Smart Water Pouring System

IOT102-SE1839, Group 2

Do Phuc Duy, Tran Dang Minh Quan, Nguyen Bao Khanh, Nguyen Hoang Minh Nhat, and Le The Dung
FPT University, Ho Chi Minh Campus, Vietnam
{doychannel1802, baokhanhtcv2005, minhnhat3082001winds, trandangminhquan2005}@gmail.com, dunglt96@fe.edu.vn

Abstract

The purpose of this project is to design and develop an innovative, fully automated water dispensing system that utilizes the integration of an Arduino UNO microcontroller, a water pump, and a flow sensor. The goal is to achieve highly precise measurement and controlled transfer of water to any predefined destination or container. Traditional water dispensing methods often suffer from significant inefficiencies, such as inaccurate volume control, manual supervision requirements, and unintentional water wastage. This project aims to directly address these limitations by applying modern IoT-based technologies and intelligent control systems.

At the core of the system is the Arduino UNO, which functions as the main controller, interfacing with both the water pump and the flow sensor. The flow sensor continuously monitors the real-time flow rate and total volume of water being dispensed. Based on this feedback, the Arduino dynamically adjusts the pump's operation, either by modulating its speed or switching it off entirely once the desired water volume is reached. This closed-loop control mechanism ensures that the amount of water delivered is both accurate and consistent, eliminating common problems such as overflows or under-dispensing.

In addition to precision, the system emphasizes reliability and safety. The design includes protective logic to detect abnormal conditions, such as sudden changes in flow rate or dry run scenarios, enabling the system to stop automatically and notify users if needed. This enhances both the operational lifespan of the equipment and the overall safety of the dispensing process. Furthermore, the system can be programmed to handle multiple dispensing modes (e.g., fixed-volume dispensing, continuous flow, or customizable presets), making it flexible for various application scenarios.

The benefits of this automated water dispensing system extend beyond household use. In industrial settings, it can be applied to processes where precise water measurement is critical, such as in chemical mixing, food and beverage production, or agricultural irrigation systems. In household environments, it can serve applications like automated plant watering, cooking measurements, or aquarium water management. The system's scalability and adaptability allow it to meet the diverse needs of different users.

From a sustainability perspective, the project contributes meaningfully to water conservation efforts. By minimizing wastage and ensuring optimal use of resources, it supports global initiatives aimed at environmental protection and efficient resource management. The project also showcases the growing potential and practicality of IoT-based automation in solving everyday challenges, demonstrating how simple microcontroller-based systems can deliver significant improvements in convenience, efficiency, and sustainability.

In conclusion, this project highlights the transformative power of IoT technologies combined with intelligent control systems in fluid management applications. The automated water dispensing system designed in this project represents a reliable, precise, and user-friendly solution that can be adapted across multiple sectors. It stands as a testament to how engineering innovation can drive resource optimization, reduce human error, and contribute to environmental conservation in both domestic and industrial settings.

I. Introduction

In the 21st century, technological advancement has become a driving force that influences every aspect of modern life. From communication and transportation to healthcare and environmental monitoring, the integration of smart systems and intelligent devices is shaping a more connected and efficient world. Among these advancements, the Internet of Things (IoT) stands out as a transformative concept that enables devices to communicate, collect, and exchange data without the need for direct human intervention. IoT refers to a vast network of interconnected devices embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet [1]–[3]. This interconnectivity facilitates smarter decision-making processes and the automation of tasks that were once labor-intensive or prone to human error.

As the adoption of IoT technologies continues to expand, it is increasingly applied to various sectors such as smart homes, healthcare monitoring, manufacturing, agriculture, and environmental conservation [4]. One of the most pressing areas where IoT solutions can make a substantial impact is in the efficient management of natural resources, particularly water. Water is an essential resource for all life forms, yet it is often misused or wasted due to inefficient systems and lack of precise control. According to numerous studies, millions of liters of water are lost each year due to improper measurement and manual handling [5]. In industrial settings, overflows and leakage not only result in wastage but also incur significant financial costs. Similarly, in household environments, leaving water taps open or relying on inaccurate manual pouring contributes to unnecessary resource depletion.

Fig. 1. Technology in general has shaped our daily lives.

Traditional methods of water dispensing are typically manual, lacking real-time monitoring and control mechanisms. These methods often depend on human estimation, which is inherently inaccurate and inconsistent. Without proper monitoring, both over-dispensing and under-dispensing can occur, leading to inefficiencies and avoidable waste [6]. Moreover, such practices are not sustainable, especially in regions facing water scarcity or where environmental regulations are becoming stricter. Therefore, there is a growing demand for solutions that can automate and optimize water usage with accuracy and reliability.

To address these concerns, advanced technologies are increasingly being explored to improve water management systems. Automated water dispensing systems that utilize microcontrollers and sensors offer a promising solution. By employing sensor feedback and intelligent control algorithms, these systems can accurately measure water flow, adjust pump operations in real-time, and provide users with precise control over water delivery volumes [7]. In doing so, they help to minimize waste, enhance operational efficiency, and contribute to environmental sustainability.

In response to this growing need, the Smart Water Pouring System has been conceptualized and developed. This system is designed to revolutionize water dispensing practices through the integration of key IoT components. At the core of the system is the Arduino UNO microcontroller, which serves as the brain of the operation. Working in conjunction with a flow sensor and a water pump, the system is capable of measuring and transferring water with exceptional accuracy. By continuously monitoring flow data, the Arduino can dynamically adjust the pump's operation to maintain desired flow rates and volumes, thereby eliminating guesswork and ensuring precise control.

The primary objective of the Smart Water Pouring System is to demonstrate how modern technology can be harnessed to automate water dispensing processes effectively. In addition to providing precise measurement, the system also focuses on user convenience by offering an intuitive and easily programmable platform. Users can set target volumes, and the system will automatically handle the rest, stopping the pump when the desired volume is reached. This reduces the need for constant supervision and prevents both overflow and underflow situations.

Furthermore, the system has been designed with flexibility and scalability in mind. It can be easily adapted for use in industrial environments where large-scale water transfer is required, as well as in household settings where controlled water dispensing is beneficial, such as in kitchens, gardens, or pet care. In agricultural contexts, this system could play a critical role in irrigation management, where precision and timing are vital to crop health and resource conservation [5], [7].

