PROCEEDING

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Intelligent and sustainability in Manufacturing, Management, Engineering and Environment

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GCMM2024

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About GCMM2024

GCMM2024 is the 18th international conference in manufacturing and management which is venue at Rajamangala University of Technology Krungthep (RMUTK), Bangkok, Thailand. GCMM stands for Global Congress on Manufacturing and Management which is the forum where leading researchers and practitioners comes together and disseminate knowledge and views on advancement in manufacturing, management, engineering, technology, business, environment, and control. Sustainable development goals (SDGs) and growth are more concern in Universities all over the world whereas this year is very special for 72nd anniversary of RMUTK and fortunately GCMM is cyclically back to venue in Bangkok again after 12-year times which was in venue in Bangkok in 2002 and 2012. In addition, the world has been changed in terms of digital transformation, smart manufacturing system and industry 4.0. Therefore, the GCMM 2024 organizes a special event with new popular topics for both presentation and contest among university students and open to industry such as digital twin engineering platform, cyber physical system communication or manufacturing real-time automation.

The conference was previously held every two years in Malaysia (2023,) New Zealand (2022, 2012), the UK (2020), Australia (2018), China (2016), India (2014), and Thailand (2010, 2002), with delegates from over 25 countries globally.This year, GCMM 2024 comes to Bangkok, the capital city of Thailand which is the best city for tourism in Asia Pacific.

GCMM 2024 is organized for academics and scientific community. We facilitate both networking and publishing needs expected from participating in a conference with high quality of article and publishers

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GCMM2024

CONTENTS

TOPICS:
Intelligent and Autonomous Robotics

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Implementation of Mobile Collaborative Robot Using Modbus

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Abstract

This article presents the implementation of a mobile collaborative robot that integrates an autonomous mobile robot (the Youibot P200) and a collaborative robot (the Dobot CR5), using the Modbus protocol for communication. The primary goal is to study and control the collaboration between the Youibot P200 and the Dobot CR5, which work together to support the product delivery process within the Manufacturing Automation and Robotics Academy. An experiment is conducted to evaluate the positioning accuracy of the mobile collaborative robot in various positions and to establish communication between the Youibot P200 and the Dobot CR5. Achieving high accuracy is crucial in this process. The outcome of this study is a mobile collaborative robot configuration that can be deployed to transport objects in both small and industrial settings as needed.

Keywords: *Mobile collaborative robot; autonomous mobile robot; collaborative robot; robotic arm; Modbus protocol*

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1. Introduction

Mobile robots are designed to operate in various environments, requiring them to navigate and manoeuvre around obstacles, as demonstrated by Abu et al. [1]. These robots can be categorized based on their use and functionality. Collaborative mobile robots (CMRs) are gaining popularity due to their combination of a robotic arm's dexterity and the ability to navigate the shop floor, assisting human operators, as highlighted by Ramasubramanian et al. [2].

Robot arms are commonly used in industry for various tasks, including pick-and-place operations, as demonstrated by Tahtawi et al. [3]. Controlling a robotic arm with a Kinect camera to pick up and place objects, as presented by Suphalak et al. [4]. Many brands of robot arms are available today, such as ABB, Dobot, Fanuc, Kinova, Kuka, Neuromeka, Universal Robots, and Yaskawa, as noted by Ojha et al. [5]. Collaborative robots (cobots), a type of robot arm designed to work alongside humans, have become increasingly popular.

A mobile collaborative robot (mobile cobot) is a cobot mounted on a collaborative mobile robot (CMR). A mobile cobot can autonomously navigate between various work areas, seamlessly transition between tasks, and transport materials simultaneously, as described by Dimalog Oy

Ltd. [6]. Research on mobile cobots equipped with multi-camera systems aims to enable self-navigation and understand human voice commands in challenging or small work environments, as presented by Hsu et al. [7]. Additionally, the mobile robot's error correction algorithm helps the cobot avoid collisions with operators in the workspace, as discussed by Cichosz & Gurocak [8].

