ResQBot: An Innovative Rescue Resource Management model for Cloud-Based IoT Environments

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Abstract

This study introduces, a novel IoT-based system designed to improve the efficacy of rescue operations through enhanced resource management techniques in cloud-based environments. ResQBot integrates advanced functionalities such as obstacle detection using ultrasonic sensors, precise robotic arm control for object manipulation, and real-time camera feedback for situational awareness. This integration facilitates a sophisticated platform that significantly boosts operational efficiency in complex rescue scenarios. We detail the architectural design of ResQBot, which includes hardware components like the Raspberry Pi for processing and Mecanum wheels for omnidirectional mobility, alongside a comprehensive suite of sensors and actuators. The software framework supports obstacle avoidance, arm manipulation, and a user interface optimized for mobile device interactions and live video streaming. The system's performance was rigorously evaluated through experimental testing and simulation scenarios, highlighting its improved navigational capabilities, effective object manipulation, and enhanced user interaction. The results demonstrate ResQBot's potential in real-world rescue operations, underscoring its contribution to the field of IoT applications in emergency management. The research validates the practical utility and scalability of ResQBot, positioning it as a significant advancement in leveraging cloud based IoT technologies for critical rescue missions.

Keywords: Internet of Things (IoT), ResQBot, Robotic Arm Control, Rescue Missions, Raspberry Pi, Mecanum Wheels, Situational Awareness, Real-World Deployment.

1. Introduction

In recent years, the integration of Internet of Things (IoT) technology into various fields has revolutionized the way we interact with and perceive our environment. One particularly promising application of IoT lies in the realm of rescue missions, where the need for efficient, versatile, and technologically advanced tools is paramount. In response to this demand, we present "ResQBot," an innovative IoT-based Model specifically designed to address the challenges encountered in rescue operations.

ResQBot encompasses a suite of functionalities tailored to enhance the capabilities of rescue teams in navigating hazardous environments, manipulating objects, and gaining real-time situational awareness

Motivation and Significance

The motivation behind the development of ResQBot stems from the critical need to improve the efficiency and effectiveness of rescue operations. Traditional rescue methods often face significant challenges, including difficult terrain, limited visibility, and the inability to remotely manipulate objects.

The significance of ResQBot lies in its potential to transform rescue missions by integrating advanced IoT functionalities. The system's ability to detect obstacles, control a robotic arm, and provide real-time video feedback can significantly enhance the decision-making process during rescue operations. This can lead to quicker, more accurate responses, ultimately saving lives and reducing the risk to rescue personnel.

In this paper, we provide a detailed overview of the ResQBot model, outlining its key features, design considerations, and implementation strategies. We discuss the hardware and software components utilized, including the Raspberry Pi for computation, Mecanum wheels for omnidirectional movement, and a combination of sensors and actuators for obstacle avoidance and arm manipulation

ResQBot represents a significant advancement in IoT-based solutions for rescue missions, offering a versatile and capable platform for addressing the unique challenges faced by rescue teams. By leveraging the power of IoT technology, ResQBot aims to enhance the efficiency, safety, and effectiveness of rescue operations, ultimately contributing to saving lives and mitigating risks in emergency situations.

Objectives

The main aim of the ResQBot model is to develop an IoT-based platform tailored for rescue missions, integrating obstacle detection, robotic arm control, and mobile device interaction to enhance the capabilities of rescue teams. The objectives include:

- Implementing obstacle detection for navigating hazardous environments.
- Enabling precise control of a robotic arm for object manipulation.
- Integrating mobile device interaction for remote operation.
- Providing live camera feedback to enhance situational awareness.
- Evaluating the effectiveness and usability of ResQBot in simulated rescue missions.

2. Related Work

In recent years, researchers have increasingly integrated advanced technologies such as cloud computing, IoT, and AI to enhance the efficiency and effectiveness of disaster management, health management, and emergency response systems. This technical review surveys recent studies leveraging these technologies, detailing their methods, results, and implications. Various Disaster management, health management, and emergency response systems have increasingly integrated advanced technologies such as cloud computing, IoT, and AI to improve efficiency and effectiveness. This literature review surveys recent studies that leverage these technologies, highlighting their methods, results, and limitations. The authors Cheikhrouhou et al. (2020) introduced a cloud-based disaster management system utilizing 3D visualization and real-time feedback for enhanced rescue planning. In cloud robotics, Botta et al. (2021) developed the DewROS platform, emphasizing the minimal impact of video length on response time but noting the dependence on network connection round-trip time. These studies collectively underscore the potential and challenges of integrating modern technologies in disaster management and health care systems.

Table 1 provides a comparative analysis of recent studies integrating advanced technologies such as cloud computing, IoT, and AI into disaster management, health management, and emergency response systems. It summarizes key findings, outcomes, results, methods used, and practical implications, highlighting advancements in real-time data processing, predictive accuracy, and system optimization, along with the associated challenges and limitations.

Table 1: Review of Recent Technological Advances and Methods

Ref.	Key Findings	Outcomes	Results	Methods Used	Practical Implications
Liu et al. (2022)	Cloud-centric IoT-based health management framework	Perceived usefulness and ease of use positively impact adoption intention, perceived risk negatively impacts adoption	Adoption intention affected by perceived usefulness, ease of use, and perceived risk	Online semi-structured questionnaire, mature scales from previous studies	Healthcare companies can design marketable systems based on IoT and medical diagnostics
Botta et al. (2021)	DewROS framework for Cloud Robotics application	Video length has minimal impact on response time, response time depends on network connection round-trip time	Experimental evaluation using different network technologies and Cloud services	Experimental evaluation, different network technologies, and Cloud services	Effective in scenarios where network conditions vary
Talavera et al. (2023)	Autonomous ground robot for indoor emergency interventions	Robot detects fire sources and cold smoke, provides environmental information	Simulator offers alternative routes for faster and safer access/exit	Robotics and remote sensing technologies, simulator for reproducing emergency scenarios	Enhances safety and efficiency of firefighter interventions in indoor emergencies
Tkachenko et al. (2020)	Ensemble method improves prediction accuracy of missing IoT data	Outperforms existing methods in accuracy based on MAPE and RMSE	Improved prediction accuracy using GRNN-SGTM ensemble approach	GRNN-SGTM ensemble approach, weighted summation	Enhances reliability and accuracy of IoT data prediction
Wu et al. (2022)	Edge-assisted cloud framework with RC-FCN for beam correction in IoT meteorology	Proposed framework achieves better performance and efficiency in radar data analytics	RC-FCN model outperformed other deep learning models for beam correction	Edge-assisted cloud framework, RC-FCN model, experimental evaluation	Facilitates effective communication and progression in radar data analytics
Zuo et al. (2022)	Gravity model for travel time budget, space-time accessibility measurement for emergency network	Space-time accessibility model improves maintenance investment allocation strategy	Global optimization model for railway emergency rescue network maintenance allocation	Gravity model, space-time accessibility measurement method, global optimization model	Enhances efficiency of emergency response in railway networks
Patel et al. (2022)	Closed-loop automated critical care platform for resuscitation	Autonomous critical care platform avoids hypotension, manages hypertension	Animals experienced hypotension 15.3%, hypertension 7.7%, normotension 76.9%	Vasopressor titration algorithm, closed-loop algorithm for resuscitation	Potential for improved critical care management in emergency medical scenarios
Khan et al. (2023)	RoboDoc for remote interaction with contagious	Successful experimental results of basic vitals of remote patients	RoboDoc can take readings of pulse oximeter, IR temperature, and e-	Remote doctor interaction via RoboDoc, mechanical, electrical/electronic,	Protects healthcare staff while providing essential patient care remotely