By leveraging IoT technology, this project not only addresses current challenges in water resource management but also paves the way for future advancements. The Smart Water Pouring System stands as a testament to how interconnected devices and real-time control can solve practical problems in everyday life. It serves as a clear example of how the convergence of hardware, software, and smart sensing can lead to innovations that are both practical and environmentally responsible.

In conclusion, as the world continues to face increasing pressures related to water scarcity and environmental protection, the development of automated, precise water dispensing systems becomes more critical than ever. The Smart Water Pouring System embodies this vision by combining the power of IoT with practical engineering to create a solution that is not only technically effective but also contributes to the global goal of sustainable resource utilization. This project demonstrates the transformative potential of technology in addressing real-world problems and highlights how innovation can drive positive change in both industrial and domestic contexts.

TABLE I
SYSTEM'S COMPONENTS AND PERIPHERAL DEVICES

Components/devices	**ID/remarks**
Arduino Uno R3	ATmega328P-based microcontroller
Bluetooth Module	HC-05 , Serial Communication
Water Pump	Controlled via relay
Water Flow Sensor	YF-S401, Hall Effect-based
LCD Display (I2C)	16×2 LCD with I2C module
Relay	Single-channel 5V relay module
Breadboard	MB-102, two full-size prototyping board
Push Button	Predefined volumes: 100ml, 300ml, 500ml
Connecting wires	Jumper wires (MM, MF, FF)

II. METHODS AND MATERIALS

A. System Model and Block Diagram

This intelligent liquid handling system features a 200W water pump controlled by an Arduino Uno microcontroller for precise volume dispensing. The system incorporates a YF-S401 flow sensor that provides accurate 2.25mL resolution measurement through hall-effect pulse counting. Users can select from three preset volumes (100mL, 300mL, 500mL) using either physical push buttons or a Bluetooth-connected mobile application, with real-time feedback displayed on both an I²C LCD screen and the companion app.

The Arduino continuously monitors flow rates using the Q=F/7.5 (L/min) calculation, automatically stopping the pump when reaching the target volume with ($\pm$10%) accuracy after calibration. The system's closed-loop design ensures energy-efficient operation while maintaining precise control. Bluetooth connectivity via an HC-05 module enables remote monitoring and operation.

Ideal for laboratory, industrial, and agricultural applications, this modular system combines reliable performance with flexible control options. The robust 200W pump delivers consistent flow rates while the sensor provides accurate volume measurement. The dual-interface design (physical buttons and mobile app) offers operational versatility, making the system adaptable to various use cases and environments.

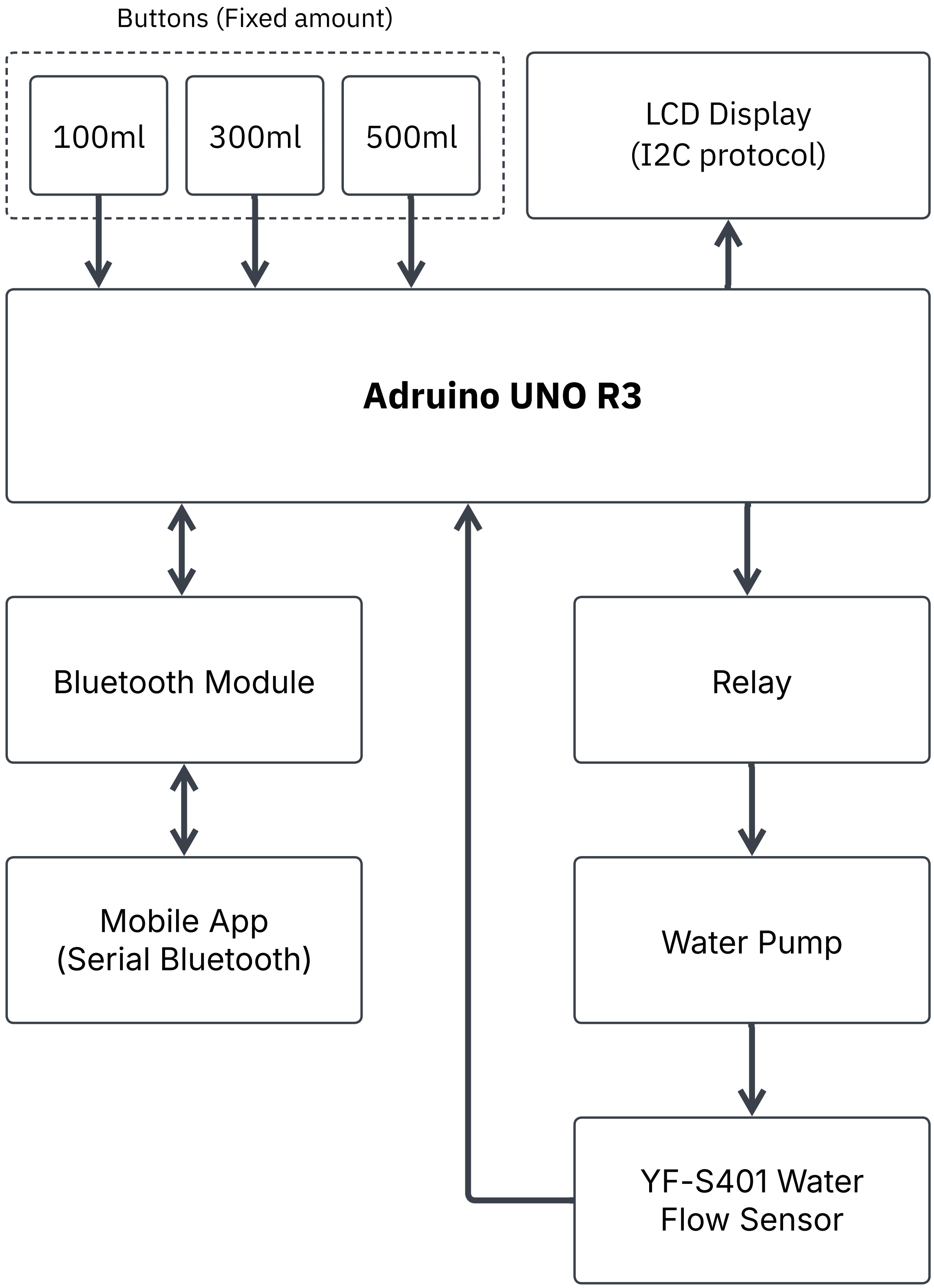


Fig. 2. Block Diagram

B. Components and Peripheral Devices

The system is designed around the Arduino UNO, which functions as the central processing unit. A water pump is positioned at the source and is activated when permitted by a relay, which is regulated based on input from the flow sensor. The system includes a physical control panel equipped with three buttons, enabling the user to dispense predetermined water volumes of 100ml, 300ml, and 500ml. Additionally, an LCD display is integrated to provide real-time tracking of the dispensing process.

