Development of a Smart Water Dispenser Based on Object Recognition with Raspberry Pi 4

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***Abstract*—In this project, we develop and apply a Smart Water Dispenser system, which is combined with object recognition and fluid level control supported by Ultrasonic Sensors, Raspberry Pi, and also DC Motors. The essence of this system is to develop a system using the Raspberry Pi 4 Model B with other components that have been integrated and interrelated Hardware and programming using OpenCV, YOLO V8, and other components, the point is that the cup can be detected, and water filling is done precisely and automatically. The process carried out is the detection of cups automatically using Raspberry Pi which is in charge of controlling the DC Motor and also the Ultrasonic sensor (HC-SR04) and detecting based on the volume of water with precision. The dispenser functions to pump water based on the condition of the volume of water in the glass and stop pumping if the volume of the glass has been fulfilled, aka not spilling with a percentage of 90%. In the scenario process, the cup search process is first carried out by scanning three times until a cup is found, if a cup is found, then the sensor component and the valve for the release of water in the hose will stop right at the position of the cup and the water will fill the cup automatically. Otherwise, the system will move backward and the system will be turned off. The first testing process has been successful and shows the effectiveness of the system in the process of finding cups and managing water levels. This innovation shows hope for improving user comfort, especially for disabilities, utilizing advanced technology in object recognition, and of course, saving water usage. In the testing process obtained 95% to 97% accuracy in object detection with different types of cups.**

***Keywords*—Smart water dispenser; object recognition; Raspberry Pi 4; YOLO VB; ultrasonic sensor**

I. INTRODUCTION

The demand for automation solutions has significantly increased in recent years, driven by advancements in Internet of Things (IoT) technologies and smart devices. IoT-based systems enable the interaction of interconnected electronic devices that can be automatically controlled and monitored, transforming various sectors, including smart homes, industries, and offices, toward enhanced convenience and efficient resource use. One of the promising applications of smart technology is in the development of automated water dispenser systems, which provide water efficiently and accurately, reducing the need for manual methods that are prone to wastage and contamination [1].

Traditional water dispensers rely heavily on manual operation, which often leads to inefficient water usage. These conventional systems cannot detect the user's needs or monitor the fluid level, which presents several limitations, particularly in environments that demand precise control of water use. Consequently, the integration of smart water dispensers equipped with sensors and object recognition technology has become an ideal solution. These systems can automatically detect the presence of objects like cups and dispense the appropriate amount of water, minimizing direct contact and saving users time. Research conducted by Raspberry Pi (2023) demonstrates that an automatic water bottle filling system using Raspberry Pi can detect bottles and adjust the water flow according to the object's needs, showcasing the practical potential of such technology [2]. In addition, the important conclusions of this research are: a) the importance of this study: the development of this research will be able to automate the process of filling water, especially cups. And can be applied to patients with disabilities and can be applied for other purposes according to their needs and development using sophisticated technology following novelty research. b) Recent advances in technologies applied to this research are how to use object recognition technology using artificial intelligence using the Convolutional Neural Network (CNN) method and a combination with other methods in Machine Learning and Deep Learning. Technology is evolving rapidly with various approaches such as Image Recognition [25-30] and Convolution Neural Network (CNN). Some studies use Image Recognition with various approach methods [31-40] and also hardware and Raspberry Pi 4 b Microprocessor as a processor.

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II. LITERATURE REVIEW

A. Object Recognition Technology in Water Dispensers

Object recognition has emerged as a core element in the development of smart devices, especially for systems such as water dispensers that require accurate detection of specific objects before initiating any action. Object recognition technology enables the system to "see" and interpret the surrounding environment so that water is dispensed only when a suitable object, like a cup, is detected. This feature not only reduces water waste but also contributes to better user convenience and hygiene. One of the widely used frameworks for object recognition is OpenCV, paired with YOLO (You Only Look Once) to enhance detection accuracy and speed in real-time applications [3], [4]. In the context of water dispensers, a camera connected to the Raspberry Pi leverages these algorithms to detect the presence of a cup accurately and in a short time, allowing for efficient control of water flow [5].