	patients during COVID-19		steth from remote patients	mechatronic, control, and communication parts	
Yao et al. (2023)	Multi-agent collaborative emergency-decision-making algorithm for highway incidents	Algorithm improves collaboration efficiency, reduces emergency response time	Reduced emergency response time and disposal processes significantly	Multi-agent deep deterministic strategy gradient (MADDPG) algorithm, Petri net-based emergency disposal model	Enhances coordination and efficiency of emergency response among highway incident management teams
IEEE Internet of Things Journal (2023)	DEOSA selects output services based on physical effect delivery effectiveness	DEOSA outperforms traditional algorithms in simulated IoT environments	Visual-service effectiveness metric improved for personalized delivery of physical effects	Dynamic selection and replacement of services, deep reinforcement learning	Improves IoT service selection based on visual-service effectiveness metric
Cvitić et al. (2021)	Effective model for IoT device classification in smart home	Model can be applied in monitoring and managing large and heterogeneous IoT environments	Developed effective model for IoT device classification, high accuracy (99.79%)	Logistic regression method enhanced by logitboost, multinomial ordinal logistic regression method	Enhances monitoring and management of large and heterogeneous IoT environments
Aboualola et al. (2023)	Survey on edge technologies for disaster management	Adoption of edge technologies can decrease casualties and infrastructure damage in crises	Emphasizes social media analytics and artificial intelligence for emergency situations	Social media analytics, artificial intelligence, edge computing	Enhances emergency prediction, detection, management, and response systems
Lee et al. (2023)	IoMT-based real-time digital health services for precision medicine	MEDBIZ platform supports real-time digital health services, effective for precision medicine	Successful real-time monitoring of vital signs using IoMT devices	Wearable devices, mobile apps, real-time monitoring	Improves precision medicine through real-time digital health services
Galera-Zarco et al. (2023)	Deep learning model for built asset operations and disaster management	Integrative simulation model enables quicker decision making in critical events	Deep learning model improves disaster management and operational resilience	Deep learning, building information modeling, integrative simulation	Enhances rapid assessment and decision-making in disaster scenarios
Conz et al. (2023)	Slack resources and entrepreneurial attitude for resilience in crises	Entrepreneurial firms leveraged slack resources and attitude to build resilience	Slack resources and entrepreneurial attitude crucial for resilience and opportunities	Abductive process, triangulation of findings using secondary data	

3. Description and Proposed model:

ResQBot is an innovative IoT-based model designed to aid rescue missions by incorporating obstacle detection, robotic arm control, and mobile device interaction. It features advanced functionalities such as real-time camera feedback for situational awareness and seamless control via smartphones. ResQBot aims to enhance the efficiency and safety of rescue operations by providing rescue teams with a versatile and capable platform for navigating hazardous environments, manipulating objects, and gaining crucial insights into the surroundings.

3.1. Functionalities (Technical / Non-Technical)

Functional qualities encompass both technical and non-technical aspects of a system, contributing to its overall performance and usability. In the case of ResQBot, these qualities are vital for ensuring the effectiveness and practicality of the platform in rescue missions.

- **Obstacle Detection:** ResQBot ability to accurately detect obstacles in its path is crucial for navigating hazardous environments safely. This technical feature relies on sensors such as ultrasonic sensors or LiDAR to perceive the surroundings and make informed navigation decisions.
- **Robotic Arm Control**: The precise control of the robotic arm enables ResQBot to manipulate objects, clear pathways, or provide assistance in rescue operations. This functionality requires precise motor control and feedback mechanisms to ensure smooth and accurate arm movements.
- **Mobile Device Integration:** Seamless integration with mobile devices allows users to control ResQBot remotely, providing flexibility and convenience in operation. This technical quality involves developing user-friendly interfaces and establishing reliable communication protocols between the robot and the mobile application.
- **Camera Feedback:** The inclusion of a camera provides real-time visual feedback to users, enhancing situational awareness and facilitating remote operation. This technical feature requires the integration of camera modules, image processing algorithms, and streaming capabilities to deliver high-quality video feeds to the user interface.

3.2. Technical Functional Qualities:

- **Usability:** ResQBot usability refers to its ease of use and intuitiveness in operation. Non-technical aspects such as ergonomic design, intuitive controls, and clear user interfaces contribute to the overall usability of the platform, ensuring that rescue teams can effectively utilize its capabilities in high-pressure situations.
- **Reliability:** Reliability is crucial for ensuring that ResQBot performs consistently and predictably in various environments and conditions. This non-technical quality encompasses aspects such as robust hardware design, fault tolerance mechanisms, and rigorous testing procedures to minimize the risk of system failures during rescue missions.
- **Safety:** Safety is paramount in rescue operations, and ResQBot must adhere to stringent safety standards to minimize the risk of accidents or injuries. Non-technical considerations such as fail-safe mechanisms, emergency stop buttons, and comprehensive user training contribute to ensuring the safety of both users and bystanders during deployment.
- **Scalability:** Scalability refers to ResQBot ability to adapt to different scenarios and scale its capabilities to meet evolving demands. This non-technical quality involves designing modular and extensible architectures that allow for easy integration of additional sensors, functionalities, or upgrades to accommodate changing requirements in rescue missions.

3.3. Main Components

The main components used in ResQBot play crucial roles in its functionality and performance. Here's an overview of the key parts integrated into the system:

- **Raspberry Pi:** Serving as the central computing unit, the Raspberry Pi provides the processing power and connectivity necessary to run the ResQBot software and interface with its various components. It facilitates communication between sensors, actuators, and external devices, enabling real-time decision-making and control.

- **Mecanum Wheels:** Mecanum wheels enable omnidirectional movement, allowing ResQBot to navigate complex environments with precision and agility. These wheels consist of multiple rollers mounted at angles, enabling the robot to move in any direction without changing its orientation.

- **Sensors:** ResQBot incorporates a variety of sensors to perceive its surroundings and gather relevant data for navigation and interaction. This includes:

  .1. **Obstacle Detection Sensors:** Ultrasonic sensors or LiDAR modules detect obstacles in the robot's path, allowing it to navigate safely.
  .2. **Camera Module**: A camera provides visual feedback to users, enabling remote operation and enhancing situational awareness.
  .3. **IMU (Inertial Measurement Unit):** An IMU provides information about the robot's orientation and movement, aiding in navigation and stabilization.

- **Robotic Arm:** The robotic arm is equipped with actuators and grippers for manipulating objects and performing tasks in rescue scenarios. It enhances the versatility of ResQBot by enabling it to clear pathways, move debris, or provide assistance to victims.

- **Mobile Device Interface:** ResQBot integrates with mobile devices such as smartphones or tablets for remote control and monitoring. This interface allows users to interact with the robot, view live camera feeds, and command its movements from a distance.

- **Power System:** A reliable power system, comprising batteries or power banks, supplies the necessary electrical energy to the components of ResQBot. It ensures uninterrupted operation during rescue missions and enables the robot to operate autonomously for extended periods.

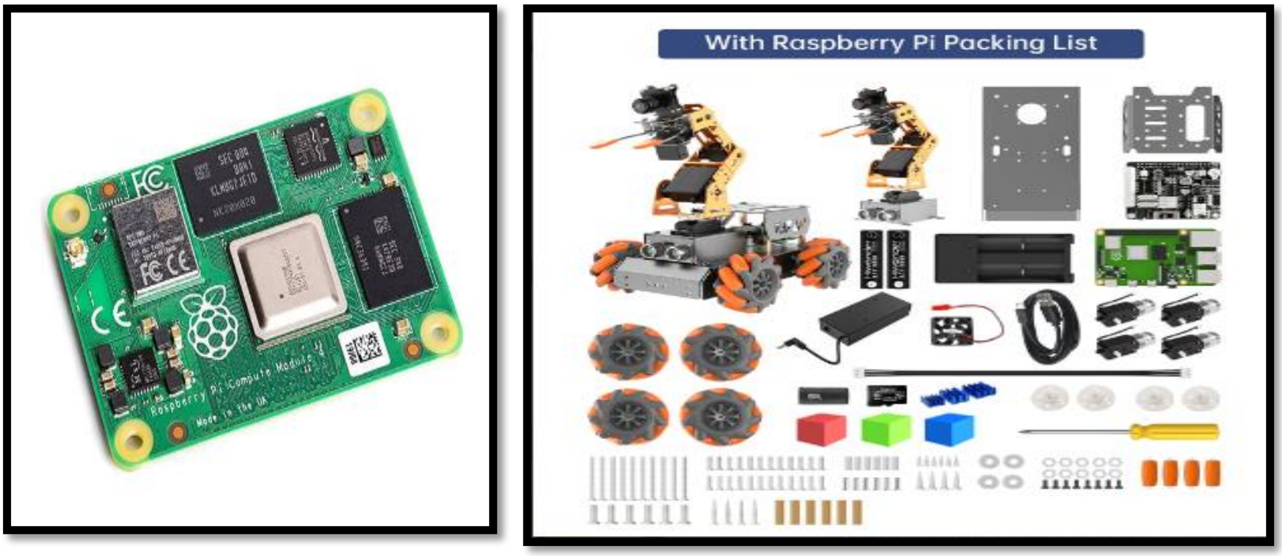


Figure 1: Components of the "ResQBot" AI Vision Robot Arm with Mecanum Wheels (with Raspberry Pi Board)