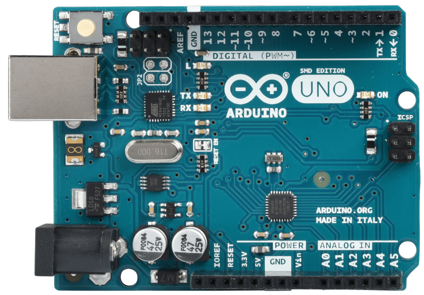


Fig. 3. Arduino UNO

- **Arduino Uno:**The Arduino Uno is a versatile and widely used microcontroller board based on the ATmega328P chip. Designed for beginners and professionals alike, it features 14 digital input/output pins, with 6 capable of PWM (Pulse Width Modulation) output for analog-like control, such as dimming LEDs or driving motors. Additionally, it includes 6 analog input pins for reading sensors or variable signals. The board is clocked at 16 MHz via a ceramic resonator, ensuring stable performance for most embedded projects. Connectivity options include a USB port for programming and power, a DC power jack for external power sources (like batteries or adapters), and an ICSP (In-Circuit Serial Programming) header for advanced firmware updates. With its built-in reset button and easy-to-use IDE, the Arduino Uno provides a complete development platform—just plug it into a computer via USB or power it externally to start prototyping. Its open-source nature and vast community support make it ideal for learning electronics, robotics, IoT, and automation.

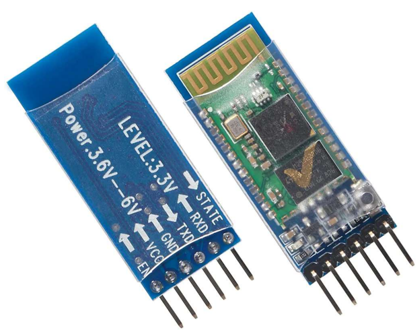


Fig. 4. Bluetooth Module

- **Bluetooth Module:** The Bluetooth module (such as the HC-05 or HC-06) is a wireless communication component that enables UART-based serial communication between an Arduino and a smartphone app or other Bluetooth-enabled devices. It typically operates on 3.3V or 5V power (VCC), with GND for grounding, TXD (transmit data) to send data from the module to the Arduino, and RXD (receive data) to accept incoming data. Some modules also feature optional pins like STATE (indicating connection status via an LED or logic signal) and EN/KEY (used to toggle between AT command mode and normal operation). This module allows bidirectional data exchange—receiving commands from a mobile app (e.g., controlling LEDs, motors, or sensors) and transmitting real-time system updates (e.g., sensor readings or status alerts) back to the app. Commonly used in IoT, home automation, and robotics, Bluetooth modules provide a simple, low-power wireless solution for short-range (typically up to 10 meters) communication without complex wiring. Their compatibility with Arduino's Serial Monitor and app development platforms (like MIT App Inventor or Blynk) makes them ideal for prototyping wireless projects.

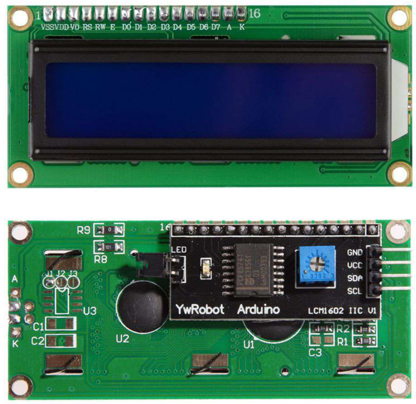


Fig. 5. LCD Display (I2C)

- **LCD Display (I2C):** The LCD Display (I2C) is a 16x2 or 20x4 character screen that comes with an I2C interface module, which simplifies connections to an Arduino by reducing the number of required wires. Instead of multiple pins, it only needs four main connections: VCC (5V power), GND (ground), SDA (Serial Data Line), and SCL (Serial Clock Line).
The I2C (Inter-Integrated Circuit) protocol enables efficient serial communication, allowing the display to show important information such as sensor readings, system status, or user messages while using minimal Arduino pins. This makes it an ideal choice for projects like data loggers, weather stations, and control panels by saving GPIO pins for other components and simplifying circuit design.
The I2C adapter, often based on the PCF8574 chip, handles signal conversion, allowing the Arduino to control the LCD using the Wire library. With low power consumption and easy integration, the I2C LCD is widely used in embedded systems, DIY electronics, and educational projects, enhancing both functionality and user interaction.

Fig. 6. Water Pumb

- **Water Pumb:**The small DC-powered water pump is a compact and efficient device designed for precise liquid dispensing in automated systems. It features two wires—red (positive) and black (negative)—for simple power connection, typically running on 5V to 12V DC, making it compatible with Arduino and other microcontroller setups. When powered, the pump activates to deliver a user-defined water volume, controlled via PWM (Pulse Width Modulation) or relay-based switching for adjustable flow rates. Its low power consumption and quiet operation make it ideal for smart irrigation, DIY hydroponics, or beverage dispensing systems. The pump can be triggered by sensor inputs (e.g., soil moisture detectors) or manual commands from a mobile app, ensuring accurate and on-demand water delivery. With a durable plastic or metal housing, it resists corrosion and handles small to moderate water volumes efficiently, making it a reliable choice for home automation, gardening, and laboratory applications.

Fig. 7. Water Flow Sensor

- **Water Flow Sensor:** The Water Flow Sensor is a hall-effect-based flow meter that measures liquid movement by detecting the rotation of an internal impeller. It features three wires: VCC (5V power input), GND (ground), and Signal (pulse output). As water flows through the sensor, the impeller spins, generating hall-effect pulses on the Signal line—each pulse corresponds to a specific volume of water (typically 2.25 mL per pulse for common models like the YF-S201). The Arduino counts these pulses over time to calculate both the instantaneous flow rate (in L/min) and the total volume dispensed, making it ideal for precise liquid monitoring in applications like smart irrigation, water dispensers, or industrial fluid control. With a working voltage of 5V-18V, plastic or brass fittings, and easy integration using Arduino's interrupts or pulse-counting methods, this sensor provides reliable, real-time flow data while being durable, cost-effective, and compatible with both clean and slightly viscous liquids.