B. The Role of Raspberry Pi in IoT Applications

Raspberry Pi, particularly the Raspberry Pi 4 model, has become a popular choice in developing IoT applications due to its affordability, compact size, and adequate processing capabilities. The Raspberry Pi 4 is capable of handling image processing and real-time object detection operations, which are critical for applications such as smart water dispensers that must respond promptly to the presence of objects. For applications that require object detection, the Raspberry Pi can be programmed to process inputs from the camera and send signals to other devices, such as water pumps and motors, to control fluid dispensing automatically [6]. This capability is particularly valuable in smart water dispenser systems, as it enables the device to function autonomously with minimal user intervention.

C. Sensor Technology and Fluid Dispensing Control

In addition to object recognition, sensor technology plays an essential role in the functionality of smart water dispensers. Sensors are used to detect the presence of objects, monitor fluid levels, or gauge environmental conditions surrounding the device. A recent article on Instructables (2023) explored a water level monitoring system using Raspberry Pi, which could be integrated into smart water dispensers to control water flow. This setup allows for controlled water dispensing according to the capacity of the container or cup being used, thereby reducing the risk of spills or underfilled containers [7]. While traditional dispensers may release excess water or require manual monitoring, sensors in smart dispensers ensure the precise amount of water is dispensed every time, supporting both user convenience and sustainability.

D. The Need for Automation in Daily Life

Automation has become increasingly relevant in modern households, primarily through smart home devices that enable a range of tasks to be conducted without manual intervention. Automation also promotes environmental sustainability by optimizing resource use, such as water. Smart water dispenser systems are designed to address two main concerns: efficient water usage and enhanced user convenience. These systems also reduce direct contact with the device, making them a hygienic solution in both public and private settings. A fully automated water dispenser that uses object recognition technology exemplifies the extent to which IoT and sensor-based automation can improve daily life by conserving resources and minimizing the risk of contamination [8].

E. Benefits of the Study and Contributions to Smart Home Technology

This research contributes to the field of smart home technology by developing a device that not only functions automatically but also interacts intelligently with the user. A system utilizing Raspberry Pi and object recognition technology can expand the capabilities of smart homes in terms of automation, providing a sustainable solution for water usage. The implementation of this technology is not only beneficial for household users but can also be applied in offices, schools, and public facilities where efficiency and reduced physical contact are priorities. By offering a self-contained water dispensing solution, this study bridges the gap between basic automated dispensers and advanced IoT-integrated devices that respond to specific user needs [9].

III. Method

This study employs an experimental method to design, implement, and test a smart water dispenser system utilizing object recognition technology and automated control. Below are the methodology steps applied in this research, complemented with relevant references.

A. System Design

1) Component selection: This study uses the Raspberry Pi 4 Model B as the main controller, the Raspberry Pi Camera V2 for object recognition, and a DC motor to drive the water flow mechanism. Other key components include a water pump and relay to control water flow as needed [10], [11].

2) Object recognition integration with OpenCV and YOLO: The system employs the OpenCV library and YOLO (You Only Look Once) algorithm for real-time object detection. YOLO allows high-speed and accurate object detection, making it suitable for detecting the presence of glass in the filling area in real-time [12], [13].

3) Sensor setup and water flow control: The DC motor and relay are connected to the Raspberry Pi to automatically control water flow. When a glass is detected, the Raspberry Pi activates the water pump through the relay and drives the motor to fill the glass to the desired level [14]. The Raspberry Pi controls the movement of the DC motor, which carries a camera to scan for the presence of a glass. When a glass is detected, the Raspberry Pi then checks the water level using an ultrasonic sensor. If the glass is empty or the water level is insufficient, the water pump is activated to fill the glass until the desired level is reached.

B. Implementation Phase

1) Raspberry Pi programming: The Raspberry Pi is programmed using Python to run the OpenCV and YOLO V8 libraries. The program processes the image input from the camera to detect the presence of a glass. When a glass is detected, the Raspberry Pi sends a signal to the relay to activate the water pump and control the DC motor [15], and The water level using an ultrasonic sensor.

2) Camera configuration and object detection algorithm: The Raspberry Pi Camera V2 is positioned at a specific angle to scan the dispenser area. The YOLO algorithm is implemented in Python on the Raspberry Pi for real-time object detection. A threshold setting in YOLO is applied to ensure that only objects meeting certain criteria (such as the shape and size of glass) and Moved by a DC motor are identified as targets [16].