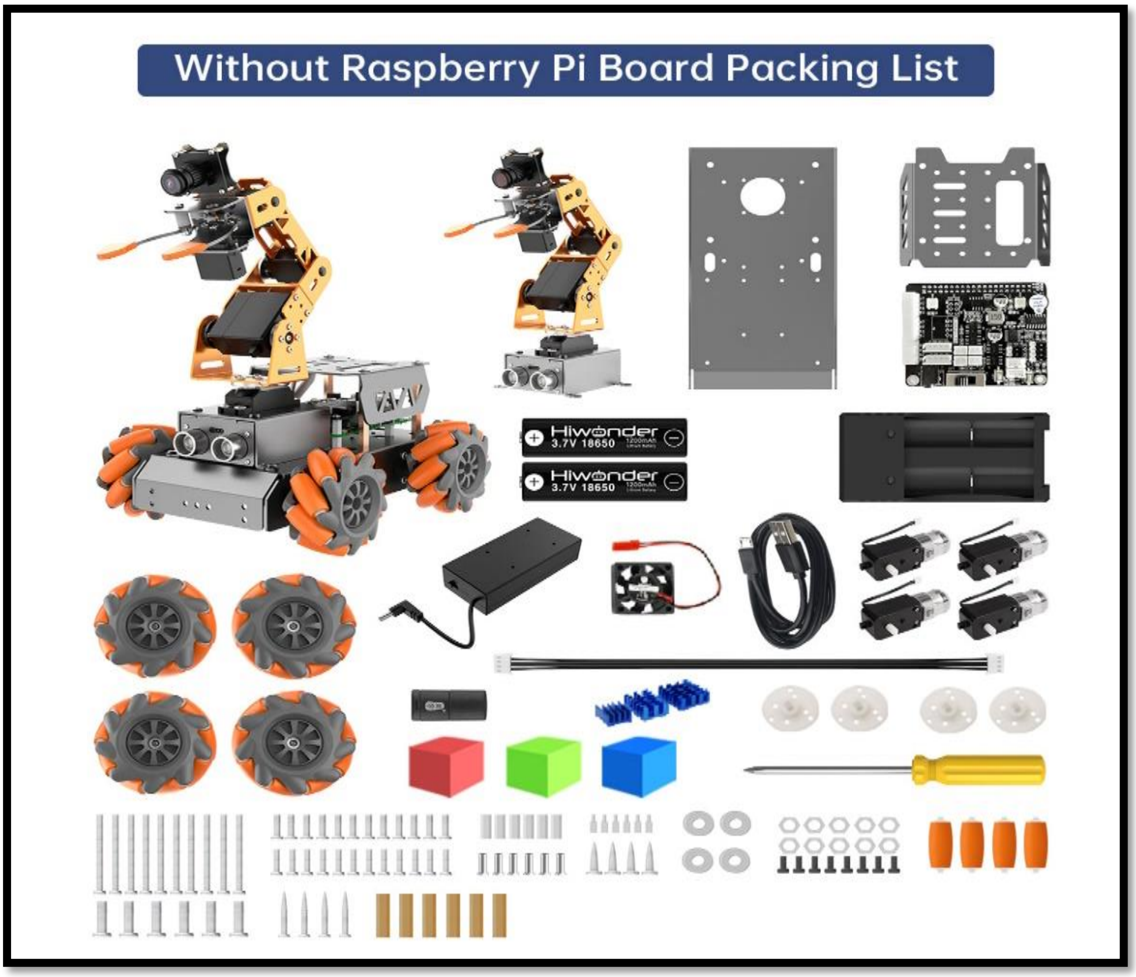


Figure 2: Components of the "ResQBot" AI Vision Robot Arm with Mecanum Wheels (Without Raspberry Pi Board)