The article aims to study and control the collaboration between the autonomous mobile robot (the Youibot P200) and the collaborative robot (the Dobot CR5). These two types of robots work together as a Mobile Collaborative Robot using the Modbus protocol. Modbus is one of the most widely used serial communication standards in industrial automation systems, used to establish data links between a Youibot P200 and a Dobot CR5. The Mobile Collaborative Robot, controlled by the Modbus protocol, will be used in the product delivery process at the Manufacturing Automation and Robotics Academy (MARA). MARA, located in Chonburi Province, Thailand [9], is a skills development centre that includes training rooms, laboratories, and a simulated industrial plant. This work focuses on the application of collaborative mobile robots and cobots, which are relatively new technologies increasingly utilized in industries in Thailand. It also serves as a guideline for upgrading SMEs in alignment with the government's 10-point policies.

This article is organized as follows: Section 2 covers autonomous and collaborative mobile robots, Section 3 presents a proposal for a collaborative mobile robot using Modbus, Section 4 details the experimental setup, Section 5 discusses the results and analysis, and Section 6 provides a summary and suggestions for future work.

2. Autonomous Mobile Robot and Collaborative Robot

This section provides details on autonomous mobile robots and collaborative robots. In this research, two types of robots were selected to work together.

2.1 Autonomous Mobile Robot

This section describes the autonomous mobile robot called Youibot P200 and its specifications. Developed by Youibot Robotics Co., Ltd., the Youibot P200 is designed for transportation and logistics automation. Its designation reflects its capacity to transfer weights up to 200 kg.

Table 1. Specifications of the Youibot P200 [10]

Property	Unit	Value
Length	mm	1,020
Width	mm	655
Height	mm	280
Weight	kg	180
Payload	kg	200
Positioning accuracy	mm	±10
Max. speed	m/s	1.5
Lidar detection distance	m	30
Wheel diameter	mm	150
Operation time	hours	15
I/O connectors	-	Ethernet/USB
Wireless		IEEE802.11 ac
Battery	V	48

The specifications of the Youibot P200 are detailed in Table 1, as provided by Youibot Robotics Co., Ltd. [10]. The robot is equipped with safety features, including two safety lidars, two emergency stop buttons, and an anti-collision strip around its base. Fig. 1 shows a photograph of the Youibot P200.

Fig. 1. Autonomous mobile robot Youibot P200

2.2 Collaborative Robot

A cobot, short for collaborative robot, refers to robots designed to work alongside humans to perform various tasks. Typically, cobots adhere to a standard 6 degrees of freedom (DOF) design, as presented by Ojha et al. [5]. The Dobot CR5, a product of Dobot Robotics, is designed to operate in close proximity to humans without requiring separate spaces or work zones. Table 2 provides basic information about the Dobot CR5, including its weight, payload, working radius, maximum reach, rated voltage, repeatability, and communication. Fig. 2 shows its dimensions, as presented by Dobot Robotics [11].