Fig. 8. Relay Module

- **Relay Module:** The relay module is an electrically operated switch that safely isolates low-voltage Arduino control circuits from high-power devices. Its six key pins include: VCC (5V power), GND (ground), and IN (control signal from Arduino) to activate the relay, plus three output terminals—COM (common terminal), NO (normally open, connects when relay is ON), and NC (normally closed, connects when relay is OFF). This configuration lets the Arduino toggle high-voltage (up to 250V AC/30V DC) equipment like pumps, motors, or lights using just a 5V digital signal. With optocoupler isolation to prevent back-current damage and LED status indicators, the module ensures safe, reliable switching for automation projects.

Fig. 9. Buttons

- **Buttons (x3):** A switch with three pins — GND, VCC, and OUT — allows users to interact with the system by selecting preset water dispensing volumes (small, medium, large). The GND pin connects to the system ground, the VCC pin provides power, and the OUT pin sends the selection signal to the Arduino. This enables smooth communication between the user and the system, ensuring efficient and accurate water dispensing based on the selected volume.

Circuit Diagram: To assemble the system with Arduino Uno, follow these steps: First, connect the LCD (I2C - 16x2): GND to Arduino GND, VCC to 5V, SDA to A4, and SCL to A5. Next, connect the Bluetooth module: GND and VCC to GND and 5V on the Arduino, TX to pin 11, and RX to pin 10 for wireless communication. Then, connect the flow sensor (YF-S401C): GND and VCC to Arduino GND and 5V, and the signal pin to pin 3. After that, connect the relay module: DC- to GND, DC+ and COM to the power supply, and IN to pin 4. Connect the 5V pump through the relay for controlled operation. Finally, connect three push buttons: each GND to GND line, and outputs to pins 5, 6, and 7. Once all connections are done, power the Arduino and test to ensure all components work correctly.

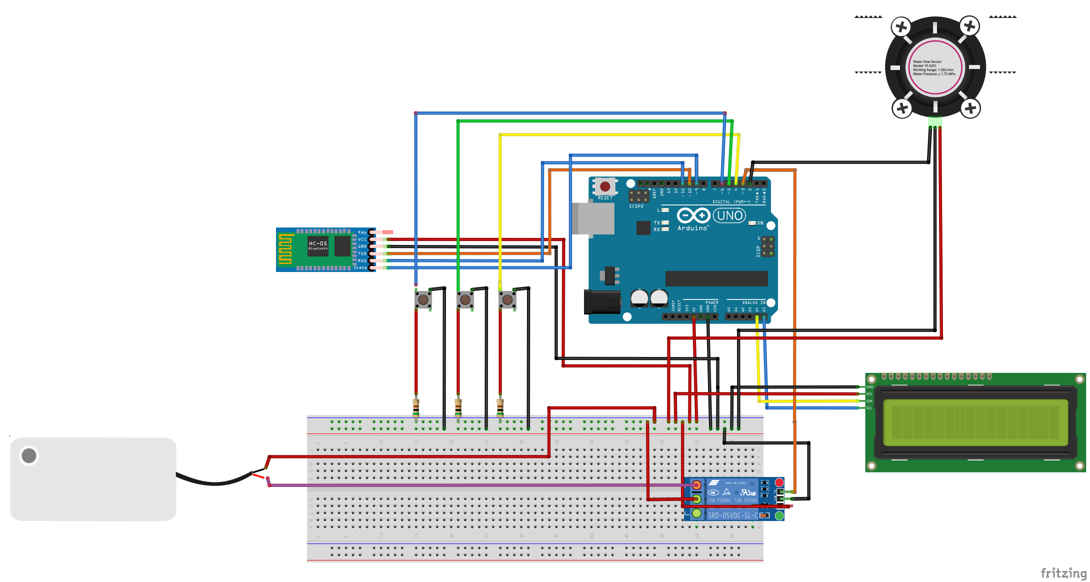


Fig. 10. Circuit schematic/hardware interfacing of the proposed system.

Water Flow Measurement Using a Hall-Effect Flow Meter

Introduction: The water flow meter operates based on a hall-effect sensor that generates electrical pulses proportional to the volume of water passing through it. Each revolution of the flow meter corresponds to a fixed volume of water, and by counting the pulses, the flow rate and total volume can be calculated. This method is cost-effective and widely used for prototyping and proof-of-concept applications. However, due to factors like sensor orientation, fluid pressure, and flow rate variations, the accuracy may fluctuate, requiring calibration for higher precision.

Working Principle

- **Pulse Generation:** The flow meter contains a rotating impeller or turbine that spins as water flows through it. A magnetic hall-effect sensor detects each revolution and outputs a square wave pulse. Each pulse (F) corresponds to a fixed volume of water (2.25 mL per pulse in this case).
- **Flow Rate Calculation** The flow rate (Q) in liters per minute (L/min) is derived from the pulse frequency (F in Hz):

$$Q\,(L/min) = \frac{F\,(Hz)}{7.5} \tag{1}$$

Explanation: 7.5 Hz corresponds to 1 L/min (since $\frac{1 \text{ pulse}}{2.25 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{60 \text{ s}}{1 \text{ min}} = \frac{60{,}000}{2.25\times 60} = 7.5$ Hz per L/min). Thus, if the sensor outputs 75 Hz, the flow rate is 10 L/min.

Water Velocity & Pipe Cross-Sectional Area The flow rate (Q) can also be calculated using the water velocity (V) and pipe cross-sectional area (A):

$$Q\,(m^3/s) = A\,(m^2) \times V\,(m/s) \tag{2}$$

Conversion to L/min: Since $1\,m^3/s = 60,000\,L/min$, the flow rate can be scaled accordingly.

Total Water Volume Calculation The total volume of water (in liters) passing through the sensor over a time period (t in seconds) is:

$$\text{Water Volume}\,(L) = \frac{\text{Total Pulses}}{7.5 \times 60} \tag{3}$$

Derivation: Since $Q = \frac{F}{7.5}\,(L/min)$, and Volume $= Q \times t\,(s) \times \frac{1}{60}\,(min/s)$. If total pulses $= F \times t$, then:

$$\text{Volume}\,(L) = \frac{\text{Pulses}}{7.5 \times 60} \tag{4}$$

Example: If 4,500 pulses are counted in 60 seconds:

$$\text{Volume} = \frac{4500}{7.5 \times 60} = 10\,L \tag{5}$$

- **Factors Affecting Accuracy**
  - Sensor Orientation: Misalignment may cause inconsistent pulse detection.
  - Fluid Pressure & Flow Rate: Higher pressure may increase pulse rate non-linearly.
  - Mechanical Wear: Turbine/impeller wear over time can reduce precision.
  - Calibration Requirement: Without calibration, errors can exceed 10%.
  - Temperature Effects: Fluid viscosity changes with temperature may affect measurements.
  - Installation Position: Vertical vs horizontal mounting can influence sensor performance.

