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Development of Web-Based Teleoperation VOCAFE Service Robot

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Abstract— **The design and implementation of a service robot that communicates effectively via the MQTT Protocol is presented in this research. This study focuses on creating a web-based application to control and monitor the movement of restaurant service robots in one of the university's cafes called VOCAFE. This research uses the MQTT communication protocol which allows smooth interaction between the robot and the operator. The design and construction of service robots, including their mechanical parts and communication systems, is described in the engineering section. The test results show the response time of the robot's navigation system, showing performance within a reasonable range. The conclusion highlights the importance of additional testing and research to improve the system. Overall, this research advances the creation of teleoperated restaurant service robots with reliable and effective communication using MQTT.**

Index Terms— **Web-Based, Service Robot, Restaurant, MQTT**

I. INTRODUCTION

Web-based teleoperation of service robots has gained significant attention in recent years due to advancements in communication systems and computer networks [1]. This technology has found applications in various fields such as service and home robotics, rehabilitation systems, and social robotics [1]. The use of augmented reality has been explored as a means to enhance the teleoperation of industrial robot manipulators [2]. By overlaying virtual information onto the real-world environment, operators can have a more intuitive and immersive teleoperation experience [2].

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Cloud robotics architectures have also been investigated to enable reliable and efficient teleoperation of robots [3]. These architectures leverage cloud computing to provide robust robot services, even in the presence of communication issues and system errors [3]. Haptic teleoperation systems have been developed to enable users to remotely control mobile robots using force feedback which allow operators to perceive the environment and manipulate objects through the sense of touch [4].

Adjustable autonomy has been explored as a means to improve the teleoperation of personal service robots [5]. By allowing users to adjust the level of autonomy, these systems can adapt to different user preferences and task requirements [5]. Mixed reality has been utilized in robot teleoperation systems, combining elements of virtual reality and augmented reality to provide a more immersive and interactive teleoperation experience [6].

Stability analysis of teleoperation systems is crucial to ensure safe and reliable operation. Researchers have investigated the stability of sampled-data scaled bilateral teleoperation systems, considering the dynamics of both the master and slave robots [7]. Sensor fusion techniques, such as Kalman filtering, have been employed to enhance the human-robot interaction interface in teleoperation systems. By fusing sensor data from different sources, the reliability and accuracy of the interface can be improved [8].

Workspace mapping techniques have been developed to address the challenge of controlling kinematically dissimilar robots in teleoperation systems. These techniques integrate position control and rate control methods to span the workspace of the robots and enable seamless teleoperation [9]. Semi-autonomous robots have also been explored, where robot autonomy and human teleoperation are combined to accomplish complex tasks [10]. This approach leverages the strengths of both human operators and autonomous robots to achieve efficient and effective teleoperation [10].

In summary, the development of web-based teleoperation for service robots has been driven by advancements in communication systems, augmented reality, cloud robotics architectures, haptic technology, adjustable autonomy, mixed reality, stability analysis, sensor fusion, workspace mapping, and the integration of human and autonomous robot capabilities. These research areas have contributed to improving the teleoperation experience, enabling more intuitive control, enhanced perception, and reliable operation of service robots in various applications.

II. LITERATURE REVIEW

MQTT (Message Queuing Telemetry Transport) is a messaging protocol commonly used in the Internet of Things (IoT) domain Ekoramaradhya & Thorpe [11]. It is a lightweight and efficient protocol designed for constrained devices and low-bandwidth networks [12]. MQTT follows a publish-subscribe model, where devices publish messages to topics, and other devices subscribe to those topics to receive the messages [13].

One important aspect of MQTT is its security. MQTT can leverage TLS/SSL protocols to ensure secure communication between devices [12]. However, specific security solutions for MQTT often depend on the project requirements and may vary [12]. There have been efforts to develop security mechanisms for MQTT, such as the Secure-MQTT approach that uses fuzzy logic to detect Denial of Service (DoS) attacks [14].

In addition to security, there have been advancements in the implementation and benchmarking of MQTT protocols. For example, the BORDER framework provides a benchmarking framework for distributed MQTT brokers, enabling the evaluation of their performance and scalability [15]. This is particularly relevant as MQTT-ST, a distribution protocol based on MQTT, allows the creation of a distributed architecture of brokers organized through a spanning tree [15].

Furthermore, MQTT has been integrated with other protocols to enhance its capabilities. The integration of MQTT with OPC UA (Open Platform Communications Unified Architecture) enables the interconnection and intercommunication of industrial equipment and data transmission to the cloud [16]. This integration facilitates the integration of MQTT-based IoT systems with cloud computing technologies.

The use of MQTT extends beyond IoT applications. It has been utilized in real-time messaging services and communication systems [17]. Additionally, MQTT has been explored in the context of multicast communications, where the DM-MQTT protocol, based on Software-Defined Networking (SDN), enables efficient and scalable communication in massive IoT deployments [18].

In summary, MQTT is a lightweight and efficient messaging protocol commonly used in IoT applications. It offers a publish-subscribe model and can ensure secure communication using TLS/SSL protocols. There have been advancements in security mechanisms, implementation frameworks, and integration with other protocols to enhance the capabilities of MQTT in various domains.