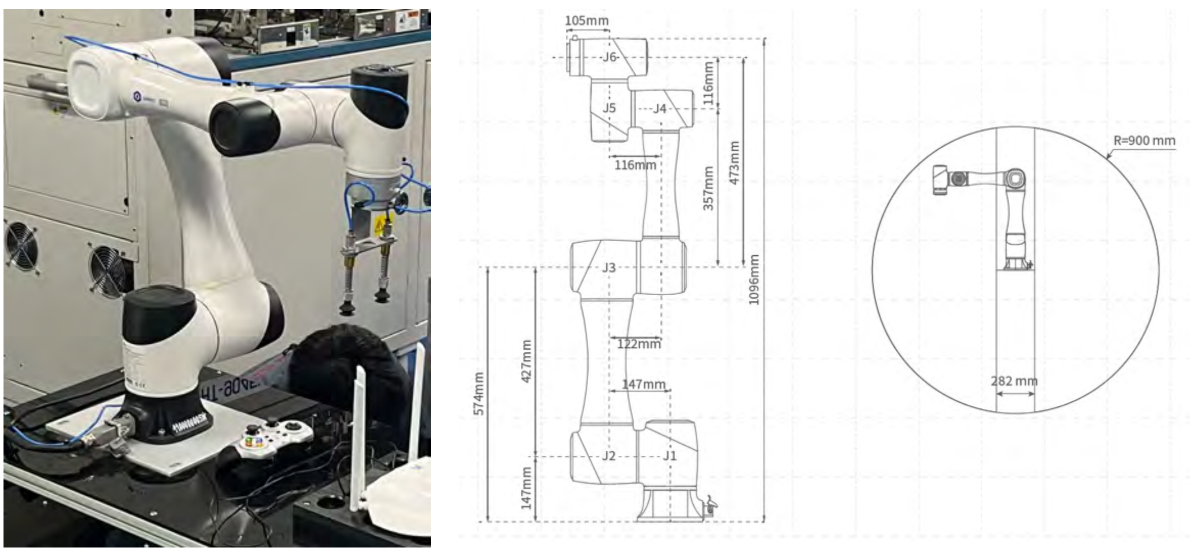

Fig. 2. Dimensions of Dobot CR5 [11].

Table 2. Specifications of a Dobot CR5 [11]

Property	Unit	Value
Weight	kg	25
Payload	kg	5
Working radius	mm	900
Max. reach	mm	1096
Rated voltage	V	48
Repeatability	mm	±0.02
Communication	-	TCP/IP, Modbus, Wireless

3. Proposed of the Mobile Collaborative Robot Using Modbus

This topic introduces mobile collaborative robot using Modbus, organized into three sections: mobile collaborative robots, configuration and settings, and mobile collaborative robots using Modbus. The details are as follows.

3.1 Mobile Collaborative Robot

A mobile collaborative robot is proposed that integrates an autonomous mobile robot (the Youibot P200) and a collaborative robot (the Dobot CR5), using the Modbus protocol for communication, as shown in Fig 3. The Modbus communication system consists of the Youibot P200, Dobot CR5, MOXA switch, and TP-Link WiFi router, all connected via LAN cables. The power supply is a crucial component of this mobile collaborative robot, requiring a voltage of 48V. The Youibot P200 battery serves as the main power source for the Dobot CR5.