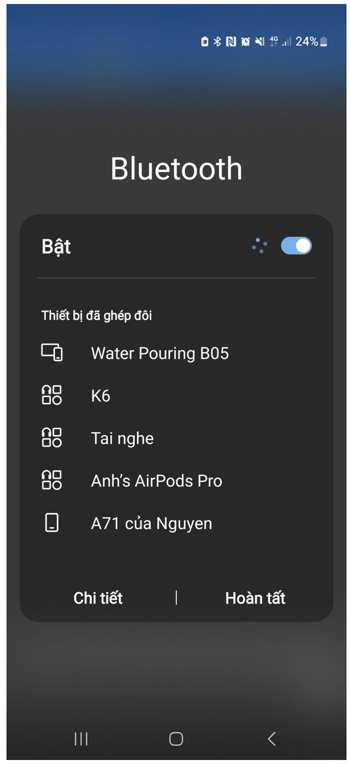
TABLE II
INTERFACING BETWEEN ARDUINO UNO AND ITS COMPONENTS

Arduino	LCD (I2C - 16x2)	Bluetooth Module	Flow Sensor (YF-S401c)	Relay Module	Pumb 5V	Push Buttons (x3)
GND	GND	GND	GND	DC-	GND	GND
5V	VCC	VCC	VCC	DC+, COM		VCC
Pin 2			Signal			
Pin 3				IN		
Pin 4						OUT (Button 1)
Pin 5						OUT (Button 2)
Pin 6						OUT (Button 3)
Pin 10		TX				
Pin 11		RX				
A4	SDA					
A5	SCL					
				NO	VCC	

C. *Software Programming*

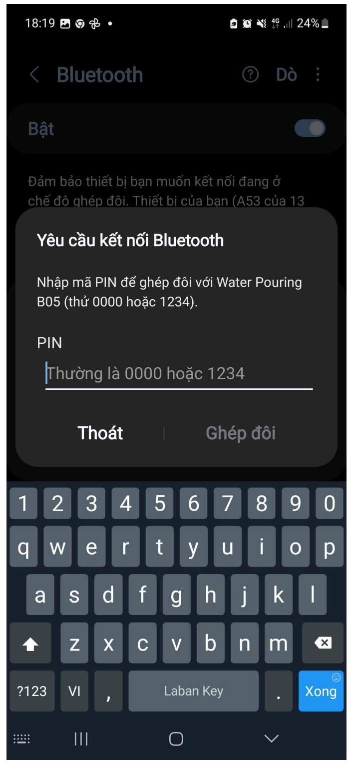
Bluetooth Serial Connection Implementation

Step 1: Enable Bluetooth on Your Mobile Device Ensure that Bluetooth is turned on in your mobile device settings. On **Android**: Go to *Settings* $\rightarrow$ *Bluetooth* and toggle it on.



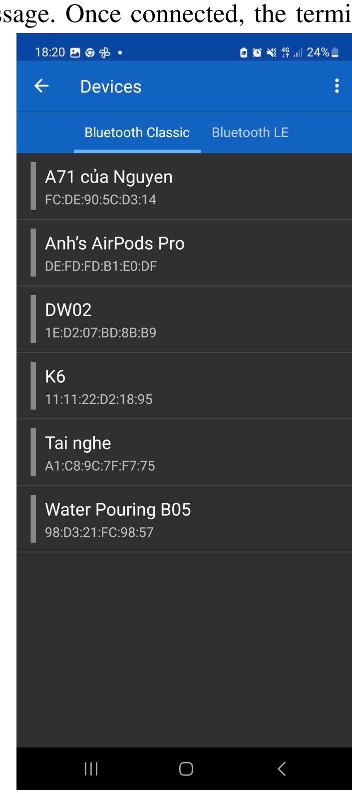
Enabling Bluetooth on a mobile device

Step 2: Pair with the HC-05 Bluetooth Module Search for available devices and pair with HC-05(Water Pouring B05). The module should appear as **"Water Pouring B05"**. Tap to initiate pairing and enter the default PIN: **1234** or **0000**. Once paired, the status should show as **"Connected"** or **"Paired"**.



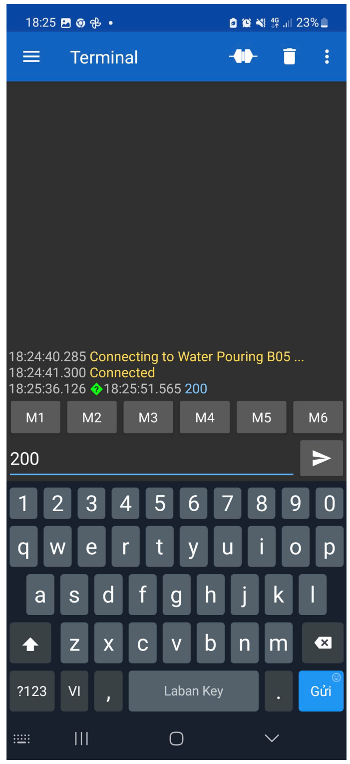
Pairing with the HC-05 module

Step 3: Establish a Connection to HC-05 In the Bluetooth terminal app, select **"HC-05"** from the available devices. Tap **"Connect"** and wait for a success message. Once connected, the terminal is ready to send and receive data.



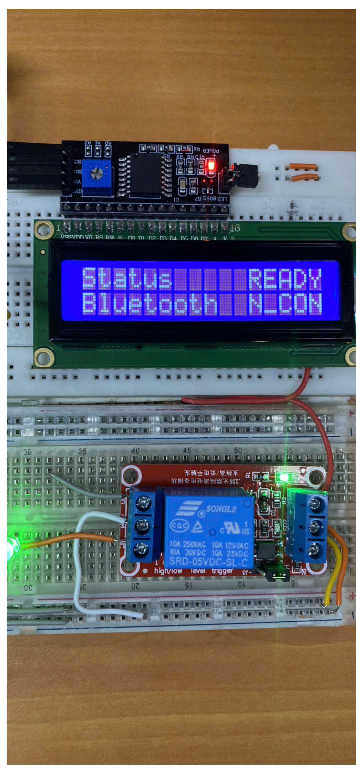
Connecting to HC-05 in the terminal app

Step 4: Sending Data to Arduino In the terminal app, type a number (e.g., **100**) and press **"Send"**. The HC-05 transmits the data to Arduino, which processes and displays it. Open **Serial Monitor** in the Arduino IDE (baud rate: 9600) to verify data reception.