3) Initial testing and system calibration: After the hardware and software integration is complete, initial testing is conducted to ensure all components function as designed. Testing includes camera calibration or positioning to detect objects accurately and setting the Pump activation timing based on the measurement of the water level based on ultrasonic sensor readings [17]. Pump activation timing based on measurement of the water level based on ultrasonic sensor readings.

C. Testing and Data Collection Phase

1) *Object detection accuracy testing*: The system is tested to detect the presence of glasses of various shapes and sizes. This test aims to ensure that the YOLO and OpenCV algorithms can detect objects accurately under different lighting conditions and positions [18].

2) *Reliability testing of automatic water dispensing*: The system is tested with different glass sizes to ensure the automatic water dispensing matches the glass's capacity. Data is collected to evaluate the system's reliability in stopping the water flow once the desired volume is reached [19].

3) *System stability testing*: Stability testing is performed to ensure the system can operate consistently over a long period without failure. This test includes monitoring power consumption, sensor durability, and detection accuracy over multiple usage cycles [20].

D. Data Analysis

1) *Object detection accuracy analysis*: The object detection test results are analyzed based on the success rate of detection relative to the number of trials. This analysis aims to determine the system's accuracy level in recognizing the presence of a glass under various conditions [21].

2) *Automatic water dispensing effectiveness analysis*: The effectiveness of automatic water dispensing is analyzed by measuring the precision of the dispensed water volume according to the glass size. The error percentage in the dispensed water volume is calculated to evaluate the system's precision [22].

3) *Overall system evaluation*: An overall evaluation of the system is conducted by considering data from object detection accuracy testing, water dispensing reliability, and system stability. The analysis results will demonstrate the system's effectiveness in reducing water waste and enhancing user convenience [23].

E. Conclusion and Development Recommendations

The data analysis results will be summarized to conclude the success of implementing this smart water dispenser system. Recommendations for further development will also be included, particularly in improving detection accuracy and water dispensing efficiency [24].

This diagram provides a visual representation of the workflow and integration of each component, helping readers understand the process from start to finish within the system.

F. Flowchart Smart Water Dispenser

The smart water dispenser flowchart and explanation are depicted in Fig. 1.

Explanation of Components in the Block Diagram

1) Raspberry Pi 4 Model B:

- Serves as the main controller, handling both object recognition and control of hardware.
- Integrates with the Raspberry Pi Camera V2 using OpenCV and YOLO v8 for real-time glass detection.
- Controls the DC Motor with L298N Motor Driver to move the conveyor.

2) Camera and Detection:

- The Raspberry Pi Camera scans for the presence of a glass as it moves on the conveyor.
- If a glass is detected, Raspberry Pi stops the motor, aligns the spout, and activates the pump.

3) Water Pump and Ultrasonic Sensor:

- Raspberry Pi activates the relay to start the water pump and then uses the Ultrasonic Sensor HC-SR04 to monitor the water level in the glass.
- Once the water level reaches 90% of the glass height, the relay turns off the pump. And then activate the relay to start the water pump.

4) Process Flow:

- The DC motor moves the conveyor for glass detection.
- When the glass is detected, the motor stops, the water pump is activated, and the water level is monitored by the ultrasonic sensor.
- Once the required water level is reached, the pump stops, and the motor returns to its initial position.

