IOT-BASED MOBILE MANIPULATOR PROTOTYPE USING ESP 32 AND ESP 8266

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Abstract

This research focuses on the design and implementation of an Arduino-based mobile robot equipped with an ESP32 camera. The primary goal is to develop a mobile manipulator prototype that can be controlled remotely via a mobile or web application. This project also aims to identify the required electronic components, understand their integration with the ESP32 module, and evaluate the ESP32's advantages over the Arduino Uno. The method used is a development research approach, involving literature review on robotics, Arduino programming, and image processing with the ESP32-CAM and ESP8266. The research stages include system design, component selection, mechanical design, and electronic circuit design. Programming code development is carried out iteratively, starting with basic functions such as motor movement and image capture, to more complex functions such as simple object recognition. Testing of the mobile manipulator prototype demonstrates that the hardware and software developed are functional. The robot is capable of motion control, image transmission from the ESP32-CAM to a smartphone, and the ESP8266 can transport light objects. However, there are several challenges, such as overheating of the ESP32-CAM and ESP8266 modules, as well as potential malfunctions in the SG90 servo motor and DC gearbox motor.

Keywords: Mobile Manipulator, IoT (Internet of Things), ESP8266, ESP32-CAM, Arduino

INTRODUCTION

The development of the Internet of Things (IoT) has enabled various physical devices to be connected to the internet, allowing real-time monitoring, data exchange, and remote control. IoT technology has been widely applied in many fields, including smart homes, healthcare, industrial automation, and robotics. In robotics, IoT plays an important role in enabling remote operation, real-time data transmission, and intelligent decision-making, particularly for mobile robotic systems (Hakim et al., 2023). A robot is defined as a mechanical system capable of performing tasks automatically or semi-automatically, either through human control or programmed instructions. One type of robot that has gained significant attention is the mobile robot, which is designed to move from one location to another using wheeled locomotion systems (Hsieh & Lee, 2018). Mobile robots are commonly used in applications such as exploration, surveillance, material handling, and educational research. A mobile manipulator combines the mobility of a mobile robot with the functionality of a robotic arm, allowing it to perform manipulation tasks while moving within its environment. This combination enhances flexibility and efficiency, especially in environments that require object handling and transportation (Siciliano et al., 2009). Recent studies have shown that mobile manipulators are increasingly used in industrial and service applications due to their adaptability and extended workspace (Khalili et al., 2024).

With the advancement of microcontroller technology, low-cost and powerful devices such as ESP32 and ESP8266 have become popular choices for IoT-based robotic systems. The ESP32 offers integrated Wi-Fi, Bluetooth, and sufficient processing power to support image transmission and control applications, while the ESP8266 is widely used for wireless communication in IoT systems (Ali & Rahman, 2021). The integration of these modules enables efficient communication between hardware components and user interfaces such as smartphones or web-based applications. Based on these considerations, this research focuses on the design and implementation of an IoT-based mobile manipulator prototype using ESP32 and ESP8266. The proposed system aims to enable remote control, real-time image transmission, and basic object manipulation. This prototype is expected to serve as a practical reference for the development of IoT-based robotic systems, particularly in educational and experimental contexts.

METHOD

This study employs a development research approach, which emphasizes the design, construction, and testing of a functional prototype. Development research is commonly used in engineering studies to validate system performance through iterative design and evaluation processes (Gupta et al., 2020). The research stages include literature review, system design, hardware assembly, software development, and system testing. The literature review was conducted to understand the fundamental concepts of mobile robots, robotic manipulators, and IoT-based control systems (Siciliano et al., 2009). System design involved selecting electronic components, designing mechanical structures, and developing electronic circuit schematics. Software development was carried out using the Arduino IDE to program the ESP32-CAM and ESP8266 modules. The programming process was implemented incrementally, starting from basic motor control and camera initialization to more advanced functions such as image transmission and remote operation via a smartphone interface (Smith & Johnson, 2022). System testing was conducted to evaluate motion control, image transmission quality, and object manipulation performance under various operating conditions.

