DEVELOPMENT OF MAGNETIC CRAWLER CONTROLLED REMOTELY USING ANDROID FOR HULL INSPECTION

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ABSTRACT

This abstract introduces the development of a magnetic crawler designed for hull inspection, controlled remotely via an Android interface. The crawler's magnetic wheels provide a versatile method for negotiating difficult surfaces of the ship hull. By using this technology, operators may easily and precisely control the crawler remotely by using the ubiquity and user-friendliness of Android devices to perform the hull inspection. The system incorporates superior magnetic technology to maintain consistent adhesion to ferromagnetic surfaces, allowing for complete inspection even in harsh maritime situations. This innovation improves hull inspection operations, increasing productivity and safety while lowering operational expenses. Furthermore, the Android interface enables real-time feedback and data visualization, allowing operators to make more educated decisions during inspections. Overall, the development of this magnetic crawler represents an important advancement in maritime inspection technology, with increased capabilities and improved workflow in hull repair and safety assurance.

Keywords: *Android application; Hull inspection; Internet of Things (IoT); Magnetic crawler*

1. INTRODUCTION

The shipping industry has been pivotal in global transportation for centuries, utilizing vessels such as container ships for cargo and liquefied petroleum gas (LPG) vessels for gas transport. Regular ship inspections are crucial for safety, environmental protection, and operational efficiency, typically conducted every 12 months or following significant changes, as mandated by the UK's Maritime and Coastguard Agency. Related to this statement, traditional inspection methods have challenges and risks to perform by the inspectors due to the large size of vessels and harsh maritime conditions. As referred to as the Industrial Revolution 4.0, the study explores the development of a magnetic crawler remotely controlled by Android system hull inspections [1][2]. This innovative device adheres to a ship's steel hull using magnetic forces, allowing it to navigate and perform inspections even in difficult orientations using principles of robotics, magnetism, and IoT, the magnetic crawler adheres to ferromagnetic surfaces like a ship's steel hull through magnetic forces, enabling it to navigate various orientations for inspection purposes [3][4]. Equipped with sensors and instruments such as ultrasonic probes, cameras, and cleaning tools, the crawler can perform various inspections, including crack detection, thickness measurement, and confined space inspections. This development represents a significant breakthrough in electrical and electronics engineering, integrating specialized fields like robotics, wireless communication, and Android programming [5][6]. Furthermore, this technological advancement enhances inspection efficiency and significantly increases accuracy and safety, representing a milestone in the maritime industry.

The development of a magnetic crawler controlled by an Android application intended to facilitate process hull inspection. This crawler will be a remotely operated android system that will travel around the ferromagnetic surfaces of the ship hull to perform its inspection work such as detecting cracks, thickness measurement, cleaning, and so on [7]. It will be able to crawl on ferromagnetic surfaces of the ship hull during docking in the yard [8][9]. This crawler will remotely be controlled by an Android application that will serve as the robot's control terminal, which enables remote movement of the crawler movement either forward or backward, and left or right movement [10[11][12]. This robot also will show the real-time timeline of the crawler's battery percentage when performing the work. Finally, this Android remote control will also show the crawler's speed during the inspection. While this project has a broad scope, several limitations need to be considered in the implementation of this project. Firstly, the crawler's operation is limited only to the ferromagnetic surfaces so, this crawler cannot perform on surfaces made of non-magnetic materials such as wood, fibre, and so on. Secondly, the crawler's operation is limited to the ship under the docking on the shipyard only and does not operate in the underwater section because of limitations from Wi-Fi communication. For this project, three main objectives need to be followed, the first is to identify the methodology of a magnetic crawler using a permanent magnet and the Internet of Things (IoT) for ship hull inspection [13][14]. Second, to design a magnetic crawler using a permanent magnet and the Internet of Things (IoT) for ship hull scanning and inspection. Lastly, is to test the performance of the crawler and the ability to inspect the ship hull.

2. SCOPE OF PROJECT

The development of a magnetic crawler controlled by an Android application intended to facilitate process hull inspection. This crawler is a controlled remotely operated android system that travels around the ship hull's ferromagnetic surfaces to perform inspection work such as detecting cracks, thickness measurement, cleaning, and so on. It can crawl on ferromagnetic surfaces of the ship hull during docking in the yard. This crawler can be remotely controlled by an Android application and serves as the robot's control terminal, which enables remote movement of the crawler movement either forward or backward and left or right movement. This robot also can show the real-time timeline of the battery percentage of the crawler when performing the job. Finally, this Android remote control can also show the speed of the crawler during the inspection. While this project has a broad scope, several limitations need to be considered in the implementation of this project. Firstly, the crawler's operation is limited only to ferromagnetic surfaces, so this crawler cannot perform on surfaces made of non-magnetic materials such as wood, fiber, and so on. Secondly, the crawler's operation is limited to the ship under the docking on the shipyard only and does not operate in the underwater section because of limitations from Wi-Fi communication in about 0.3 meters underwater. Another thing is the availability of a WLAN connection is required for the Android application to function. This means that locations without a WLAN connection are inaccessible to the crawler's operation. This limitation can be improved in future studies.