III. RESEARCH METHOD

The goal of this study is to create a robot monitoring and service control system for use by restaurant staff. Delivering orders to the customer's remotely operated desk is the responsibility of the service robot. Design Construction Robot Ergonomics and simplicity of operation have been considered in the design of service robots. Robot holding a moving leftover that delivers a visitor's order plate has the appearance of a human worker. The mechanical layout of the service robot is depicted in figure 1 below.

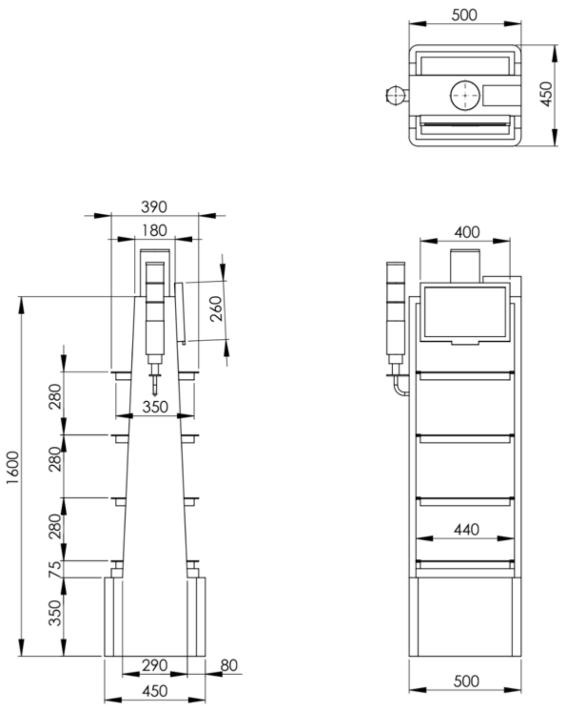

Fig. 1. The mechanical design of the service robot

Sensors and cameras let the VOBOT service robot traverse its environment and avoid obstructions. Additionally, it includes a built-in communication system that enables interaction with both customers and restaurant staff, assuring quick order delivery and happy customers. Drivers are positioned at the bottom of plastic robots and are part of their construction. The robot can navigate across various surfaces with ease and effectiveness thanks to these drives. The body of the robot is made to be both light and strong, enabling it to handle the rigors of a busy restaurant. The robot can identify and avoid any obstructions in its route because to the strategically positioned sensors and cameras that give it a 360-degree picture of its surroundings. The robot can also take orders from restaurant staff and process them via the built-in communication system, guaranteeing that items are delivered to guests accurately and on time. Overall, the VOBOT service robot's mechanical design blends utility and usability to improve productivity and the customer experience in a crowded restaurant setting. The VOBOT can maneuver through busy spaces with ease and without creating any interruptions because to its 360-degree vision. Direct employee order processing reduces the need for human interaction, minimizing mistakes and accelerating the delivery process. The VOBOT service robot is an invaluable tool to the business since it completely transforms how restaurants run.

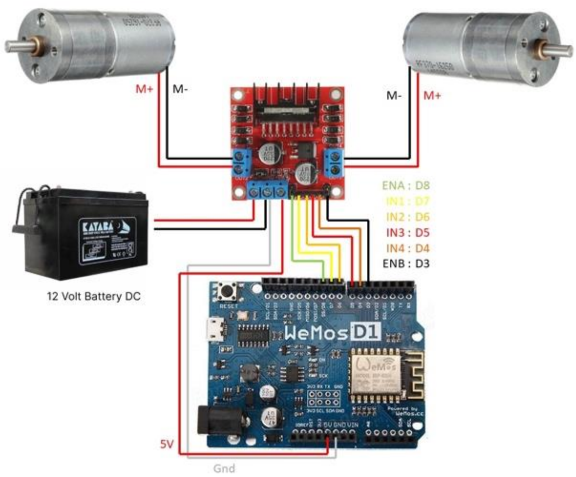

Fig. 2. Block diagram of the drive system

The most crucial job of this component is to move the robot forward, backward, left, and right. A block schematic of the drive system employing a 12-volt dry battery, an L298N motor driver, and a 12-volt DC gearbox motor actuator is shown in Figure 2. The Vobot serving robot's actual mobility across the restaurant is controlled by the drive system. It enables the robot to move swiftly to its intended locations while navigating through tight places and dodging obstacles. The primary power source for the drive system is a 12-volt DC gearbox motor actuator, which supplies the necessary torque and speed to move the robot. The central processing unit (CPU) of the robot sends signals to the L298N motor driver, which serves as the control unit by converting those signals into precise motor motions. The power source, which consists of a 12-volt dry battery, makes sure that the drive system has a steady and constant source of power. In order to avoid damage or overheating, the motor driver also controls the voltage and current that are provided to the motor. The robot's ability to maneuver smoothly and effectively thanks to the gearbox motor actuator, motor driver, and power supply makes it the perfect choice for a variety of applications, including autonomous cars and industrial automation.