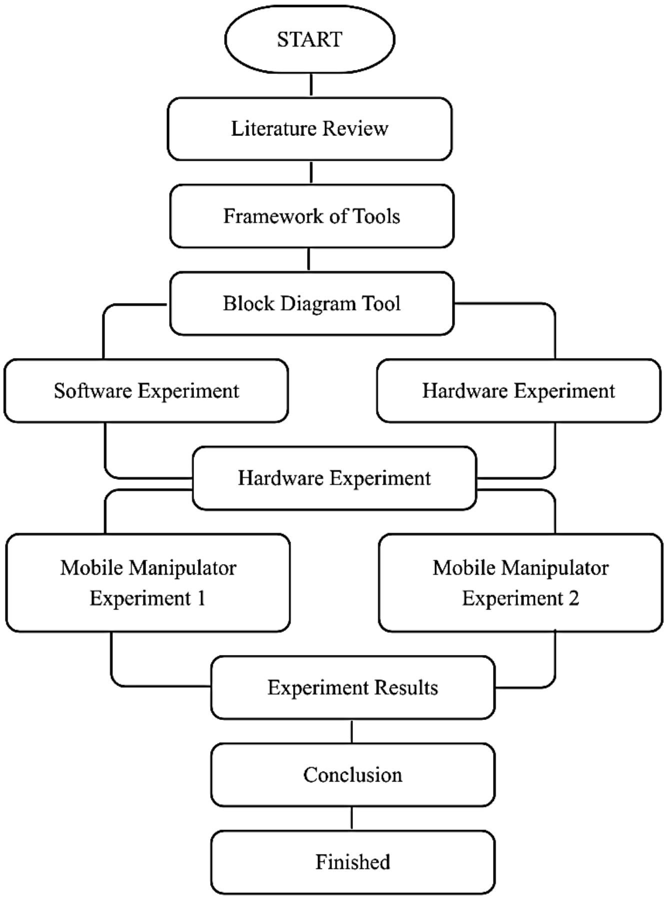

Image 1. Research Flow Diagram

RESULTS AND DISCUSSION

Result

In designing the application of a mobile manipulator prototype, first design the following block diagram:

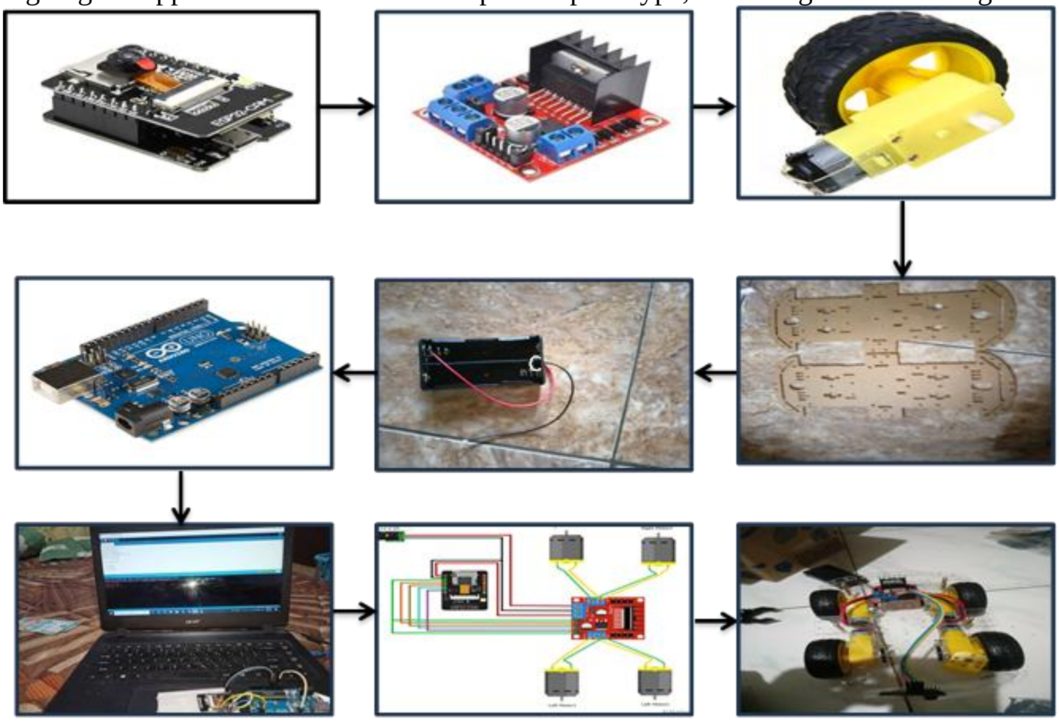

Image 2. Block Diagram of a Mobile Manipulator Tool (1)

Description:

1. ESP 32-Cam
2. Dual Driver Board L298N MP
3. DC motor
4. 4WD Speed Chassis Kits
5. 2-slot battery holder case
6. Arduino Uno R3
7. Laptop and Arduino IDE
8. Installation circuit diagram
9. Finished mobile manipulator robot (1)