3. METHODOLOGY

3.1 Operational Project Flowchart

Figure 1 shows the overall operation of the system of this project, the Development of a Magnetic Crawler Remotely Controlled Remotely by Android for Hull Inspection.

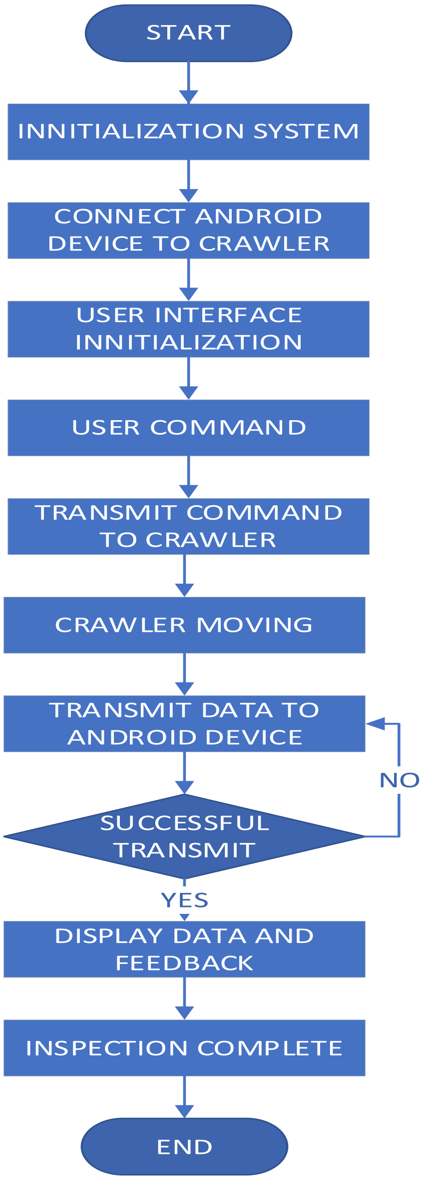


Figure 1: Operational Project Flowchart

3.2 Block Diagram

This block diagram as shown in Figure 2 starts with the Input section which includes the electronics components like the sensor and remote control, then the signal from the remote control or sensor transmits to the Processor section which includes the ESP 8266 and ESP 32CAM as a processor of this project. The ESP 32 CAM processes and transmits the data to the Output section which includes the electric components that produce output signals such as Motor 12 V to move the crawler forward, reverse, turn right, and turn left. Another thing, the ESP 8266 also processes and transmits the data to the Database section in the Firebase system that includes the Application to look at the performance of the crawler such as speed, battery level, and so on.