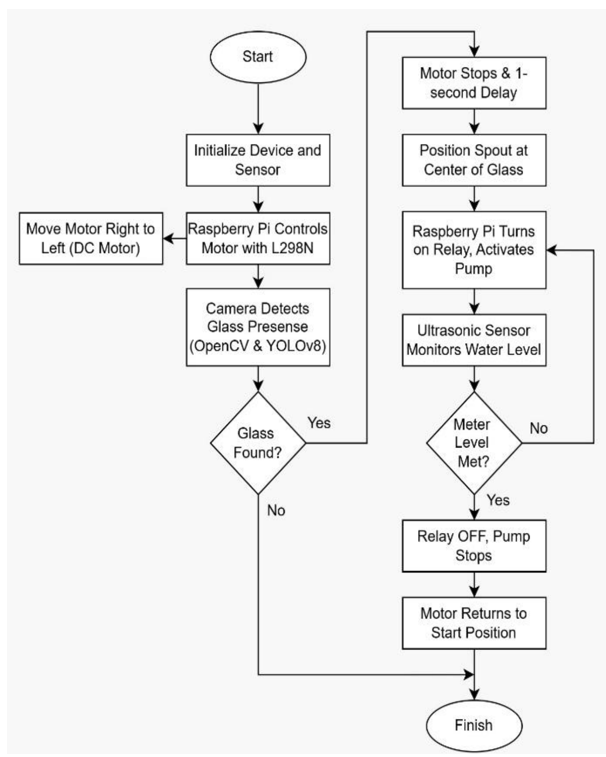

Fig. 1. Flowchart smart water dispensers.

Moreover, Fig. 3, 4, and 5 are a frame of hardware that outlines the efficient workflow of the smart dispenser system controlled entirely by Raspberry Pi, handling both the detection and water dispensing process.

Moreover, The Hardware and Software Design:

1) Raspberry Pi 4 model B: Used for object recognition programs utilizing the Raspberry Pi Camera V2. The Raspberry Pi Camera V2 is programmed with the OpenCV application and YOLO V8 algorithm.

2) Control system: Control Systems include a 17-stepper motor, L298N motor driver, HC-SR04 ultrasonic sensor, and a relay for turning the water pump on and off. The ultrasonic sensor, camera, and water hose are mounted together on a conveyor system, whose movement is synchronized with the rotation of the stepper motor.

Fig. 2 shows the system configuration built in this research. There are several sets of hardware and software installed and placed according to their functions and uses. Moreover. The method taken in this research is Object Detection and retrieval and equalization on the dataset side, such as Convolutional Neural Network (CNN) by utilizing a smart camera as hardware connected to a Raspberry Pi 4b and also the Python programming language, such as the YOLO and OpenCV platforms. The goal is to build a smart system on the dispenser Therefore, it can fill water automatically.

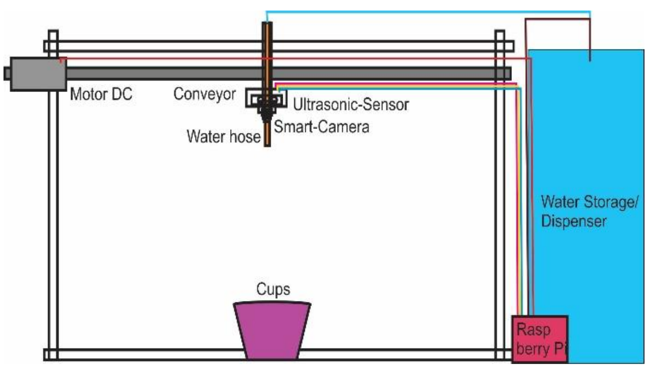

Fig. 2. Configuration of the built tool.

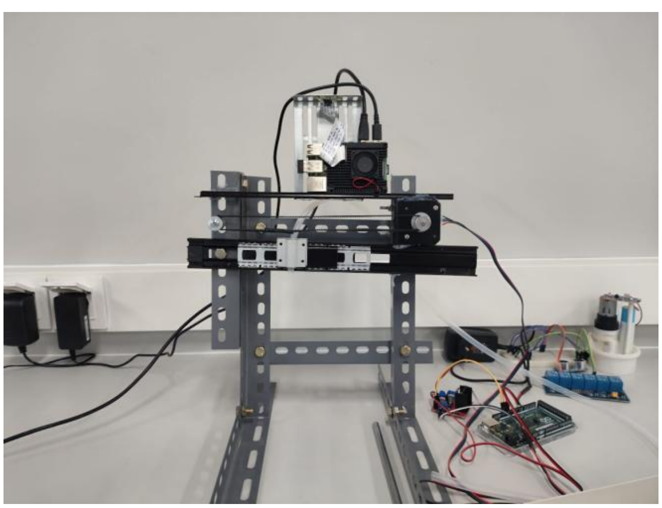

Fig. 3. A series of hardware in this system.