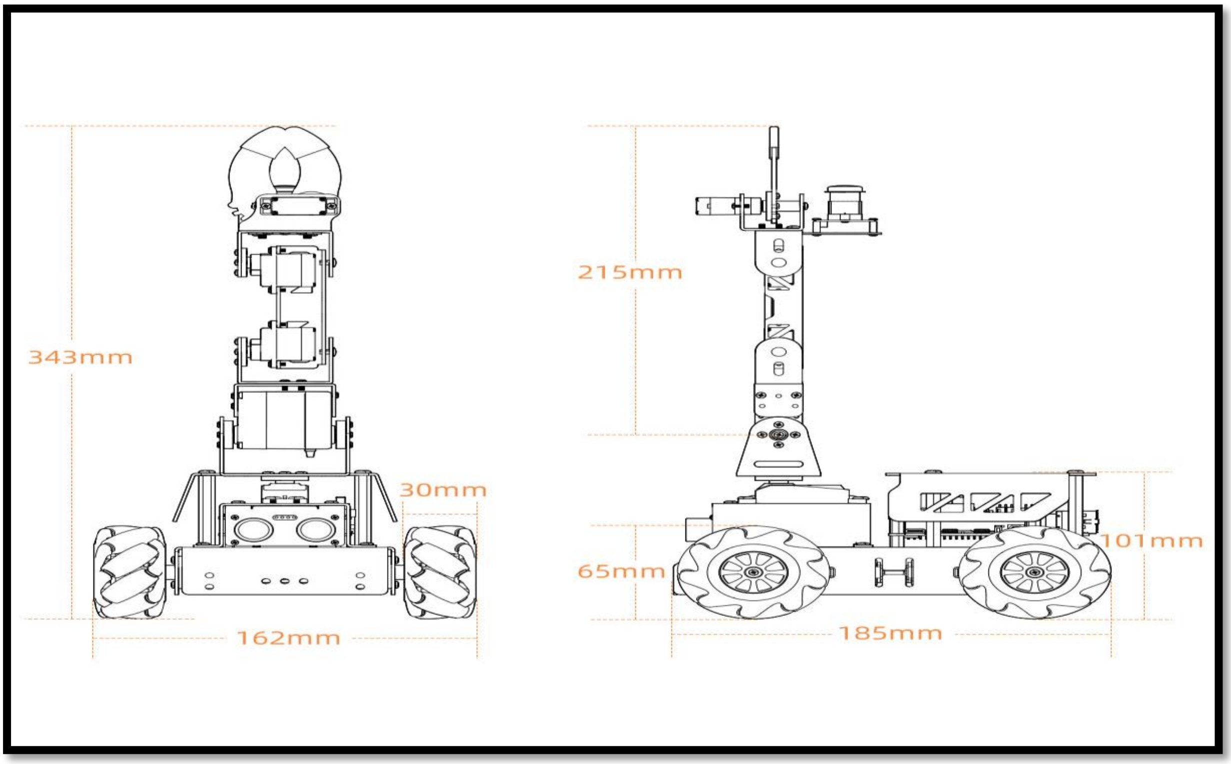


Figure 3: Dimensions of the "ResQBot" AI Vision Robot Arm with Mecanum Wheels

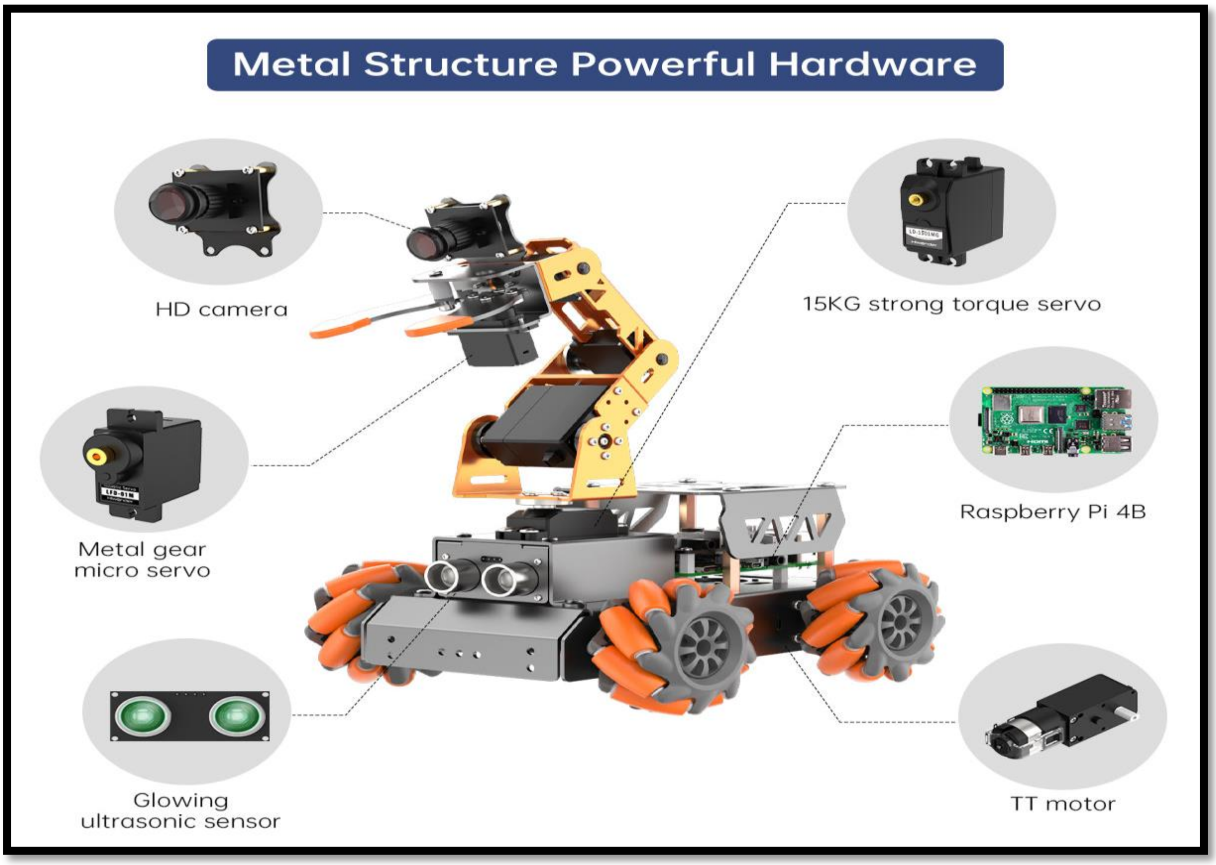


Figure 4: Metal Structure and Powerful Hardware of the "ResQBot" AI Vision Robot Arm with Mecanum Wheels

Figure 5: Remote Handling of the "ResQBot" Using Mobile Phones

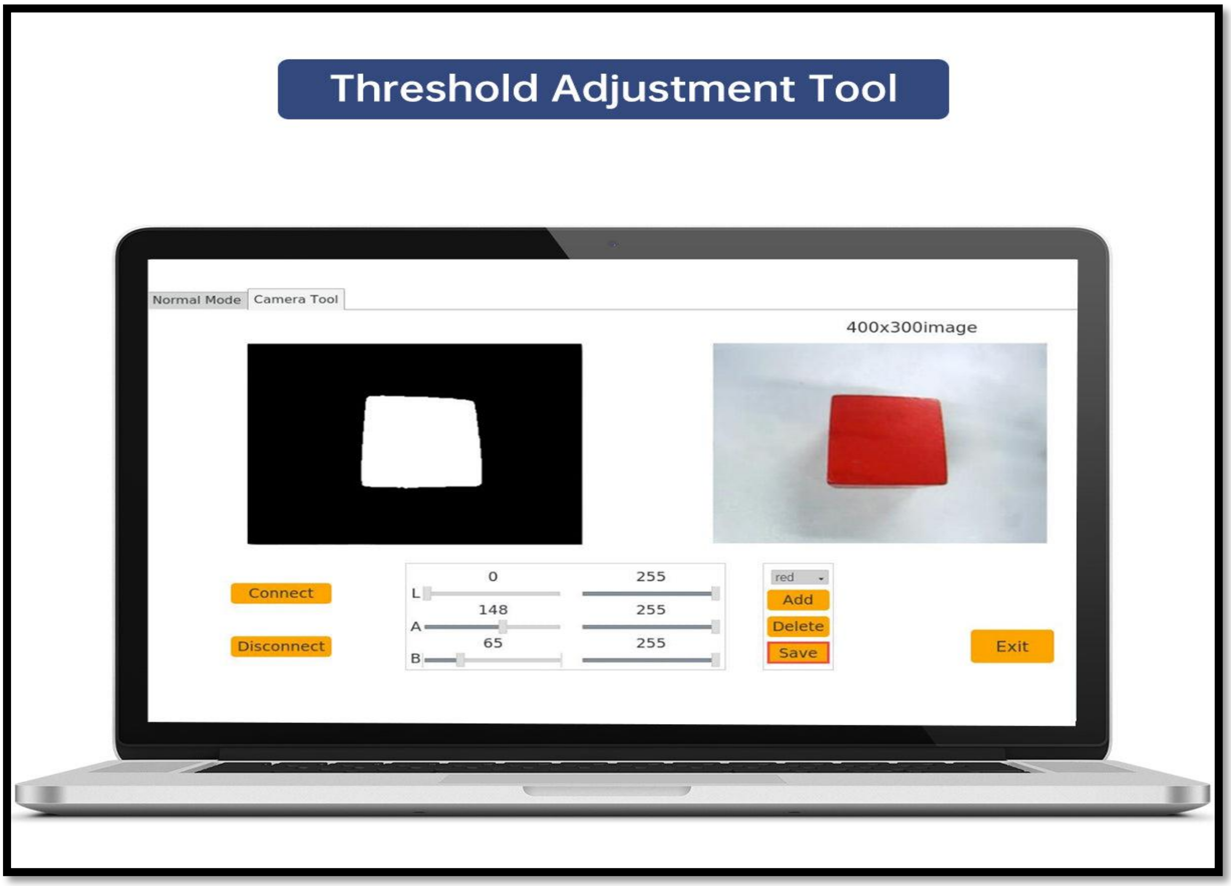


Figure 6: Threshold Adjustment Tool Interface for "ResQBot"