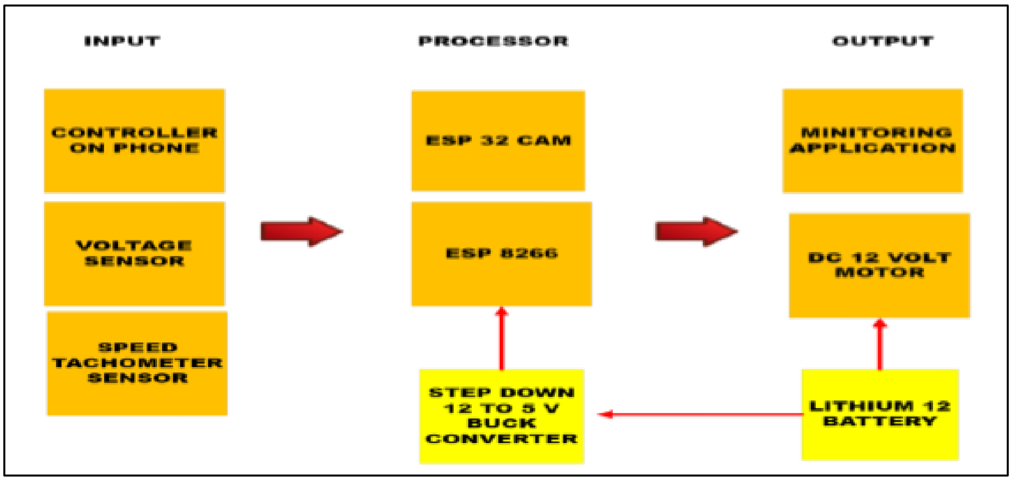


Figure 2: Project's Block Diagram

3.3 Project Design

The prototype design shows the actual design of the project to be created. This prototype design shows the actual measurement dimension, project design structure, and position of electronic components in the project. This prototype is designed according to the size and structure that is suitable for consumer use based on research conducted on existing products. These drawings are drawn by the SketchUp application that allowed these drawings to be seen in a 3-dimensional view as shown in Figure 3.

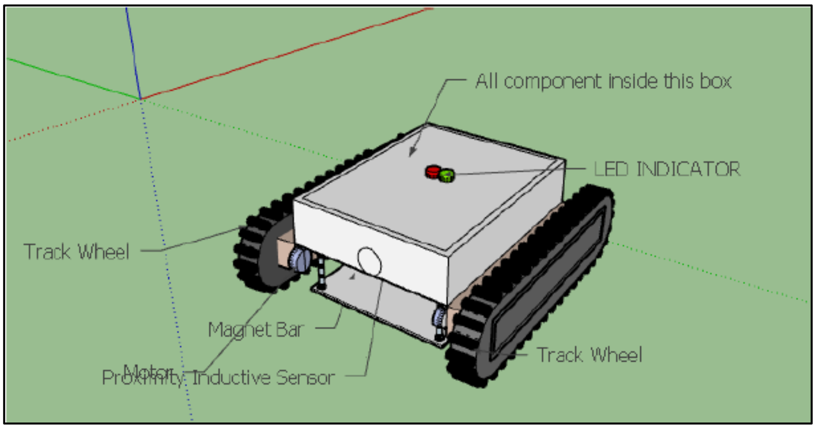
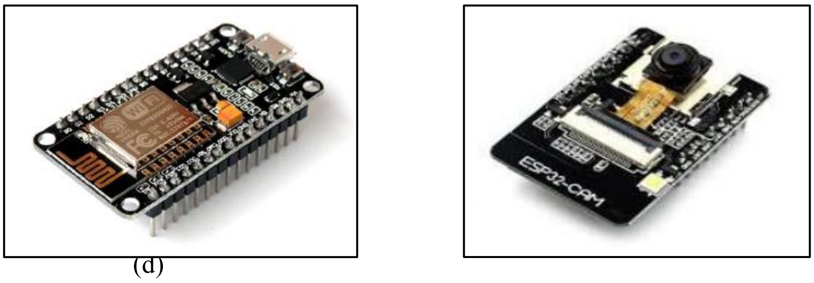


Figure 3: Design of Magnetic Crawler

3.4 Material and equipment

This Magnetic Crawler is equipped with NodeMcu ESP 8266 microcontroller as Figure 4 (a) to read data from the speed and voltage sensors, processes this information, and transmits it to a Firebase system. It enables real-time monitoring and data logging of the crawler's speed performance and battery status, ensuring efficient operation and maintenance. This integration supports remote diagnostics and analytics for optimal functionality.

The ESP32 microcontroller in Figure 4 (b) plays a pivotal role in the operation of a crawler robot, managing both its movement and real-time video streaming functionalities. In this context, the ESP32 receives movement commands (Forward, Reverse, Turn Right) from an application and the ESP32 is connected to a camera module, which captures live video feed.



(d)
(e) (b)

Figure 4: (a) ESP8266 Microprocessor, (b) ESP32 Microcontroller

A 12-volt DC motor is used to drive the wheels that allow the robot to move forward, backward, turn right, and turn left. Robots are powered by a 12-volt lithium battery as Figure 5, which is lightweight and high in energy density, making it an ideal alternative for long-term operation. This battery type delivers a steady voltage output, which is critical for powering the robot's motors, Raspberry Pi Pico, and Sensors.

A 12 V to 5 V converter for Raspberry Pi Pico is a voltage regulator that converts the input voltage from 12 volts to 5 volts, making it appropriate for powering the microprocessor. This converter provides a consistent and controlled power supply to the Pico, shielding it from potential harm caused by overvoltage. Converting the voltage to the desired level, allows the Raspberry Pi Pico to operate safely and reliably, making it suitable for a variety of projects and applications that require a 5V power source as Figure 6 (a).