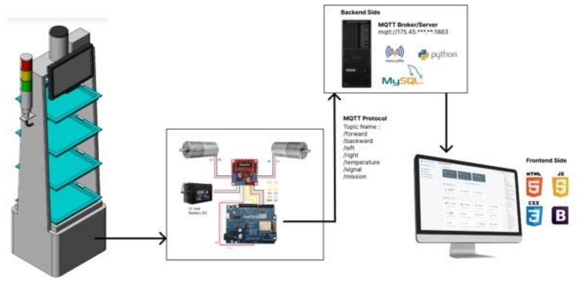

Fig. 3. Block diagram system

Figure 3 depicts the Wemos R1 board-based controller device, which is linked to the Internet through an access point WIFI. The ESP8266 controller drives a DC motor in response to user navigation requests made from the web application. To determine the operating temperature of the robot, the ESP8266 controller also gathers information from temperature sensors. The C++ programming language is used to create the software for the ESP8266.

To make sure that the connection between the service robot and the MQTT broker can function properly, the primary program consists of a communication program with the MQTT broker. The software will then subscribe to the newly established topic on the MQTT broker. The topics listed in the MQTT Broker are as follows:
/forward, /backward, /left, and /right

The aforementioned topics will be subscribed to by Service Robot. As an illustration, the controller ESP8266 will continuously watch the topic /forward and wait for commands from the user to move the wheel ahead.

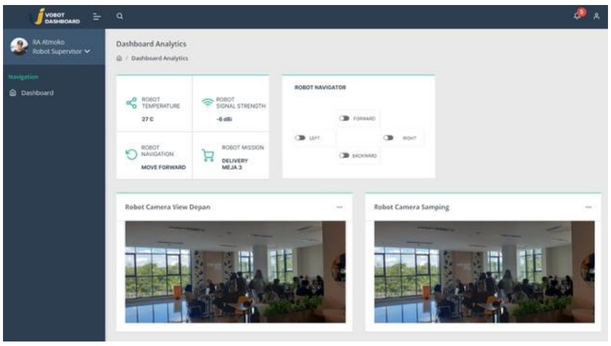

Fig. 4. Vobot Web Dashboard

On the server side, it is important to install software, such as Mosquitto as a MQTT Broker, that takes input data from the service robot and also enables commands to be delivered to the service robot. In this case, the web application dashboard administrator feature in the browser is used to publish the command to the broker's topics while the service robot manages the process of subscribing to topics in the broker in line with the publish subscribe concept of the MQTT protocol. This configuration guarantees smooth communication between the server and the service robot. Through the web application dashboard, the service robot may be controlled and monitored in real-time thanks to the publish-subscribe concept of the MQTT protocol. Both the robotic monitoring system and the robotic navigation control system are put to the test to make sure they are working properly. The monitoring system's ability to collect and show essential data as well as the service robot's ability to move about its environment are being tested. The results of these tests help guarantee the functionality and overall reliability of the service robot. The tests also assess how responsive the control system is to real-world situations like path planning and obstacle avoidance. In order to guarantee the service robot's optimal functioning and effectiveness, the data gathered during these testing aids in identifying any possible areas for development for both the navigation control system and monitoring system. Figure 4 illustrates a web-based dashboard for controlling and monitoring the service robot remotely.

IV. RESULT

In this study, the robot's response time was calculated to see how fast the robot responded to navigation inputs from the web. Here's a table showing the test results.

Table 1. Testing Results

Testing Number	**Response Time (millisecond)**
Testing - 1	1079
Testing – 2	826
Testing – 3	1078
Testing – 4	949
Testing – 5	1049
Testing – 6	820
Testing – 7	843
Testing – 8	942
Testing – 9	996
Testing – 10	874
Testing – 11	892
Testing – 12	1034
Testing – 13	1000
Testing – 14	813
Testing - 15	806
Testing – 16	959
Testing – 17	921
Testing – 18	1082
Testing - 19	873
Testing - 20	971

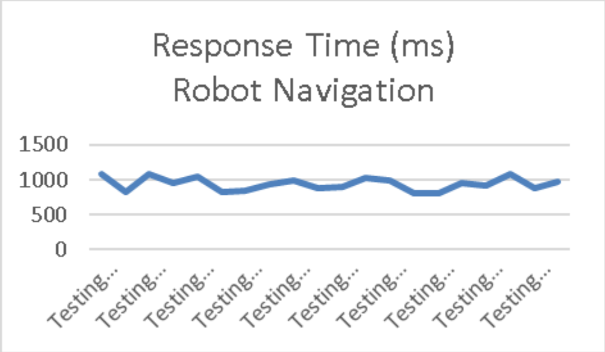

Fig. 5. Response Time Robot

These response times indicate that the robot's navigation system is performing consistently, with an average response time of 940.35 milliseconds.

V. CONCLUSION

According on the information given, the robot navigation system's response times ranged from 806 milliseconds to 1082 milliseconds. The computed average response time was 940.35 milliseconds. This shows that, with sporadic oscillations in reaction time, the robot navigation system typically operates within an acceptable range. It is crucial to remember that more testing and analysis may be needed to decide whether the system needs any upgrades or adjustments. For the majority of users, overall performance is still adequate.

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