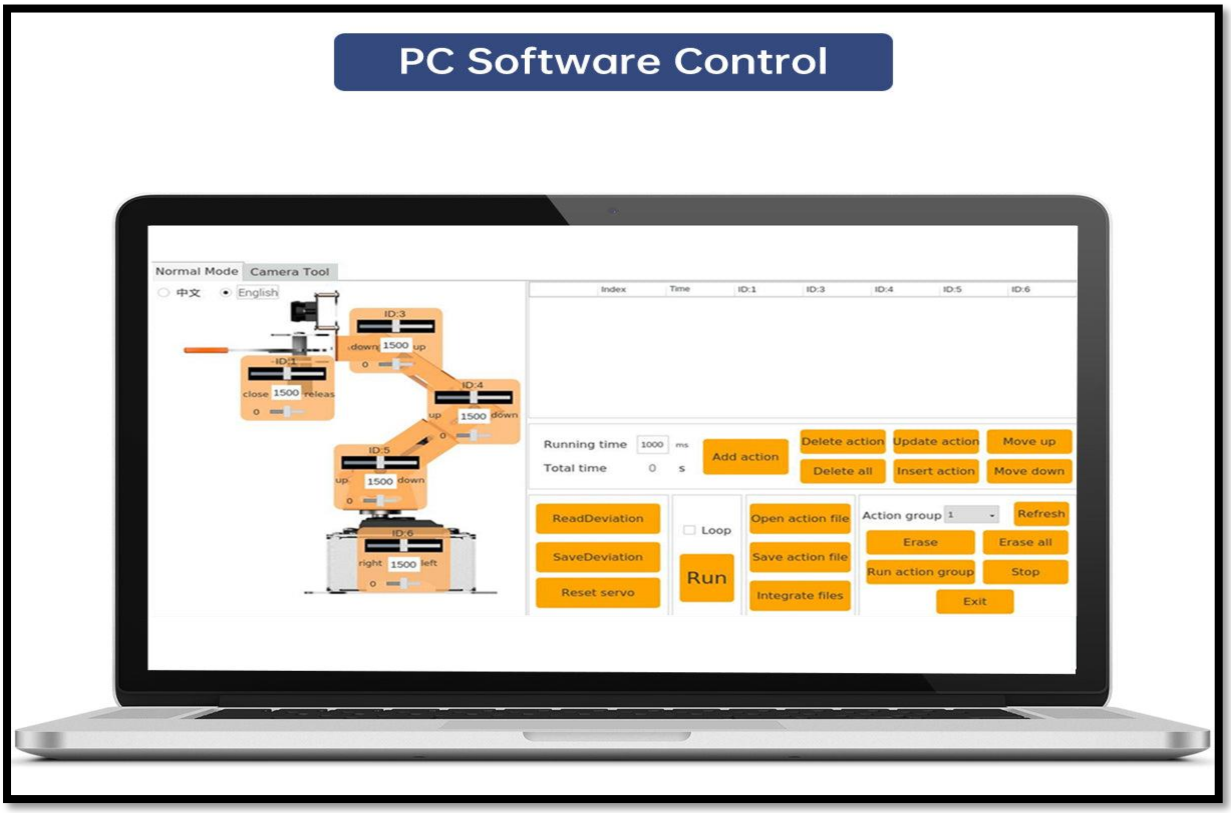


Figure 7: PC Software Control Interface for "ResQBot"

3.4. *Proposed* Working Model

The primary aim of ResQBot is to enhance search and rescue operations in hazardous environments, prioritizing the saving of lives while ensuring the safety of human rescuers.The Main Aim/ Objective of "ResQBot" is to provide the Rescue the lives of the people in the Disaster like Scenarios, when there is no human Intervention takes place.Situation where human-Intervention is not possible there "ResQbot" is available used to help and Rescue & Indicate to the main Admin by Monitoring and Tracking, With its versatile mobility, advanced sensors, and communication capabilities, ResQBot is designed to swiftly navigate through rubble, debris, and other challenging terrains to locate and assist survivors in scenarios such as earthquakes, building collapses, or industrial accidents.

By deploying ResQBot, search and rescue teams can increase efficiency, accessibility, and speed in their operations, minimizing the risk to human rescuers while maximizing the chances of locating survivors. Additionally, ResQBot serves as a valuable tool for collecting crucial data about the disaster site, aiding in decision-making and planning for rescue efforts.

Overall, ResQBot's main objective is to save lives and mitigate the impact of disasters by providing a reliable, adaptable, and efficient robotic solution for search and rescue missions.

3.5. Working of the Device in different scenarios:

- Thresholding is a fundamental technique in image processing used to separate regions of an image based on intensity levels. The basic idea is to convert a grayscale image into a binary image where pixels are classified as either foreground (object) or background based on their intensity values relative to a threshold.
- OpenCV (Open-Source Computer Vision Library) is a powerful open-source library for computer vision and image processing tasks. It provides various functions and algorithms for manipulating and analyzing images.
- PyQt is a set of Python bindings for the Qt application framework, allowing Python programmers to create GUI applications. It provides tools for building graphical user interfaces with features like windows, buttons, sliders, and more.
- Image Loading: The tool starts by loading an image from a file using OpenCV's cv2.imread() function. This image will be processed and displayed in the GUI.
- Threshold Adjustment: A slider widget from PyQt is used to allow the user to adjust the threshold value interactively. Whenever the slider value changes, a callback function updates the threshold value and reprocesses the image.
- Thresholding: OpenCV's cv2.threshold() function is used to apply thresholding to the loaded image. This function converts the grayscale image into a binary image based on the specified threshold value.
-

Figure 8: Programming and Control Options for "ResQBot"

Figure 9: Interactive Features of the "ResQBot" for Enhanced Learning

3.6. Device Specifications:

Table

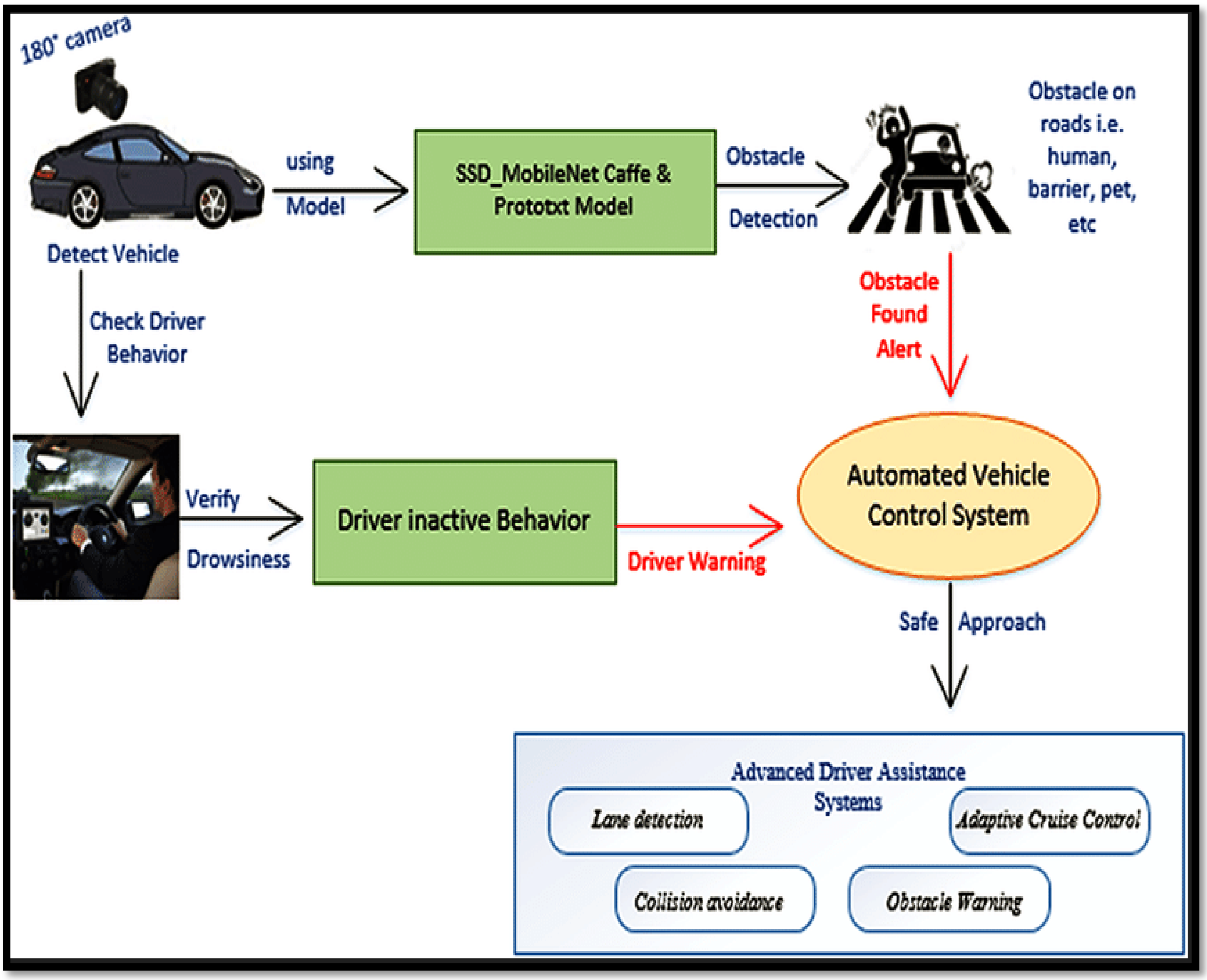
Product dimension:	185*162*343mm
Weight:	1100g
Body material:	Metal bracket
Camera resolution:	480P
Robotic arm DOF:	4DOF+gripper
Battery:	18650 lithium battery
Battery life:	work for 60min continuously
Hardware	Raspberry Pi 4B and Raspberry Pi expansion board
Software:	PC software, iOS/Android APP
Communication:	Wi-Fi and Ethernet
Servo:	LD-1501MG digital servo & LFD-01M micro servo
Control method:	PC and phone control
Package size:	330*290*85mm (length*width*height)
Package weight:	About 1600g