Figure 5: 12v Lithium Battery

A speed sensor in a crawler project measures the rotation or movement speed of the crawler's tracks or wheels in Figure 6 (b). This data is essential for monitoring and controlling the crawler's speed, ensuring efficient operation, and precise navigation, and making the data analysis.

(a) (b)

Figure 6: (a) 12v to 5v Converter, (b) Speed Tachometer Sensor.

A voltage sensor monitors the electrical potential (battery status) across components, ensuring optimal power distribution to all components of magnetic crawlers. This enhances the robot's performance, prevents damage, and enables responsive adjustments to maintain efficient operation and prolong the system's lifespan.

Neodymium magnets (NdFeB) as shown in Figure 7(a) are essential components of magnetic crawlers developed for hull examination. These magnets have a powerful magnetic attraction, allowing the crawler to firmly adhere to metallic surfaces like ship hulls during inspection activities. Their high strength-to-weight ratio allows effective adhesion even on curved or uneven surfaces, allowing for a full assessment of the hull's integrity without requiring personal touch. By securely grasping the surface, NdFeB magnets improve the crawler's stability and maneuverability, allowing for accurate navigation along the hull. Overall, they enable effective and dependable inspection operations, which ensure the safety and integrity of maritime vessels.

Motor Driver serves as an interface between the Raspberry Pi and electric motors as Figure 7(b). It is responsible for controlling the direction and speed of the motors based on signals received from the Raspberry Pi's GPIO (General Purpose Input/Output) pins.

In a crawler project, the crawler chassis serves as the foundational structure that supports and integrates the crawler's key components, such as motors, gears, and tracks. It ensures stability, durability, and efficient movement across various terrains, enabling the crawler to navigate and perform tasks effectively.

Figure 7: (a) Neodymium Magnet, (b) Motor Driver

4 RESULTS AND DISCUSSION

The Magnetic Crawler performs the inspection on the ferromagnetic surface controlled by the Android application that was developed using the MIT App inventor to ensure the safety, structural integrity, and operational efficiency of a vessel and reduce the risk for the inspector when inspecting the dangerous area. The results show the crawler moves climbing the metal plate with the different angles of the plate until the maximum angle it can climb.

4.1 Climbing at 60 Degrees Angle.

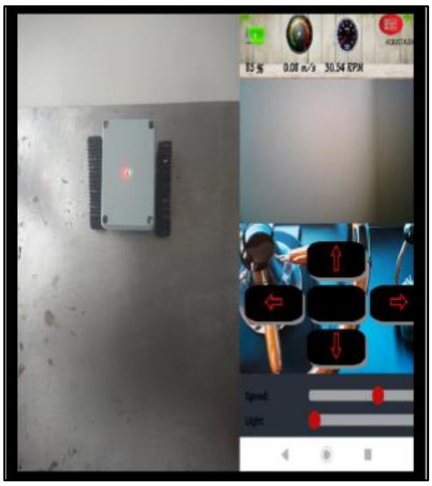


Figure 8: Crawler Climbing at Angle Of 60 Degrees

Figure 8 shows the magnetic crawler is being tested on a ferromagnetic surface inclined at a 60-degree angle. It moves at a speed of 0.08 meters per second, crawling along the metal surface controlled using an Android application through an IoT communication system.

4.2 Climbing At 80 Degrees Angle

Figure 9 shows the magnetic crawler is being tested on a ferromagnetic surface inclined at an 80-degree angle. It moves at a speed of 0.04 meters per second, crawling along the metal surface controlled using an Android application through an IoT communication system.

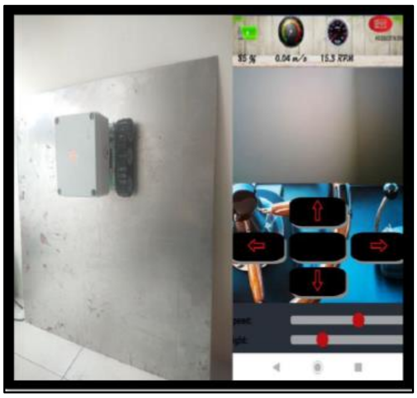


Figure 9: Crawler Climbing at Angle Of 80 Degrees

4.3 Climbing At 90 Degrees Angle

Figure 10 shows the magnetic crawler is being tested on a ferromagnetic surface inclined at a 90-degree angle. It moves at a speed of 0.03 meters per second, crawling along the metal surface controlled using an Android application through an IoT communication system.

