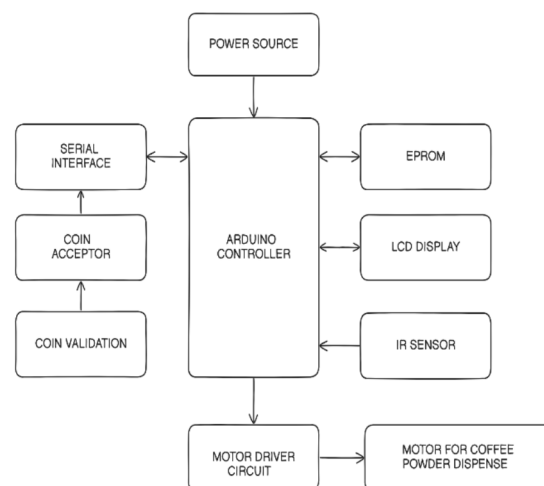


Figure 1. Block Diagram

A. Arduino Uno

Once the system detects sufficient payment, the Arduino commands the next phase: the brewing process. This seemingly straightforward task is far from simple, as it activates a carefully calibrated heater coil to elevate water temperature to the ideal brewing range, typically between 85°C and 96°C, via a relay or solid-state switch.[4][14] This process, although automated, is not devoid of safety precautions, with real-time temperature monitoring embedded to prevent any potential overheating, ensuring that every drop of water is just the right temperature for brewing the perfect cup of coffee

B. Heater coil

The LCD display, a 16x2 or 20x4 module, provides real-time user feedback, acting as the interface through which users interact with the machine. Whether it's showing a simple instruction like "Insert Coin" or providing status updates like "Dispensing Coffee," it serves as a crucial part of the user journey, guiding them through each stage of the process. Meanwhile, the motor, an unsung hero, controls the dispensing of essential ingredients like coffee powder, milk, and sugar.[5][15] It operates in tandem with the Arduino, guided by motor drivers such as the L298N or ULN2003, ensuring precise ingredient measurements and optimal blending for each brew. Storing vital data like the number of coins inserted, drinks dispensed, and user preferences is handled by an EPROM (EEPROM), a non-volatile memory that safeguards information even during power outages, enabling the machine to retain critical usage and revenue data with remarkable reliability.

C. LED Display

The solenoid valve, another pivotal component, takes charge of controlling the flow of the coffee mixture from the mixing chamber to the dispensing outlet. This electromechanical marvel uses an electromagnetic coil to activate a plunger, precisely regulating the flow of coffee, milk, sugar, and hot water into the user's cup. [13][15] When the Arduino sends an electrical signal, the coil creates a magnetic field that lifts the plunger, allowing the concoction to flow. Once the dispensing is complete, the system deactivates the valve, ensuring that the flow halts instantly. This precision and swift response are what make the solenoid valve an ideal choice for vending machines, maintaining consistent servings, hygiene, and operational efficiency, all while minimizing maintenance.