3.7.*Source* Code :

```
#include <iostream>
#include <wiringPi.h>
#include <softPwm.h>
#include <unistd.h>
#include <thread>
#include <chrono>
using namespace std;
// Ultrasonic sensor pins
const int TRIG_PIN = 4;
const int ECHO_PIN = 5;
// Servo motor pin
const int SERVO_PIN = 18;
// Function to initialize GPIO pins
void initializeGPIO() {
    wiringPiSetup();
    pinMode(TRIG_PIN, OUTPUT);
    pinMode(ECHO_PIN, INPUT);
    softPwmCreate(SERVO_PIN, 0, 180);
}
// Function to measure distance using ultrasonic sensor
float measureDistance() {
    digitalWrite(TRIG_PIN, LOW);
    delayMicroseconds(2);
    digitalWrite(TRIG_PIN, HIGH);
    delayMicroseconds(10);
    digitalWrite(TRIG_PIN, LOW);
    while (digitalRead(ECHO_PIN) == LOW);
    auto startTime = std::chrono::high_resolution_clock::now();
    while (digitalRead(ECHO_PIN) == HIGH);
    auto endTime = std::chrono::high_resolution_clock::now();
    std::chrono::duration<float> duration = endTime - startTime;
    float distance = duration.count() * 17150;
    return distance;
}
// Function to control the robotic arm
void controlArm(int angle) {
    softPwmWrite(SERVO_PIN, angle);
    delay(1000);
}
// Main function
int main() {
    initializeGPIO();
    // Example usage
    while (true) {
        float distance = measureDistance();
        cout << "Distance: " << distance << " cm" << endl;
```

```
        // If obstacle detected, stop and move the arm
        if (distance < 20) {
            cout << "Obstacle detected! Stopping and moving the arm." << endl;
            // Stop the robot
            // Move the arm
            controlArm(90);
        } else {
            cout << "No obstacle detected. Continuing..." << endl;
            // Continue moving the robot
        }
        // Sleep for some time before the next iteration
        std::this_thread::sleep_for(std::chrono::seconds(1));
    }
    return 0;
}
```

- **Real – Life Working of different Components in "ResQBot"**



3.8. Flow Chart

This flowchart outlines the workflow of a robot's operation, beginning with the initialization of GPIO pins and the measurement of distance using an ultrasonic sensor. The robot then checks for obstacles; if detected, it stops, activates alarms, sends alerts, turns on the camera, and moves its robotic arm. If no obstacles are found, it continues its operations. The robot moves in a random direction where no obstacles are present, follows the main logic behind the code, and controls the robotic arm. If it receives a command from a smartphone, it stops, moves the robotic arm, performs the required actions, and finally stops.

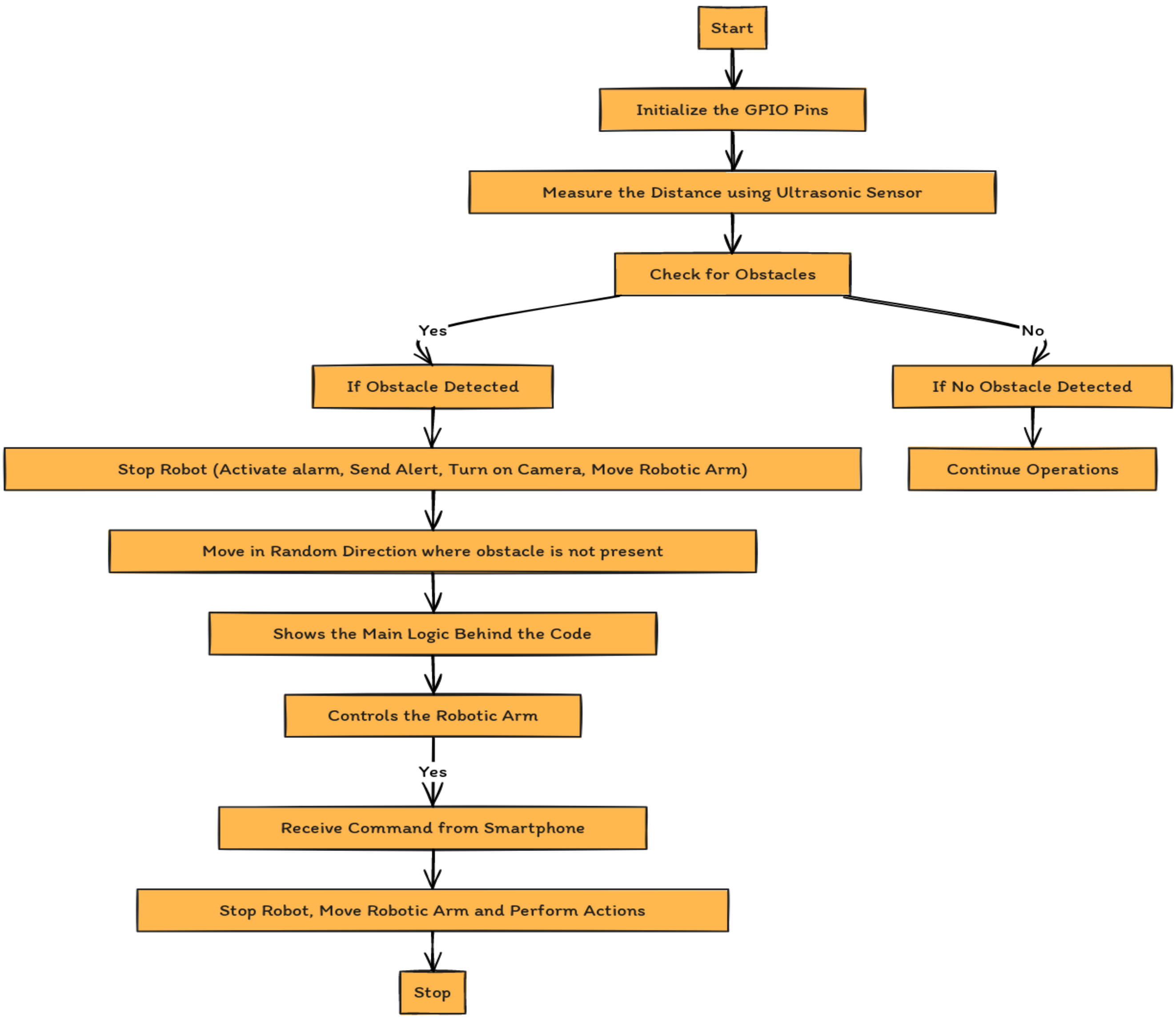


Figure 10: Flowchart of the "ResQBot" Operational Logic

3.9. *Result*

The proposed model yielded several key outcomes. A functional prototype was developed, integrating obstacle detection using ultrasonic sensors, robotic arm control via servo motors, and smartphone communication for remote operation. Hardware interfacing and sensor data processing algorithms were successfully implemented for precise obstacle detection and distance measurement. Motor control logic was integrated to manage the robotic arm's movements based on user commands. Additionally, a smartphone application with user-friendly controls was created, allowing remote operation of the robot and real-time visualization of the surroundings through a live camera feed. The proposed model highlights the feasibility and potential of IoT-based solutions for rescue missions. It provides a versatile and adaptable platform capable of navigating hazardous environments, manipulating objects, and delivering real-time situational awareness to rescue teams. This innovation advances the application of modern technologies in search and rescue operations, enhancing operational efficiency and safety.