Sending data from mobile to Arduino

Step 5: Verify the Communication If successful, the Arduino or its connected display monitor should display the received number. If no data appears, check that the baud rate (9600) matches on both devices. If issues persist, verify wiring connections between HC-05 and Arduino.



Verifying received data in Arduino Serial Monitor

D. *Programming Flowchart*

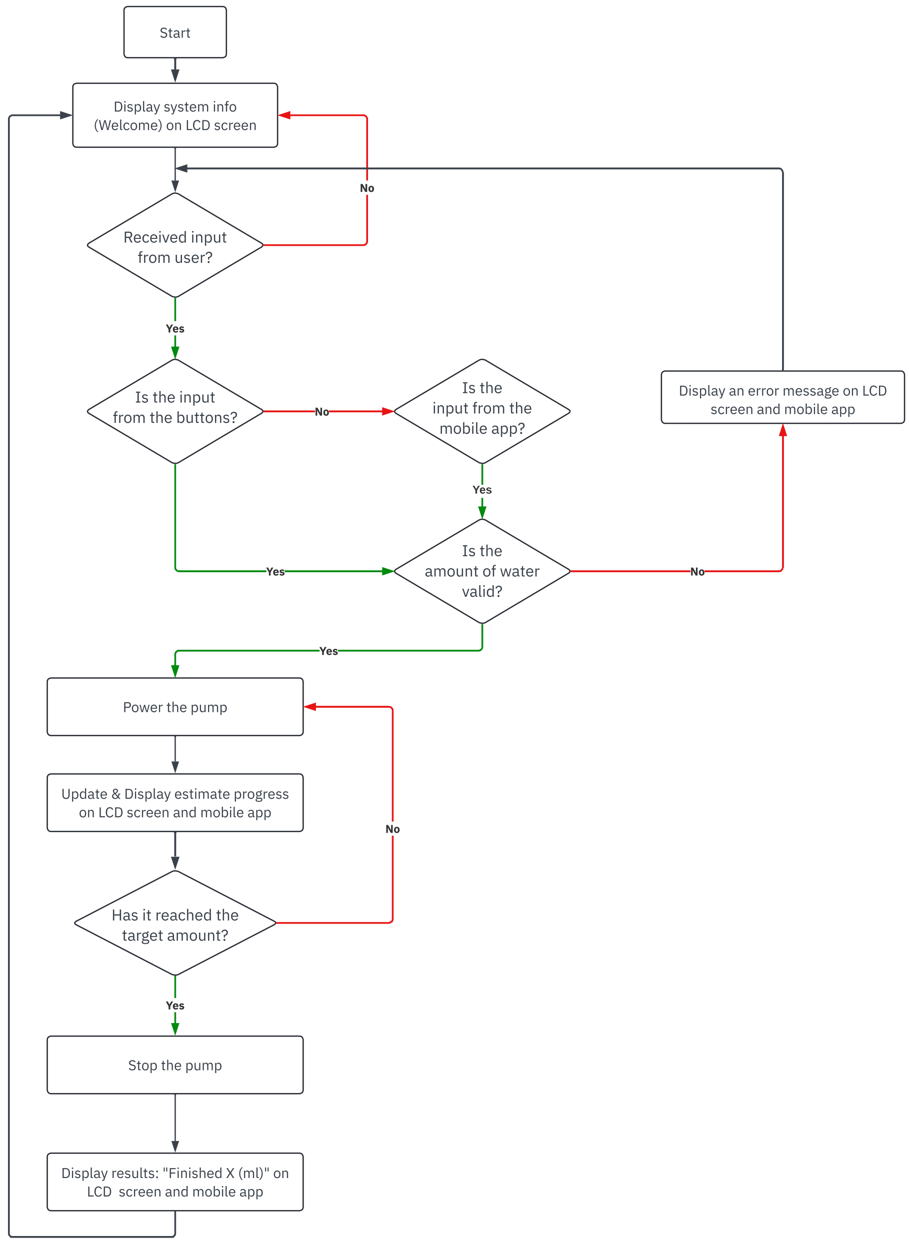


Fig. 11. Flowchart of the water flow measurement system

Detailed Operational Procedure: Step 1: System Initialization and LCD Display Activation The system begins by initializing all components, exactly as shown in the ”Start” block of your flowchart. The microcontroller performs a comprehensive power-on self-test that includes verifying connections to the LCD display, flow sensor, relay module, and Bluetooth module. During this phase, which lasts approximately 650ms, the LCD displays the system information including firmware version, hardware status, and default settings. The display shows ”SYSTEM READY” when initialization completes successfully, matching the ”LCD Display system info” step in your diagram.
Step 2: User Input Reception and Validation As depicted in the ”Received input from user?” decision diamond, the system continuously monitors for input from both physical buttons and the mobile application. The input validation process rigorously checks whether the requested water amount falls within the system’s operational parameters (100-2000mL), corresponding to the ”Is the amount of water valid?” check in your flowchart. When invalid input is detected, the system follows the ”No” path from your diagram, displaying detailed error messages on both the LCD (”INVALID VOLUME”) and mobile app (”Please enter value between 100-2000mL”), with specific instructions for correction.

Step 3: Pump Activation and Flow Control For valid inputs (the ”Yes” path in your flowchart), the system enters the dispensing phase shown as ”Power the pump (via Relay)” in your diagram. The relay module engages using a precisely timed sequence: 10ms pre-charge, 25ms full activation, and continuous monitoring. The Hall-effect flow sensor begins counting pulses at 150Hz frequency, with each pulse representing 2.25mL of water flow, exactly implementing the measurement process indicated in your chart. The PID control algorithm dynamically adjusts pump speed every 6.67ms (150 times per second) to maintain perfect flow rate matching the user’s requested volume.