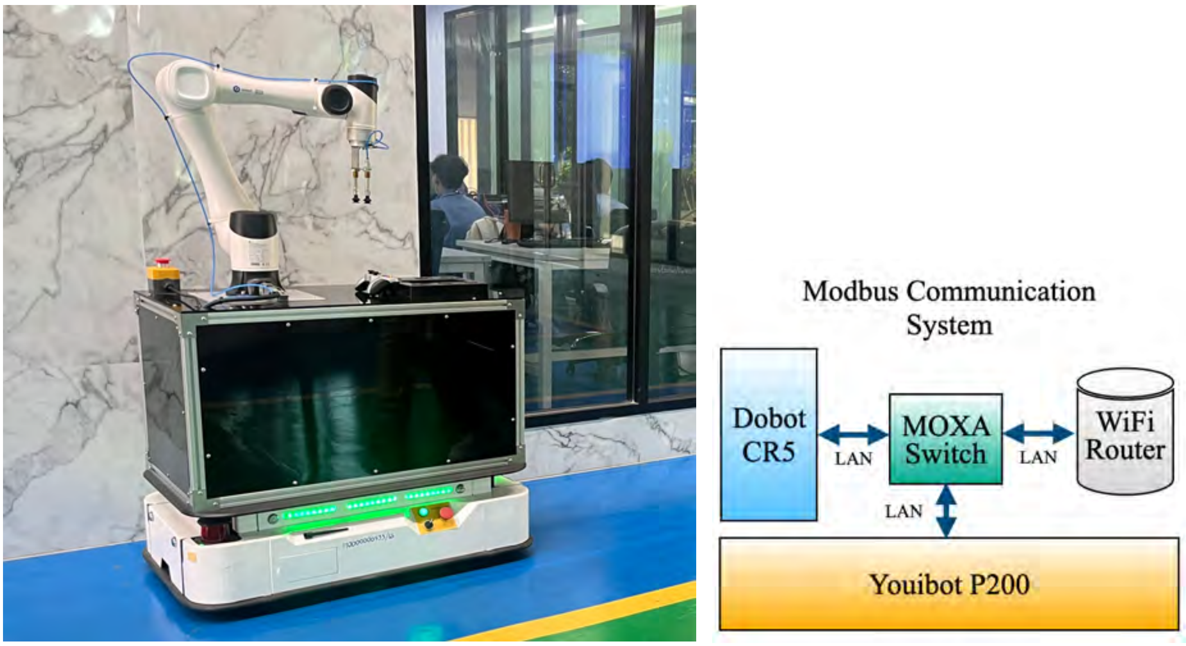

Fig. 3. Mobile collaborative robot and Modbus communication system

3.2 Configuration and Setting

All settings and configurations of the mobile collaborative robot are divided into two parts: the Youibot P200 is operated via YOUICompass, which serves as the web interface, while Dobot Studio Pro is used to configure and set up the Dobot CR5. The details are as follows.

YOUICompass is the web interface of the Youibot P200 as shown in Fig. 4. Setting the map and position for the Youibot P200's movement is divided into five steps: 1) Move the robot around the working area using the joystick. 2) Repeat step 1 until a clear map is obtained from the lidar sensor. 3) Set the robot's moving position. 4) Drag the path to define the robot's moving direction. 5) Record the settings.

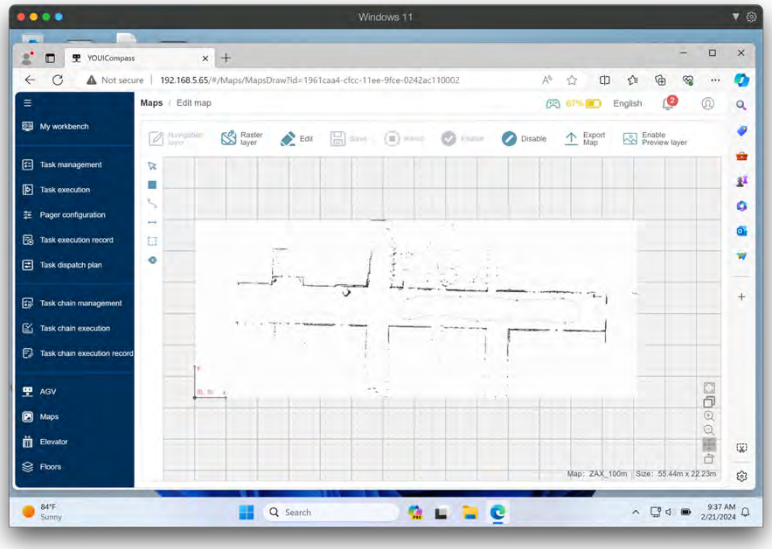

Fig. 4. YOUICompass settings for Youibot P200

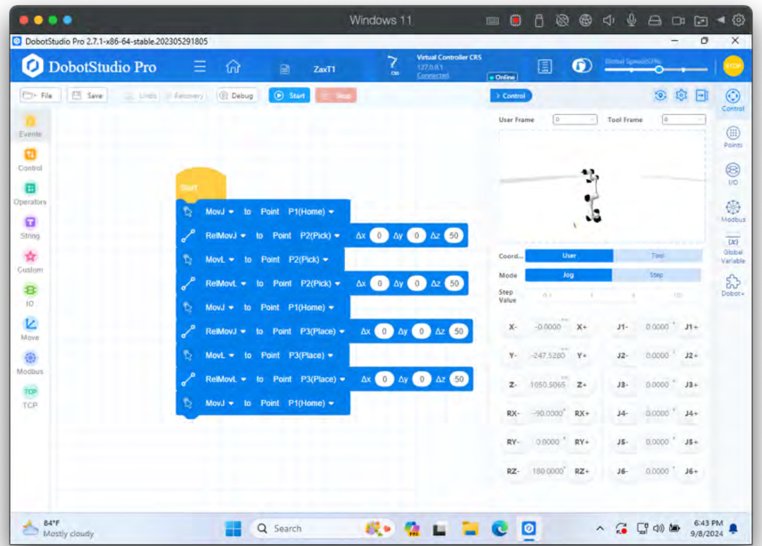

Fig. 5. Dobot Studio Pro configurations for Dobot CR5

Dobot Studio Pro is used for configuration and setup with block-based programming for Dobot CR5 as shown in Figure 5. Setting up the pick-and-place position for the Dobot CR5 cobot involves the following five steps: 1) Define the home point, which is the starting position of the cobot. 2) Move the cobot to the position where the object will be picked up, either using the pendant or manually. 3) Save the position and update the Cartesian coordinates for accuracy. 4) Move the cobot to the position where the object will be placed, either using the pendant or manually. 5) Save the position and update the Cartesian coordinates for accuracy.