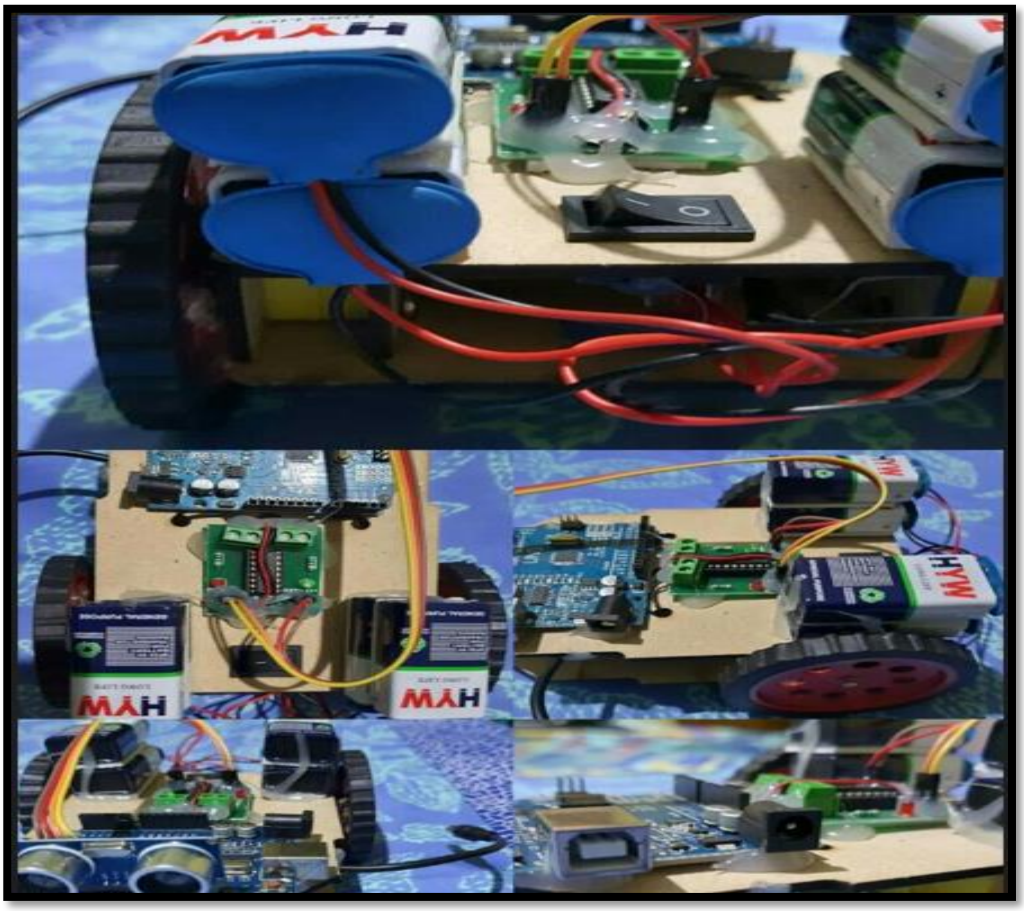
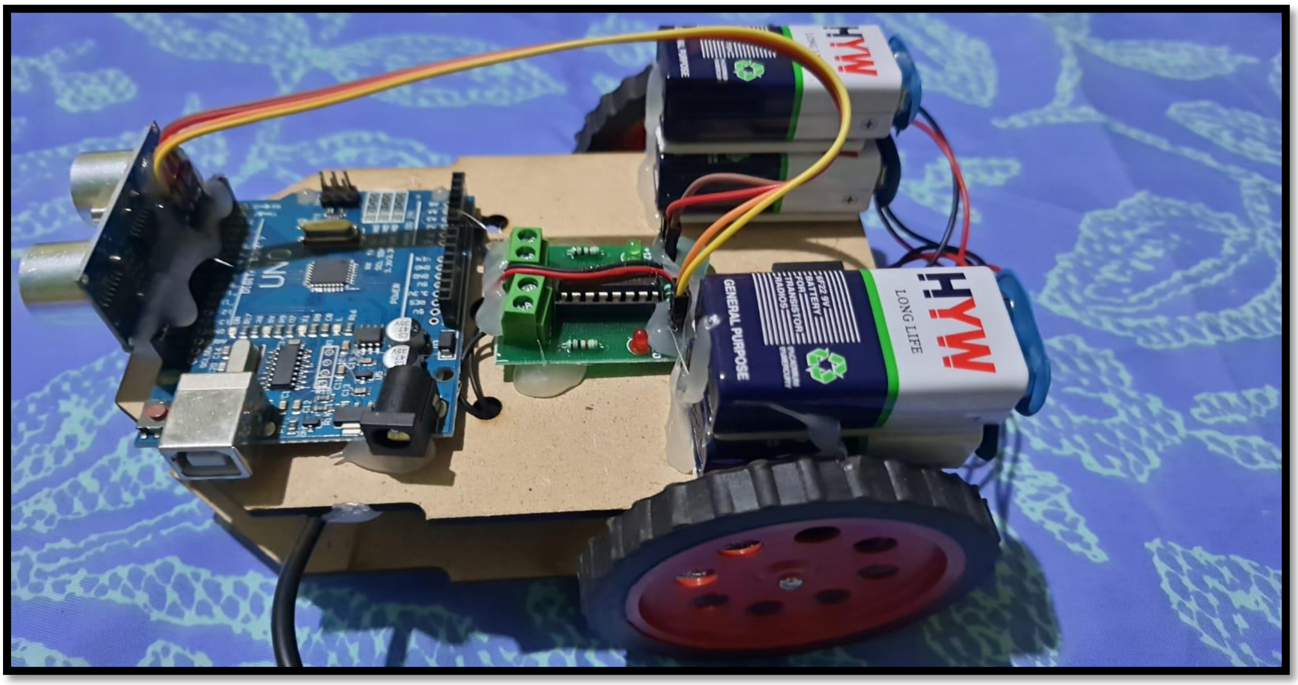


Figure 11 : Proposed model

3.10. Working / Main Functionality of the Model in Real Life.

ResQBot is powered by a Raspberry Pi 4B or CM4 controller, enabling you to undertake motion control, machine vision, and OpenCV projects. It protects the core control board from shattering and shock and can bear a larger load. The LDX-218 is a full metal gear standard digital servo with 17 kg high torque and dual ball bearings for the robot. The control angle is 180 degrees. In real-life applications, "ResQBot" demonstrates several key functionalities. The integration of the Raspberry Pi allows for precise control of the robot's movements, enabling it to navigate various terrains and obstacles effectively. Utilizing OpenCV, "ResQBot" can process visual data, recognize objects, and make decisions based on its environment. This is crucial for tasks such as search and rescue, where identifying and navigating to specific targets is essential. The design ensures that the core control board remains protected from physical damage, enhancing the reliability of the robot in harsh conditions. Additionally, the LDX-218 servo provides the necessary power and precision for manipulating objects, performing intricate tasks, and maintaining stability. Its 180-degree control angle allows for versatile movement and adaptability in various scenarios. On the whole, ResQBot is designed to operate efficiently in real-life situations, combining advanced control, vision capabilities, and robust hardware to perform complex tasks reliably.