Figure 3. Led Display



Figure 4. Solenoid valve

D. Solenoid valve

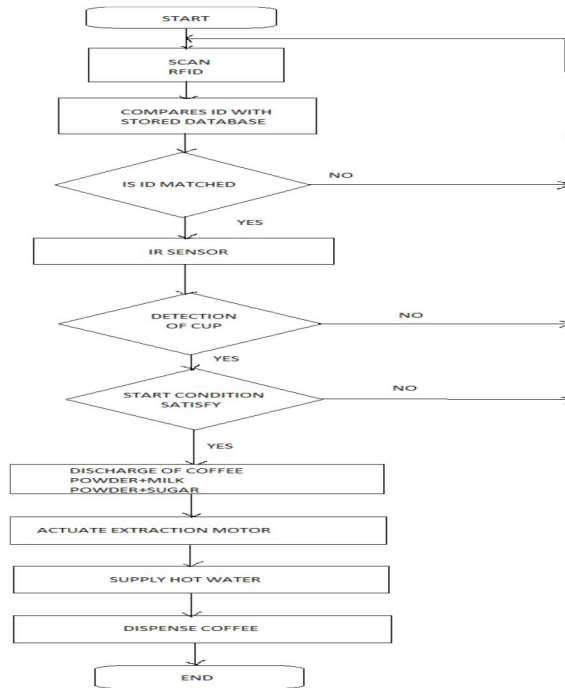
Supporting the solenoid valve's operation is the relay module, a crucial interface between the low-power Arduino and the high-power solenoid valve. [16][19] The relay acts as a safeguard, isolating the Arduino's low-power circuitry from the higher voltages needed to activate the solenoid. It operates by using a small current from the Arduino to energize an internal electromagnetic coil, which in turn toggles a switch that controls the power to the solenoid valve. [14][17] This interaction ensures that the Arduino can manage the powerful solenoid safely and reliably, protecting the system from potential damage while ensuring that the coffee flows when it should and halts at precisely the right moment. By integrating the relay module, the vending machine gains robustness and flexibility, ensuring that each cup of coffee dispensed is of the highest quality, thanks to the flawless interaction between all its components.

E. RFID Card

Contactless smart cards that use radio waves to transport data between the card and an RFID reader are known as RFID (Radio Frequency Identification) cards. The benefit of RFID cards is that they allow data transfer without direct physical touch, unlike conventional cards like barcodes or magnetic stripe cards. An RFID card's inbuilt antenna and chip use radio signals to connect with an RFID reader when it is brought within range, usually a few centimeters to a meter. The transfer of distinct identifying information stored on the RFID card's chip is made possible by this communication method. Payments, inventory tracking, controlling access to restricted areas, and verification are just a few uses for the data. Based on their power supply, RFID cards can be classified as active, semi-passive, or passive. Active RFID cards are able to send signals farther because they have an integrated battery that powers the chip and the antenna. Usually, these cards are utilized in situations requiring long-distance communication, such tracking assets or identifying vehicles. Semi-passive RFID cards, sometimes referred to as battery-assisted passive cards, still use an RFID reader to send and receive signals even if they contain a battery powering the chip. Compared to passive RFID cards, this configuration improves the card's usefulness and range. Passive RFID cards, on the other hand, lack an internal battery. Rather, they use the reader's electromagnetic field to generate electricity, which makes them long-lasting and reasonably priced. They are extensively utilized in commonplace applications including library cards, access control systems, and fare cards for public transit.

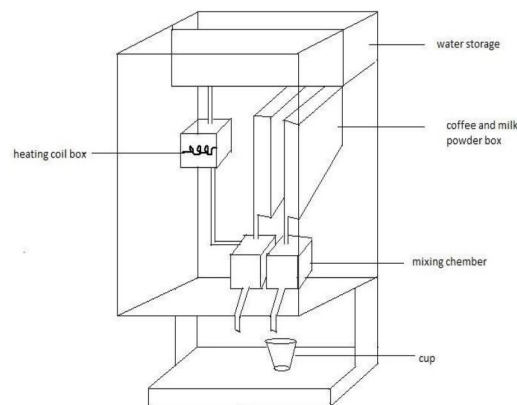
IV. METHODOLOGY

The coffee vending machine is a masterful fusion of automation and precision, orchestrated by the central brain—an Arduino Uno—serving as the conductor of this intricate, systematic process. Upon the machine's activation, the Arduino springs to life, initializing all components, triggering an interface that greets users with a welcoming LCD message, urging them to deposit coins. [13][19] The coin acceptor promptly comes into action, meticulously evaluating the incoming currency, ensuring the right amount is fed into the system. Once the required payment threshold is met, the Arduino signals the commencement of the coffee-making ritual, setting into motion an elaborate sequence of events.