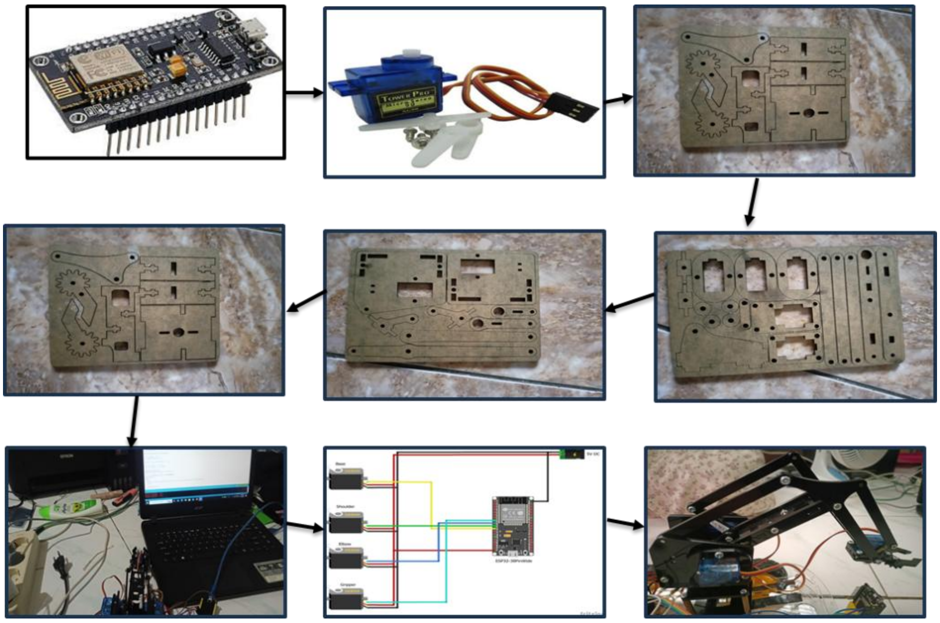

Image 3. Block Diagram of a Mobile Manipulator Tool (2)

Description:
1. NodeMcu ESP 8266
2. SG90 Servo Motor
3. 3-6 Arm Chassis Kits 4 DOF
4. Laptop and Arduino IDE
5. Installation diagram
6. Finished mobile manipulator robot (2)

Discussion

After combining the hardware and software, the device can be tested as follows:

Table 1. Mobile Manipulator Measurements

No	Distance (cm)	IOT Camera	Motor	Description
1	20	√	√	Can lift isolated loads and move smoothly.
2	40	√	√	Can lift isolated loads, but movement stops briefly.
3	60	√	√	Can lift isolated loads, but movement moves forward and backward and stops briefly.

Table 2. Battery Voltage Measurement on Mobile Manipulator (1)

No	Distance (cm)	Camera	Motor (V)		Gripper Motor	
			Move	Stop	On	Off
1	20	ON	10.48	10.76	1	0
2	40	ON	8.82	10.76	1	0
3	60	ON	8.34	10.76	1	0

Analysis:
1. During the first experiment, the mobile moved without any obstacles because the wheels with the drive simulator functioned properly at a distance of 20 cm.
2. During the second experiment, the mobile moved but with a little resistance because the left wheel did not move, so the mobile moved back and forth several times until it reached a distance of 40 cm.
3. During the third experiment, the mobile moved but with significant resistance, starting with the rear wheel malfunctioning, as well as a 3-second delay in the Wi-Fi connection with the simulator, causing the mobile to move erratically before reaching the target line after a few seconds.

Table 3. Battery Voltage Measurement on the Mobile Manipulator (2)

No	Distance (cm)	Camera	Motor (V)		Gripper Motor	
			Move	Stop	On	Off
1	20	ON	10.48	10.76	1	0
2	40	ON	8.82	10.76	1	0
3	60	ON	8.34	10.76	1	0

Analysis:
1. In the first experiment, Mobile carried the insulation load but was thrown off while moving, resulting in a stopping voltage of 10.76 V and a moving voltage of 8.70 V, but the clamp motor did not function.
2. In the second experiment, the mobile successfully carried the insulated load, but the voltage decreased to 10.76 V when stationary and 8.30 V when moving, with the clamp motor functioning.
3. In the third experiment, the mobile successfully carried the insulated load, but after reaching the target line, the load was thrown off and the mobile moved erratically.