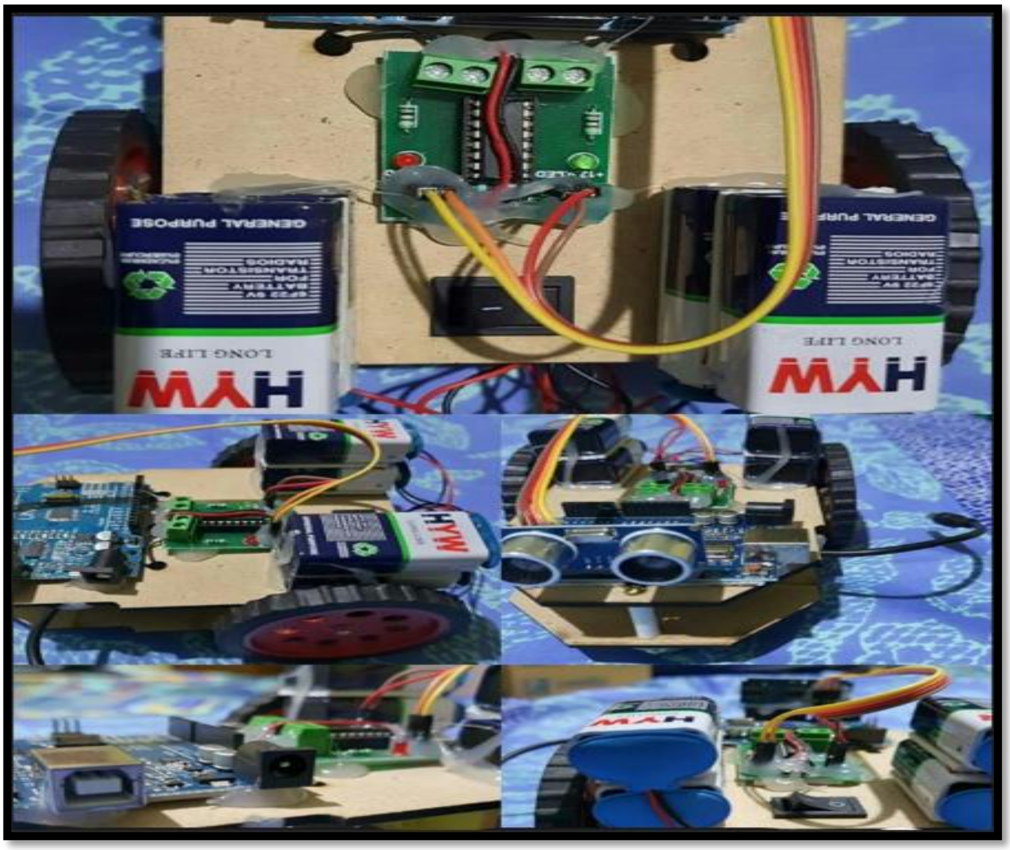
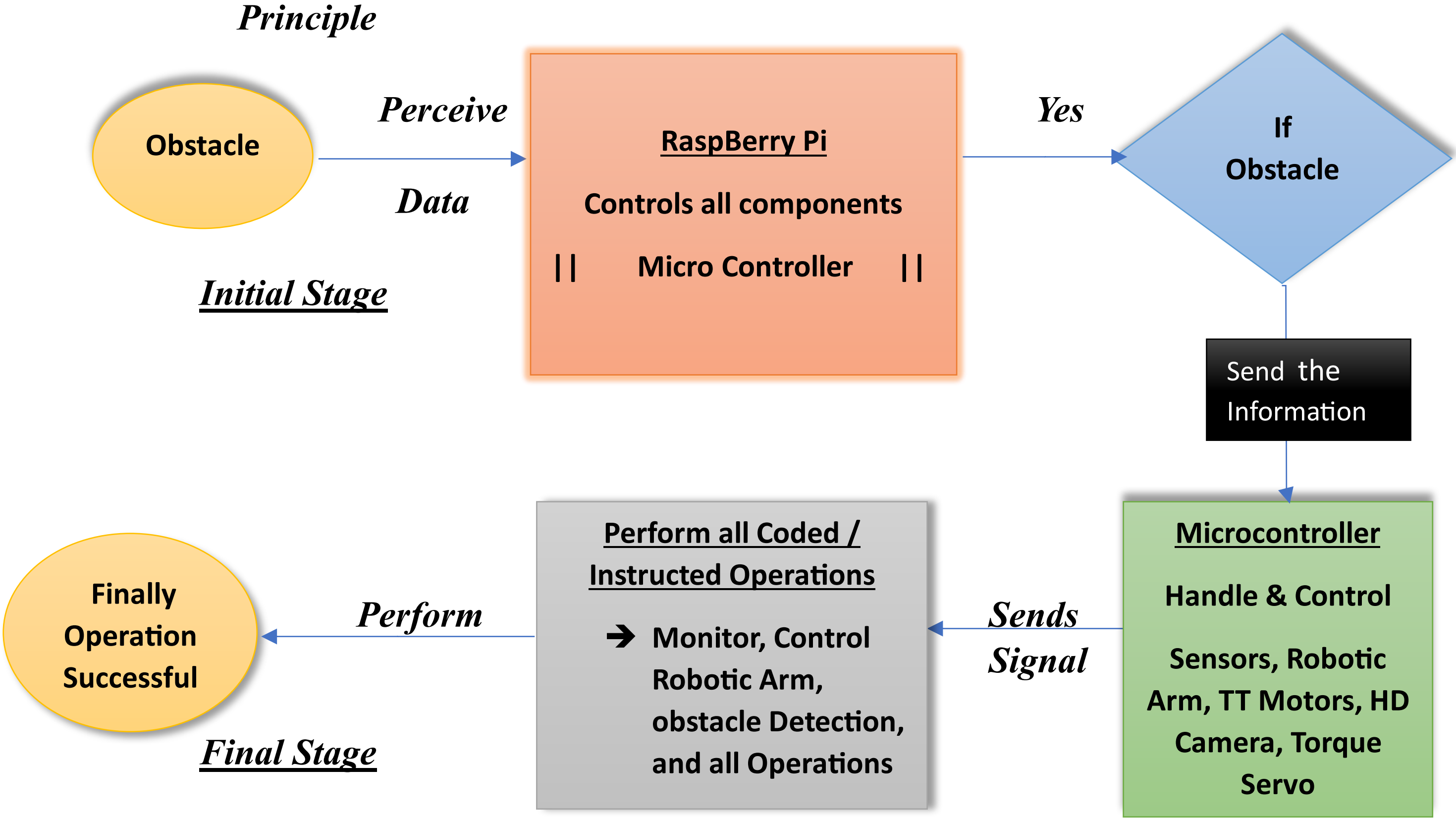


Figure 12 : ResQBot

- ***Block – Diagram Structural Framework of "ResQBot" Working Principle***



3.11. Conclusion and future directions:

The "ResQBot" AI Vision Robot Arm with Mecanum Wheels Car represents a sophisticated and versatile robotic platform designed for education, research, and hobbyist projects. Powered by a Raspberry Pi, the model integrates a variety of sensors that collectively enable a broad range of functionalities. Key sensors include the HD Camera Module for computer vision tasks, Ultrasonic Sensors for obstacle detection and avoidance, Infrared Sensors for short-range object detection, a 9-axis Inertial Measurement Unit (IMU) for orientation and motion tracking, Rotary Encoders for precise movement control, and additional sensors for environmental monitoring and force measurement. These components allow "ResQBot" to perform autonomous navigation, complex AI-driven actions, and interactive environmental engagement.

To further enhance the capabilities and applications of "ResQBot," several future directions can be explored. Advanced AI integration, including more sophisticated machine learning algorithms, can improve object recognition, decision-making, and adaptive learning capabilities. Enhanced mobility and control can be achieved by upgrading the Mecanum wheels and control algorithms, as well as incorporating advanced motor control systems for smoother robotic arm movements.

Application-specific adaptations can tailor "ResQBot" for industries like search and rescue, agricultural monitoring, or industrial automation, customizing sensor setups and control algorithms to meet unique needs. By pursuing these future directions, "ResQBot" can become an even more powerful and adaptable tool, opening new possibilities for innovation and application in various fields.

References