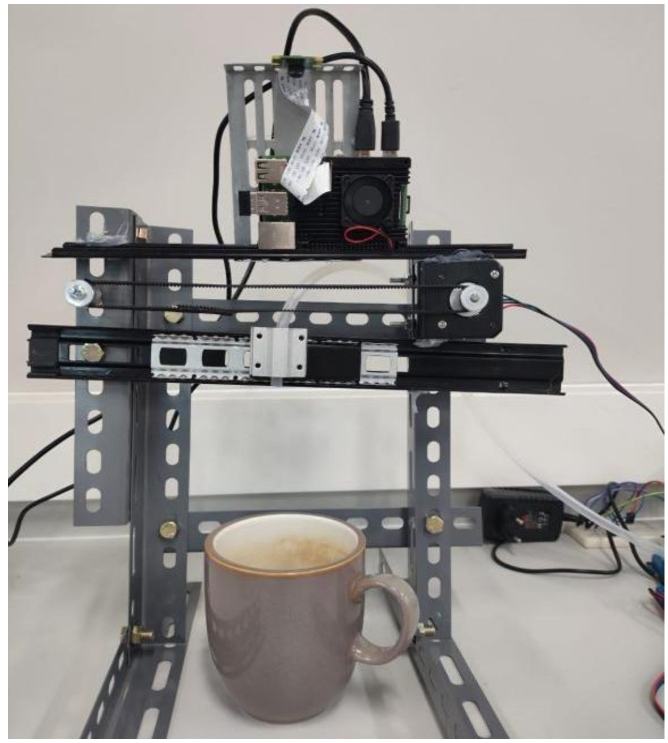

Fig. 4. Frame of hardware.

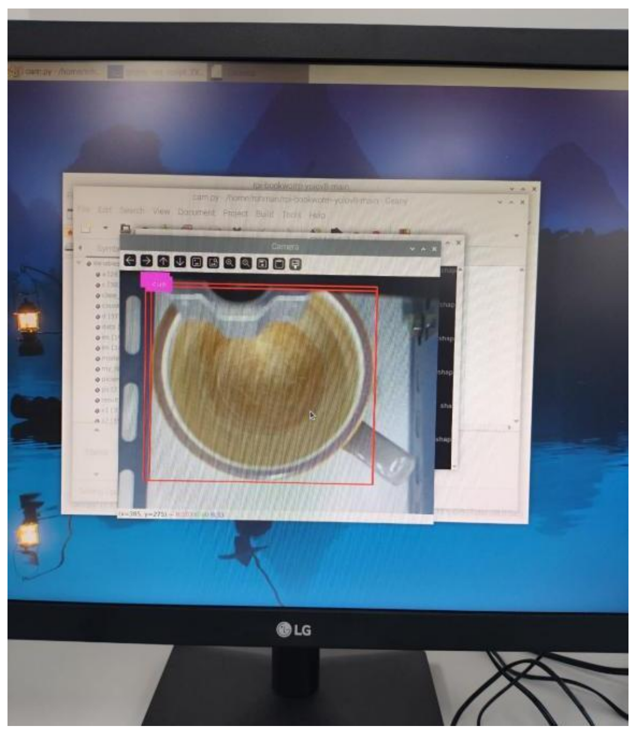

Fig. 5. Glass object detection system.

The configuration system is also carried out on the DC Motor in running the Conveyor so that the camera and other devices such as the Ultrasonic Sensor and the Mini Pump can work precisely.

IV. Result and Discussion

This section presents the outcomes of testing conducted to evaluate the performance of the smart water dispenser system in terms of object detection accuracy, reliability of automatic water dispensing, and overall system stability. The discussion is based on data obtained from various testing scenarios to assess system effectiveness and identify potential improvements. The innovation proposed in this research is how to produce an invention that can have intelligence in terms of automatic water filling, specifically in terms of detecting glass objects and classifying them. The camera moves to detect the presence of a glass. Once a glass is detected, water will flow, and the level is monitored using an ultrasonic sensor. When the water level reaches the desired point, the filling process stops, and the motor returns to its initial position. If the camera does not detect a glass by the end of its path, it will return and continue scanning until a glass is found, or the user turns off the device.

Steps of Operation:

1) Initialization and Conveyor Movement: When the device is powered on, the Arduino Mega commands the motor to move the conveyor from right to left. This movement shifts the camera's position to scan for the presence of a glass.