3.3 Mobile Collaborative Robot Using Modbus

In this research, Modbus Transmission Control Protocol (Modbus TCP) was selected for use as the Ethernet-based protocol on port 502 because it can transmit data at a maximum speed of 100 Mbps over a distance of 100 meters. The mobile collaborative robot is deployed using the Modbus TCP protocol, integrating the Youibot P200 and Dobot CR5. Modbus communication operates in two modes: transmitting and receiving data. In transmission mode, the mobile robot sends data to the cobot by setting the read/write register through the task management function of the Youibot P200 via YOUICompass, as shown in Fig. 6. Key details such as connection type, IP address, port, function code, slave ID, and start address are specified.

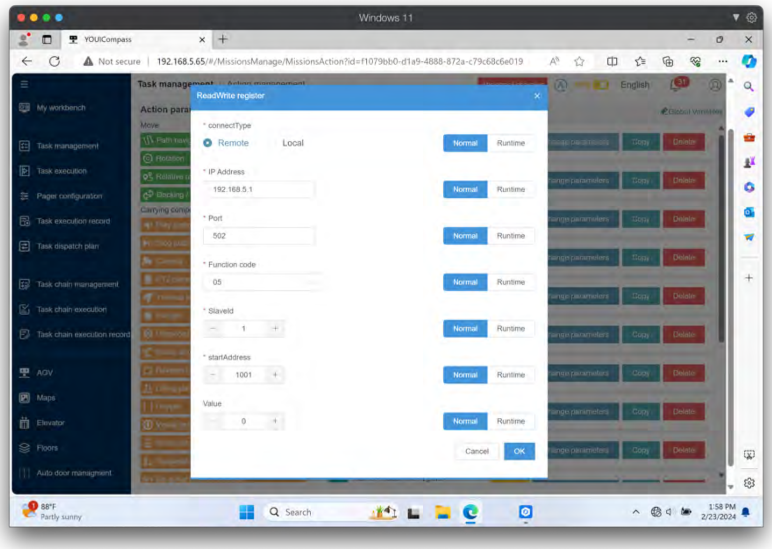

Fig. 6. Modbus TCP transmission data mode

In receiving mode, data is transmitted from the cobot to the mobile robot. The cobot operates using an algorithm written in Lua, as shown in Fig. 7. This algorithm is divided into two parts: the first part establishes Modbus TCP communication (ModbusCreate) and checks the Modbus status (GetCoils), while the second part involves a loop operation that waits for the Modbus signal, commands the robotic arm to pick up and place objects, and sends signals through Modbus (SetCoils). On the mobile robot, this is achieved by setting the check register through the task management function of the Youibot P200 via YOUICompass, as shown in Fig. 8. The specified details must be consistent with those in the data transmission mode.