CONCLUSION

This study confirms that TPACK-based learning management through the POAC (planning, organizing, implementing, and monitoring) function plays a strategic role in improving the quality of learning and student achievement in elementary schools. Planning based on student needs analysis, clear organization through role distribution and the use of ICT facilities, creative and dialogical implementation, and reflective supervision form an effective management cycle. This pattern not only ensures that learning is more adaptive to the demands of the digital age, but also contributes to improving teachers' pedagogical skills, student engagement, and the creation of a collaborative school culture. Based on the results of testing conducted on the “IoT-Based Mobile Manipulator Prototype Using ESP 32 and ESP 8266,” it can be concluded that:

1. The hardware for the “IoT-based Mobile Manipulator Prototype Using ESP 32 and ESP 8266” device was successfully created with an ESP 32 microcontroller supported by its built-in software and combined with several mutually supportive circuits. The supporting circuits for this device are a power supply in the form of a battery, a Dual Driver Board L298N MP, a DC Gearbox Motor, an Arduino Uno R3, an SG90 Servo Motor, a NodeMCU ESP 8266, and a smartphone.
2. The software for the “IoT-Based Mobile Manipulator Prototype Using Esp 32 and ESP 8266” was successfully created because the Esp 32 Cam is capable of displaying images along with lighting and a motor driver as a drive connected to the circuit on the ESP 32 cam.
3. The overall performance of the “IoT-Based Mobile Manipulator Prototype Using ESP 32 and ESP 8266” device functions well. The parameters used to determine the success rate of this device are:
   a. This device is capable of performing maneuvers (motion control) between the ESP 32 Cam and Motor Driver to a smartphone device (Drive Simulator).
   b. This device is capable of transmitting images captured by the ESP 32 Cam module via images or displays on a smartphone screen.
   c. This device is capable of transporting light objects such as insulation that can be carried or moved as desired.The conclusion explains what is expected in the Introduction section, as well as conclusions from the Results and Discussion section. Conclusions can also be added to the development plan for the implementation of the future service.

REFERENCES

Amoozad Khalili, A., Fouladi, R., Hogan, F. R., & Namvar, M. (2024). Technical report of mobile manipulator robot for industrial environments. arXiv:2409.06693.

Hakim, L., Fitria, G., & Sulistyo, A. (2023). A survey on Internet of Things (IoT) and wireless sensor networks. Journal of Robotics and Control.

J. Smith, & L. Johnson. (2022). "Real-Time Video Streaming from ESP32- CAM for Mobile Robotics." Journal of Robotics and Control, 3(1), 45-52.

Khalili, E. A., Ghasemzadeh, K., Gohari, H., Jafari, M., Jamshidi, M., Khaksar, M., AkramiFard, A., Hatamzadeh, M., Sadeghi, S., & Moaiyeri, M. H. (2024). Technical Report of Mobile Manipulator Robot for Industrial Environments. *ArXiv Preprint ArXiv:2409.06693*. https://doi.org/10.48550/arXiv.2409.06693

M. A. Hsieh, & C. H. Lee. (2018). Introduction to Robotics: Mechanics and Control. Upper Saddle River: Pearson.

M. A. M. Ali, & A. A. A. Rahman. (2021). ESP32 Programming for the Internet of Things: A Beginner's Guide. New York: Packt Publishing.

Maulana, Y. A., Nandika, R., Iksan, M. Z., & others. (2023). Goods movement robot prototype design with wheel arm system. International Journal of Robotics and Automation Systems, Lamintang Academic Publisher.

Rama, A. (2021). ANALISIS KECEPATAN MOBILE ROBOT SEARCH AND ... [PDF]. Diakses dari https://repository.unsri.ac.id/112191/2/RAMA_21201_0305128 1924058_0025127104_01_front_ref.pdf

Rama, A. (2021). DESAIN SISTEM PENGGERAK WEBCAM PADA MOBILE ROBOT ... [PDF]. Diakses dari https://repository.unsri.ac.id/130586/3/RAMA_21201_0305118 1924017_0025127104_01_front_ref.pdf

Revadiaz, M. R., Fatkhurrokhman, A., & Aribowo, A. W. (2022). Prototype automated manipulator robot menggunakan mikrokontroler NodeMCU ESP8266 berbasis Internet of Things (IoT). (ResearchGate publication).

Rofi'i, M., Supriyono, M., Kurniawan, A., & Yuliyanti, L. (2025). Development of robotics learning modules based on IoT and ESP32. Politeknik Negeri Jember Publications.

Sarkar, T., Das, S., & Jain, R. (2025). Development of CoAP protocol for communication in mobile robotic systems using IoT technique. Scientific Reports.

Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G. (2009). *Robotics: modelling, planning and control*. Springer.

S. K. Gupta, R. K. Gupta, & A. K. Sharma. (2020). Robotics: Fundamentals and Applications. New Delhi: Wiley India Pvt. Ltd.

Waveshare. (2021). Kit AI ROS Versi Profesional JetBot, Robot AI Pengendali ... Diakses dari https://id.aliexpress.com/item/1005004607984385.html.