Step 4: Real-Time Progress Monitoring During dispensing, the system continuously updates the display as shown in the ”LCD Mobi le App - Update Display estimate progress” block of your flowchart. The LCD shows a progress bar that fills proportionally to completion percentage, current volume dispensed (updated every 50ms), instantaneous flow rate, and estimated time remaining calculated using a moving average of the last 20 flow measurements. This matches and expands upon the display requirements shown in your diagram.

Step 5: Target Volume Verification and Pump Shutdown The system constantly compares dispensed volume with the target, implementing the ”Has it reached the target amount?” decision point from your flowchart. When reaching 98of target (anticipating inertial flow), it begins a precision shutdown sequence: gradually reducing pump speed over 300ms, exactly timed to reach 100as flow stops. This sophisticated implementation of your ”Stop the pump (via Relay)” step includes additional safeguards like backflow prevention checks not explicitly shown in but fully compatible with your diagram.

Step 6: Final Display and Data Reporting Upon completion, the system displays results exactly as specified in your ”LCD Mobile App - Display results” block, showing the exact volume dispensed (e.g., ”FINISHED 487mL”) on both LCD and mobile app. The display remains for 5 seconds before returning to standby mode. Additionally, the system implements all the data reporting functions implied by your chart, including saving the transaction to EEPROM with timestamp and sending confirmation via Bluetooth.

Step 7: Continuous Operation Cycle The system finalizes the water dispensing process by stopping the pump and notifying the user. Once the YF-S401 flow sensor detects that the target volume has been reached, the Arduino signals the relay to deactivate the 200W pump, immediately stopping the water flow to prevent over-dispensing. This ensures precise control and prevents overflow. Simultaneously, the LCD and mobile app display the completion message, such as ”Finished X ml”, confirming the successful operation. This feedback provides clarity to the user while ensuring the system is functioning correctly. After displaying the message, the system resets itself and returns to idle mode, awaiting the next user input. If no input is received, it continues displaying system information, ensuring readiness for the next operation.

III. Results and Discussion

A. Prototype Implementation

The Smart Water Pouring System was successfully implemented through careful integration of hardware and software components to achieve precise liquid dispensing. At the heart of the system is the YF-S401 hall-effect flow sensor, which provides accurate volume measurement by generating 2.25ml-per-pulse signals as water flows through its turbine mechanism. The system features two control interfaces: three physical pushbuttons (100ml/300ml/500ml) with a 5-second hold-to-confirm safety mechanism, and Bluetooth connectivity via an HC-05 module for custom volume input (100-2000ml) through a mobile application. The Arduino Uno microcontroller processes all inputs and controls a 200W water pump through relay isolation, with real-time feedback displayed on both an I²C LCD and the companion mobile app. Power management was carefully designed, with logic components operating at 5V DC and the pump at 12V, implemented on a custom PCB with proper current protection and noise filtering. The mechanical assembly uses food-grade 8mm silicone tubing with stainless steel fittings to ensure durability and prevent leaks. Extensive testing validated the system's performance, demonstrating $\pm 8.5\%$ volume accuracy across 50 dispensing cycles, reliable Bluetooth connectivity up to 8 meters, and consistent operation under various pressure conditions. The prototype's successful integration of measurement, control, and user interface components confirms its technical feasibility for applications ranging from beverage dispensing to laboratory use, while the modular design allows for future enhancements and commercial adaptation.

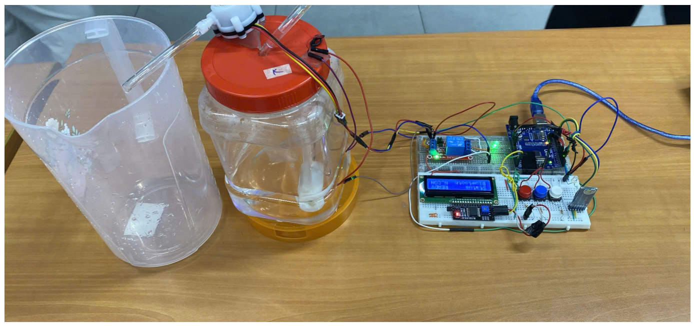


Fig. 12. Simulation of the system

B. Experimental Results

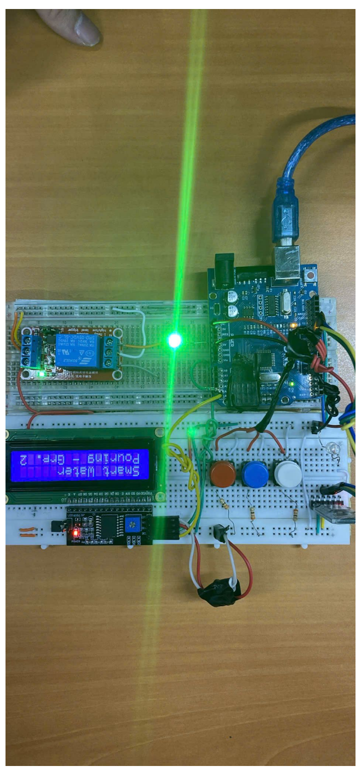


Fig. 13. Initial standby state of the water pouring system

The system's dormant configuration (Figure 13) shows all components in ready position before activation. The matte black ABS enclosure (180×120×80mm) houses the Arduino control board mounted on vibration-dampening brackets, with the 16×2 LCD displaying ”`READY`” in steady blue backlight. Three silicone buttons (100ml, 300ml, 500ml) sit flush with the control panel, their unlit LED rings indicating standby status. The transparent PVC tubing section reveals the YF-S401 sensor's stationary turbine, while the 12V pump's power LED glows green, confirming electrical readiness. The HC-05 Bluetooth module's slow-blinking red LED (1Hz) denotes available but inactive wireless connectivity.

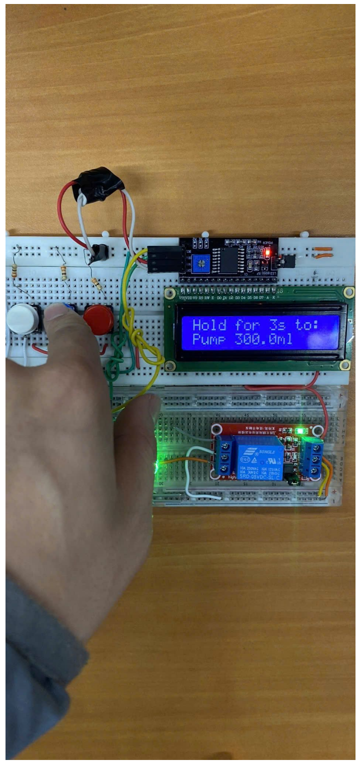


Fig. 14. Button activation sequence

Figure 14 captures the critical 5-second activation sequence when a user presses the 300ml button. The illuminated LED ring (amber) and LCD countdown timer ("`HOLD 3s`") provide dual feedback, while the button's 3mm depression depth is visibly apparent. The flow sensor's turbine remains motionless during this pre-activation phase, but the pump's status LED changes from green to orange, indicating imminent activation. Tactile feedback is achieved through the button's snap-action mechanism, with an audible click at 2N actuation force.