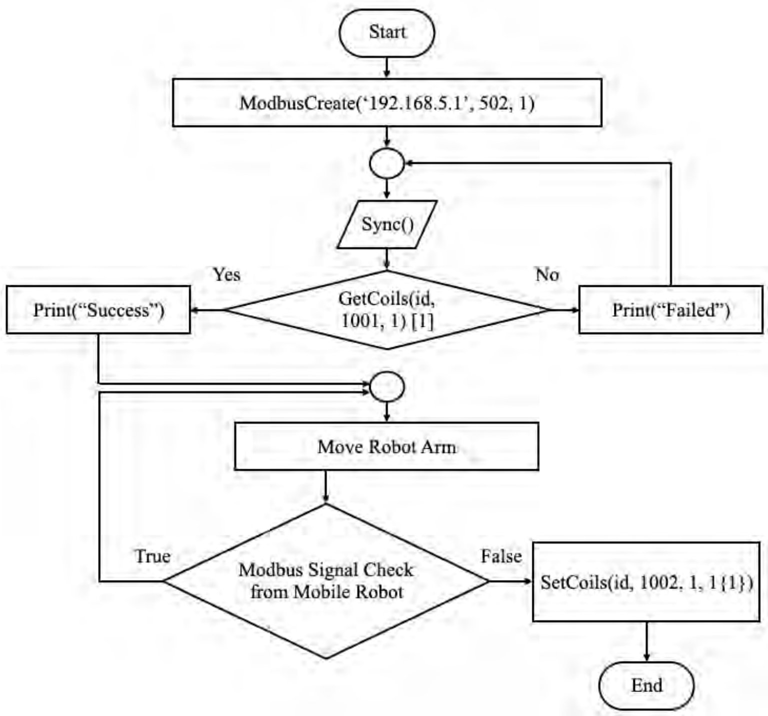

Fig. 7. Modbus TCP algorithm for cobot

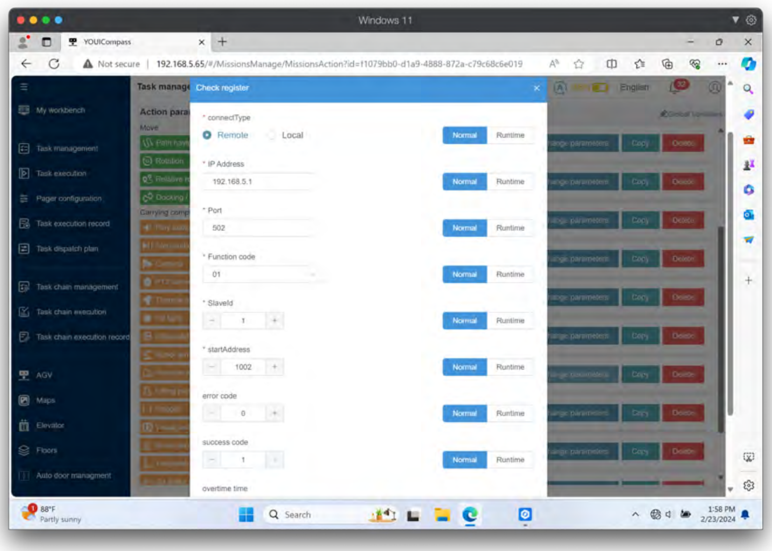

Fig. 8. Modbus TCP receiving data mode

4. Experimental Setup

The mobile collaborative robot, controlled by the Modbus protocol, will be used in the product delivery process at the Manufacturing Automation and Robotics Academy (MARA) in Chonburi Province, Thailand. As shown in Fig. 9, MARA is a skills development centre that include training, testing, and supporting target groups such as employees, maintenance technicians, system integrators, supervisors, and trainers.

Fig. 9. Manufacturing Automation and Robotics Academy (MARA)

The experimental setup is as follows: starting with a simulation of automated production and warehouse storage, the process is divided into seven stations. Station 1 produces and forms the products, Station 2 washes them with air, Station 3 inspects the products with a camera, Station 4 sorts and stores the products, Station 5 moves the products using an automatic robotic arm, Station 6 stores them in the warehouse shelving, and Station 7 retrieves the products from the shelves. These stations are then matched to seven locations on the map. Each location is 3 meters apart, except for locations 1 and 7, which are 4 meters apart. Location 1 is designated for picking up and placing products, as shown in Fig. 10. The product used is a wooden box measuring 13 x 20 x 4 cm.

Fig. 10. Experimental setup with simulation of automated production and warehouse storage

The experiment begins with the robot moving to location 1 to pick up a square wooden box, then proceeding through the specified locations in order, and finally returning to location 1 to place the box. The experiment is repeated to record the results. The recorded results are divided into three categories: obstacle avoidance, the smoothness of the robot's movement between locations, and the process of picking up and placing the square wooden box. Fig. 11 shows the obstacles, including (a) a mobile robot obstacle, (b) a glass door barrier, and (c) a human obstacle.