2) Object Detection by the Camera: The Raspberry Pi Camera V2, running an OpenCV and YOLO V8 program, detects objects. When a glass (cup) is identified, the motor stops after a 1-second delay. This delay ensures that the water hose is positioned directly above the center of the glass.

3) Water Pump Activation: When the motor halts (assuming the hose is centered over the glass), the Arduino Mega triggers the relay to turn on the water pump, starting the filling process.

Monitoring Water Level: The ultrasonic sensor monitors the water level until it reaches a predetermined height (e.g., 90% of the glass height). Once the desired level is reached, the relay is turned off, and the pump stops. Return to Initial Position The motor moves back to the initial position (left side) after completing the filling process. Moreover, the Pseudocode 1 will explain in detail how this system works.

A. Test Results

1) Object detection accuracy: The initial test focused on the system's ability to detect the presence of glass using the YOLO algorithm integrated with OpenCV. Tests were conducted with glasses of different sizes and shapes under various lighting conditions. The results showed that the system achieved an accuracy rate of 94% under optimal lighting and 89% in low-light conditions. Some inaccuracies were observed with objects that had high reflectivity, such as metal or transparent glasses, which affected detection accuracy.

1. **Import library**, GPIO, Camera, OpenCV, YOLO
2. Setup GPIO
3. Function definition (motor movement, Ultrasonic distance reading, water filling)
4. The motor starts moving forward
- Record start moving time (initial time set) 4.

5. LOOP for True:
- Take a picture from the Pi camera
- Object detection using YOLO on the image

A. If the detected object is a "*cup*":
- Stop the motor
- Record the time after the motor stops (set stop time)
- Call the water fill () function to start filling the water
- Calculate the rewind duration (stop time - start time)
- Rewind the motor for the calculated duration
- Stop the motor

B. If the motor runs for more than 20 seconds without detecting the glass:
- Stop the motor
- Rewind the motor for 20 seconds (to return to the starting position)
- Stop the motor
- Display the detection result image

--------- *Pseudocode 1*------------

2) Reliability of automatic water dispensing: The second test assessed the system's reliability in filling glasses to their respective capacities. The system was tested with three different glass sizes (small, medium, and large). Results indicated that the system consistently dispensed water with a margin of error of ±5% from the target capacity. Automatic filling stopped precisely when the volume matched the glass capacity, demonstrating the system's effectiveness in preventing water spillage and overuse. +10% and -16%. With a target water level of 5cm, the water level varies between 4.2 to 5.5cm. error range + 0,5cm and - 0,8cm. This is due to the uneven water surface when filling the water.

3) System stability: Stability tests were conducted to evaluate the system's ability to operate consistently over multiple cycles. The system was tested across 50 continuous usage cycles without a reset, and results showed no performance degradation or component failure. This test demonstrated that both the hardware and software components of the system are stable and reliable for long-term use.

B. Discussion

The test result and analysis are explained in Table I.

1) Analysis of object detection accuracy: Test results revealed that high detection accuracy can be achieved with the YOLO algorithm running on a Raspberry Pi, especially under well-lit conditions. However, accuracy slightly decreased in low-light scenarios, highlighting the importance of lighting in detection performance. To improve accuracy for reflective or transparent objects, additional techniques such as image preprocessing or adjusting the camera angle to reduce reflection effects can be considered.

2) Evaluation of automatic water dispensing reliability: The system's success in filling glasses accurately demonstrates the effectiveness of its automated control mechanisms. A small margin of error indicates that the system provides precise control over water volume, which is crucial for water conservation and spill prevention. The use of relays and DC motors controlled by the Raspberry Pi proved capable of delivering rapid and stable responses for automatic water dispensing. For applications requiring higher precision, additional sensors to measure water levels within the glass could enhance control accuracy.

3) System stability evaluation: Stability testing indicated that the system operates consistently over extended periods without failure. This highlights the durability of the hardware, including the Raspberry Pi, camera, and control components. Such reliability is critical for household or industrial applications where repeated use is expected. The stability test also demonstrated that the system functions efficiently with minimal power consumption, avoiding overheating or technical issues.