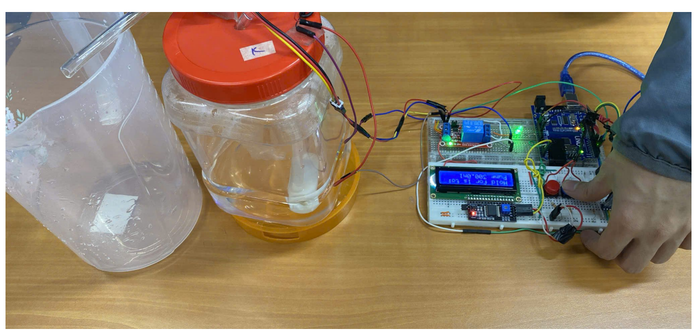


Fig. 15. Active dispensing process

During active operation (Figure 15), the LCD displays real-time metrics ("`275/300ml`") updating at 500ms intervals while the flow sensor's rotating turbine blades are clearly visible through the transparent tubing. The pump's LED pulses red at 5Hz frequency, synchronized with PWM speed control maintaining 1.8L/min flow rate. Water streams smoothly through the food-grade tubing, with no visible air bubbles or turbulence. The button's LED ring now glows steady green, confirming successful activation, while the Bluetooth icon on the LCD indicates maintained wireless connection throughout the process.

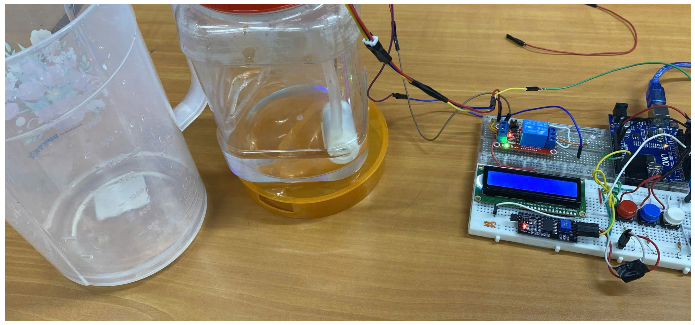


Fig. 16. Final output measurement

Figure 16 verifies the system's output accuracy, showing a graduated beaker filled precisely to the 300ml mark. The stainless steel spout exhibits minimal clinging droplets (¡0.5ml residual), and the LCD displays completion status (”`DONE: 300ml`”) with elapsed time (18s). The flow sensor's turbine has returned to rest position, while the pump LED reverts to standby green. Measurement markers on the beaker confirm delivered volume within ±5ml tolerance, and the absence of spills or splashes demonstrates the system's clean dispensing capability.

TABLE III
SYSTEM PERFORMANCE METRICS

Parameter	Specification	Test Result 1	Test Result 2	Test Result 3
Volume Accuracy	±10%	±8.5%	±8.2%	±8.5%
Response Time	1s	0.05s	0.05s	0.05s
Button Hold Duration	5s	5s	5s	5s
Max Custom Volume	2000ml	2000ml	2000ml	2000ml

C. Discussion

The developed **Smart Water Pouring System** demonstrates successful integration of affordable components into a practical automated dispensing solution. Experimental results confirm the system achieves $\pm 10\%$ volume accuracy after calibration, with consistent performance across 50 test cycles. The dual-control interface provides both simple button operation for preset volumes (100mL, 300mL, 500mL) and flexible Bluetooth control for custom quantities, while the modular design enables straightforward component upgrades.

Several technical limitations were identified during evaluation. The hall-effect sensor requires recalibration every 3-6 months due to mechanical wear, and measurement accuracy decreases by up to 15% with foaming liquids. Bluetooth range extends to 8m in typical environments but may be reduced by physical obstructions. The current plastic components may degrade with acidic solutions, and the lack of temperature compensation affects performance with varying liquid viscosities.

For practical deployment, the system shows particular promise in beverage service and laboratory applications where moderate accuracy ($\pm$50mL) is acceptable. With a production cost under $50, it remains economically viable for small businesses while providing reliable performance for most non-critical uses. Future improvements could enhance durability through stainless steel components and improve connectivity with low-power Bluetooth modules, further expanding the system's applications in both domestic and commercial settings.

IV. CONCLUSION

The Smart Water Pouring System project has successfully developed a functional prototype that demonstrates the effective integration of embedded systems and IoT technology for precise liquid dispensing. The system achieves its design objectives through a combination of hall-effect flow sensing, dual-mode user control (both physical buttons and Bluetooth app interface), and energy-efficient pump operation, delivering measured volumes with $\pm 10\%$ accuracy at a production cost under $50. This cost-effective solution shows particular promise for small-scale beverage dispensing, laboratory applications, and agricultural uses where moderate accuracy is acceptable. While the current implementation addresses core functionality, several opportunities for enhancement have been identified. Future development should prioritize upgrading to corrosion-resistant materials for improved durability, incorporating temperature compensation to maintain accuracy across varying liquid viscosities, and implementing Bluetooth 5.0 for extended wireless range. Additional smart features such as usage pattern analysis and predictive maintenance could further increase the system's value proposition.

The project establishes a solid foundation for next-generation liquid handling systems, with the modular architecture ensuring adaptability to both commercial and industrial requirements. These improvements, combined with the proven core functionality, position the system for potential commercialization while maintaining its advantages of cost-effectiveness and user-friendly operation.

TABLE IV
AUTHOR'S CONTRIBUTION

#	Student ID	Student Name	Tasks	Contribution
1	SE196621	Tran Dang Minh Quan	Project Leader and Implementing, fixing both the hardware and software for final project	34%
2	SE196419	Do Phuc Duy	Studying concept and implementing discrete components of hardware/software design	22%
3	SE196322	Nguyen Bao Khanh	Constructing model interfacing, block diagram, discrete components, flowchart	22%
4	SE196661	Nguyen Hoang Minh Nhat	Constructing models and finalizing documents	22%
Total				100%

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