(a) Mobile collaborative robot obstacle　　(b) Glass door barrier　　(c) Human obstacle

Fig. 11. Obstacle avoidance

5. Results and Discussion

Several experiments were conducted to determine the efficiency and accuracy of a mobile collaborative robot using Modbus based on simulations of automated production and warehouse storage. The experimental results are shown in Table 3 - 5, which are divided into three categories: obstacle avoidance, smoothness of robot movement between locations, and the process of picking and placing square wooden boxes.

Table 3. Obstacle avoidance results

Obstacles	Description	Percentage of success
Mobile collaborative robot	Mobile collaborative robots can move in opposite directions without colliding with each other.	100
Glass door barrier	The mobile collaborative robot can move around open glass doors.	100
Human	Mobile collaborative robot can move around and avoid standing still humans.	100

Table 3 presents the obstacle avoidance performance of the collaborative mobile robot, showing that 100% of obstacles were successfully avoided.

Table 4. Experimental results on the smoothness of robot movement between locations

Locations	Description	Percentage of success
1	The mobile collaborative robot can move smoothly from its starting location.	100
2	Mobile collaborative robot can move from its starting location to its second location, changing direction on average 2-3 times.	100
3	A mobile collaborative robot can move from location 2 to location 3 in an arc, changing direction an average of 1-2 times.	100
4	The mobile collaborative robot can move from location 3 to location 4 with reduced speed and change direction on average 4-5 times as it approaches the wall.	100
5	The mobile collaborative robot can move from position 4 to position 5 with smooth increasing speed.	100
6	Mobile collaborative robot can move from location 5 to location 6 with reduced speed, changing direction on average 4-5 times while approaching the wall.	100
7	The mobile collaborative robot can move from location 6 to location 7 in an arc, changing direction on average 1-2 times.	100
1	The mobile collaborative robot can move from location 7 to its final location by changing direction on average 2-3 times, along with deceleration when parking.	100

Table 4 presents the movement results of the collaborative mobile robot, demonstrating a 100% success rate in reaching different locations. It was also observed that the robot's movement near walls caused a greater change in direction compared to when it moved away from walls.

Table 5. Result of picking and placing square wooden boxes

	Picking	Placing
Percentage of success	100	100

Table 5 presents the results of the pick-and-place operations with square wooden boxes, achieving 100% success. This demonstrates the efficiency and accuracy of controlling the collaborative mobile robot using Modbus commands.

6. Conclusions and Future Work

This article presents a study on the implementation of a mobile collaborative robot using the Modbus protocol, focusing on its application in an automated production and warehouse setting at the Manufacturing Automation and Robotics Academy (MARA). The study specifically examined the performance of the Youibot P200 autonomous mobile robot and the Dobot CR5 collaborative robot.

The integration of the Youibot P200 autonomous mobile robot and the Dobot CR5 collaborative robot using the Modbus protocol demonstrated a high level of effectiveness. The protocol facilitated smooth communication between the two robots, enabling efficient collaborative operation.

The mobile collaborative robot exhibited excellent obstacle avoidance capabilities, successfully navigating around various obstacles such as other robots, glass doors, and humans. The robot achieved a 100% success rate in avoiding collisions, underscoring its reliability and safety in complex environments. The robot's movement between locations was precise and smooth, with a 100% success rate. It effectively managed direction changes and speed adjustments, particularly in challenging conditions such as proximity to walls. This highlights the robot's advanced mobility and control. Also, the robot demonstrated high efficiency in pick-and-place tasks, achieving a 100% success rate in handling and placing wooden boxes. This indicates the robot's accuracy and reliability in performing essential automated tasks.

In summary, the study validates the effectiveness of using the Modbus protocol for coordinating mobile collaborative robots, showcasing their potential to significantly enhance automated production and warehouse operations. Future work could explore further optimization of communication protocols, integration with additional sensors, and application in diverse industrial contexts. Additionally, the following topics could be explored for future research.

- Explore enhancements to the Modbus protocol or alternative communication standards to improve data exchange efficiency and reliability.
- Incorporate sensors like vision systems or advanced lidar to enhance navigation, object detection, and obstacle avoidance.
- Test the robot system in various industrial environments to assess its versatility and effectiveness in different contexts.
- Improve control algorithms to enhance decision-making, movement precision, and task execution.

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