4) Implications and potential for further development: The test results suggest that the smart water dispenser system holds significant potential for household or public applications. With reliable object detection, precise water dispensing, and high system stability, it offers an effective solution for water conservation and user convenience. Potential improvements include integrating additional sensors for water level detection, employing enhanced filters for transparent object detection, and optimizing the algorithm to improve accuracy under diverse lighting conditions.

TABLE I. TESTING RESULT FOR SMART WATER DISPENSER SYSTEM

No.	Test Type	Parameter	Test Result	Description
1.	Object Detection Accuracy	Optimal Lighting Condition	94 % Object detection accuracy	High accuracy under optimal lighting conditions
		Low Lighting Condition	89 % Object detection accuracy	Reduced accuracy in low-lighting
		Transparent/Reflective Objects	75 % Object detection accuracy	Transparent and reflective objects are harder to detect
2.	Automatic Water Dispensing Reliability	Small Glass (150 ml)	95% accuracy (±5 % margin of error)	Accurate dispensing for small glass capacity
		Medium Glass (250 ml)	97% accuracy (±5 % margin of error)	Accurate dispensing for medium glass capacity
		Large Glass (500 ml)	96% accuracy (±4 % margin of error)	Accurate dispensing for large glass capacity
3.	System Stability	Continuous Operation Cycles	50 cycles without failure	The system operates stably over 50 cycles without interruptions
		Power Consumption	5V, 2.5 A (Rasberry Pi Standard)	The system operates with minimal power consumption
		Operating Temperature	40-45° (no overheating)	Temperature remains stable during prolonged operation

Explanation of the Table I Testing:

1) Object detection accuracy: Tests were conducted to measure the system's accuracy in detecting the presence of a glass under various conditions. Under optimal lighting, the system achieved 94% accuracy, while low lighting conditions slightly reduced accuracy to 89%. Transparent or reflective objects, such as glass, resulted in lower detection accuracy (75%). In optimal lighting conditions or less light, glass detection can still run well. but if the size of the glass used is not standard, it will affect the detection accuracy, especially if the glass is transparent without color, the accuracy will decrease even more.

2) Automatic Water Dispensing Reliability: This test measured the system's accuracy in dispensing water according to the glass capacity. Three different glass sizes were tested, showing a low margin of error across all sizes (small, medium, and large), indicating high accuracy in controlling the water volume dispensed.

3) System Stability testing: It was conducted to ensure the system could operate continuously over multiple cycles. The system showed consistent performance over 50 cycles without failure, maintained stable operating temperatures (40-45°C), and consumed minimal power (5V, 2.5A).

V. CONCLUSION

This study successfully developed and implemented a smart water dispenser system using Raspberry Pi and object recognition technology to automate water dispensing based on the detection of a glass. The system incorporates OpenCV and YOLO algorithms for real-time object detection and controls a DC motor and water pump to ensure precise and reliable water filling. Testing demonstrated that the system achieved a high detection accuracy of 94% under optimal lighting conditions and maintained stable performance over multiple cycles, with no operational failures observed.

The system's ability to accurately detect different glass sizes and automatically adjust the water volume demonstrates its effectiveness in reducing water waste and enhancing user convenience. Moreover, the stable operating temperature and minimal power consumption indicate that the system is suitable for continuous use in real-world applications, whether in household settings or public spaces.

In summary, the smart water dispenser system shows promising potential for improving the efficiency and sustainability of water use in smart homes and IoT applications. Future improvements, such as adding sensors for enhanced water level detection and optimizing algorithms for detecting transparent or reflective objects, could further enhance the system's robustness and broaden its range of applications.

The strength of this research is the process of filling water in the glass automatically, by involving the Convolutional Neural Network (CNN) method, so that the water filling process has its intelligence and can be applied to patients with disabilities, but this research has a weakness, namely still using a scanning system on the cup at point A to point B statically, not having a Degree of Freedom (DOF) like the Robot Arm.

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FUTURE RESEARCH

The development of this Smart Water Dispenser is still static, so it is necessary to make changes to the side of the water filling hose and Degree of Freedom (DOF) as in the Robot Arm, so that the position of the cup that is anywhere in the X, Y, Z coordinates, can fill water with great precision.

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