Flow Diagram Overview

As seen in the provided image, the water supply is held in a storage tank located within the heating chamber. The heater coil is strategically placed to efficiently heat the water, while two separate chambers store various coffee powders, offering a diverse range of flavors.[13][18] Beneath the chambers, the mixing motor is connected to a small mixing chamber that ensures the precise blending of ingredients. Finally, the dispensing mechanism works in perfect harmony to transfer the freshly brewed coffee into the user's cup, completing the cycle of automation and delivering a high-quality coffee experience every time.



Mechanical Layout

V. RESULT AND DISCUSSION

The coffee vending machine, a marvel of automated engineering, represents the culmination of intricate technology working in symbiosis to create the perfect cup of coffee with minimal human intervention. At the heart of this precision-driven operation lies the Arduino Uno microcontroller, the brain that orchestrates every aspect of the machine's performance, with an almost choreographed sequence of components springing to life once the system powers on. [6][12] From the initial hum to the flicker of the LCD, the machine signals the user to insert their coins. Upon detection of the right amount, the magic begins. A single coin triggers a cascade of processes—like gears in a well-oiled machine—that deliver the desired result: a steaming, perfectly brewed cup of coffee. As the coin acceptor springs into action, it scrutinizes each coin with meticulous care, analyzing their

size, weight, and material composition. Once the system determines that the correct amount has been inserted, it provides the green light, and the Arduino takes the reins. [12][18] The first task? Heating the water to the precise temperature for brewing, which involves activating the heater coil, a resistive element that efficiently converts electrical energy into heat. This is no simple feat—achieving the perfect brewing temperature of 85°C to 96°C requires precision, and any variation could disrupt the delicate extraction process, resulting in a lackluster cup. The machine also employs robust safety measures like temperature monitoring to mitigate risks, ensuring that the water heats within the optimal range, guaranteeing a consistent brew every time.

Simultaneously, the Arduino commands the motors to dispense the correct portions of coffee powder, milk, and sugar into the mixing chamber, where the alchemy of ingredients begins. [6][18] These motors, fine-tuned by the Arduino through motor drivers such as L298N or ULN2003, valve enters the scene when the ingredients are ready, controlled by a relay module. [4][16] With an electrical signal from the Arduino, the solenoid valve opens to allow the hot coffee mixture to flow into the waiting cup, ensuring that the flow is both steady and accurate, crucial for maintaining consistency in each serving. The LCD display, meanwhile, provides a real-time, user-friendly interface, continuously updating the user with messages like "Heating Water" or "Dispensing Coffee." This seamless communication fosters a sense of control, allowing the user to track the brewing process step-by-step. Behind the scenes, [5][20] the EEPROM silently records vital operational data—tracking the number of cups dispensed, coins inserted, and revenue generated—preserving this information even during power failures. This data not only ensures operational transparency but also enhances long-term machine efficiency, providing operators with the insights needed to adjust pricing, restocking schedules, or service intervals. A critical innovation in this setup is the integration of an IR sensor, which ensures that coffee isn't dispensed unless a cup is correctly placed beneath the outlet. [15][28] A seemingly small yet crucial feature, this sensor removes any possibility of spillage, contributing to the system's overall efficiency. If no cup is detected, the machine pauses until it receives the correct signal. [6][26] With every step accounted for, this automated process ensures the perfect brew with no room for error.



Figure 7. Prototype model

VI. CONCLUSION

The automated coffee vending machine, built around the Arduino Uno, demonstrates the seamless integration of embedded systems and mechanical components. It ensures precise coin validation and consistent coffee delivery, ideal for offices, schools, or public spaces. Key components like the heater coil, solenoid valve, and motors work together to dispense accurate amounts of ingredients. Intelligent sensors, such as the IR cup detector, prevent errors like dispensing without a cup. The LCD provides real-time feedback, while EEPROM stores essential data like usage and revenue. Automation, safety, and user-friendliness define the system's core design. This machine stands as a model of smart engineering, blending hardware and software for efficient beverage service.

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