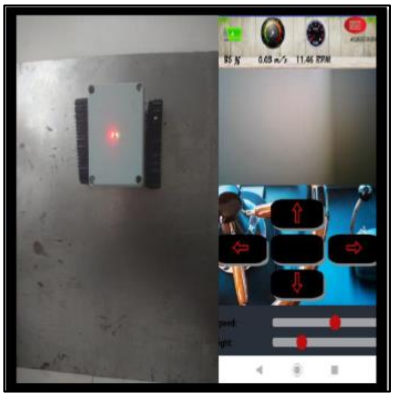


Figure 10: Crawler Climbing at Angle Of 90 Degrees

Figures 11 and 12 show the graph of the Speed Vs Metal Angle and Power Consumption Vs Metal Angle.

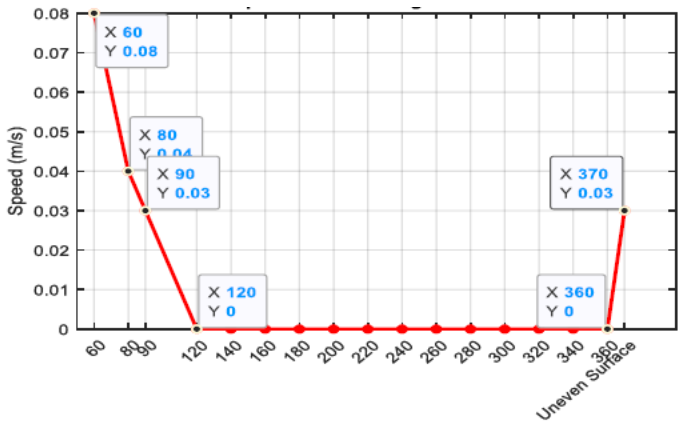


Figure 11: Speed Vs Metal Angle/Surface

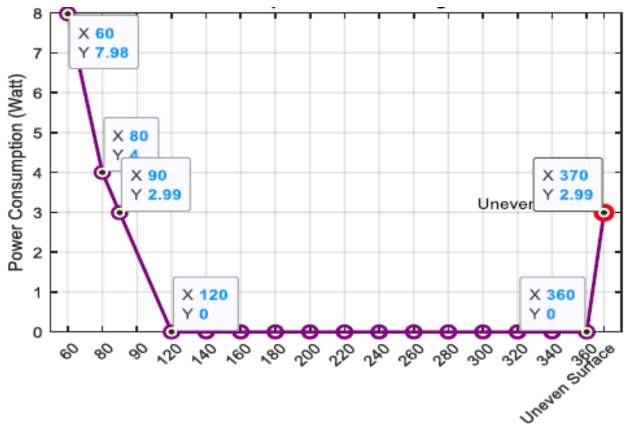


Figure 12: Power Consumption Vs Metal Angle/Surface

This Magnetic Crawler can perform the inspection on the ferromagnetic surface with an angle of 84 degrees and reaches the limitation of 94 degrees and above as Figure 3.4. The crawler slips down when it reaches its limit. Another thing, the crawler moves at a speed of 0.08 m/s on 60-degree metal angles and the crawler moves at a speed of 0.03 m/s on 90-degree metal angles as Figure 3.5. In this context, the relationship shows when the angle of the metal plate increases, the velocity of the crawler (speed) moving on the surface decreases. As the angle increases, the power consumption of the crawler decreases due to the motor ceasing operation at high angles, resulting in the absence of motor movement. Moreover, the crawler moves at about 0.03 m/s on uneven surfaces and cannot handle bumps higher than 1 cm because its magnetic platform is 1.3 cm above the metal surface. In addition, this crawler has a lightweight design of 1.3 kg, allowing it to move easily on ferromagnetic surfaces. This is because the heavier material of the crawlers needs more magnets and a stronger magnetic field to overcome increased gravitational pull.

5. CONCLUSION

The development of a magnetic crawler remotely controlled via an Android system for hull inspection represents a significant advancement in maritime maintenance technology. This innovative solution offers a safer, more efficient, and cost-effective method for inspecting the hulls of ships and underwater structures. By leveraging the magnetic crawler’s ability to adhere to metal surfaces and the convenience of Android-based remote control, operators can conduct thorough inspections on docking yard. The system's real-time data transmission and user-friendly interface enhance the accuracy and ease of inspections, allowing for timely identification of structural issues. Ultimately, this technology not only improves operational efficiency and safety but also ensures the longevity and integrity of maritime vessels through regular, detailed inspections. Finally, this crawler has undergone modifications and improvements to allow it to operate at angles exceedingly more than 90 degrees in further studies to make it function more efficient and reliability when do the inspection on ship’s hull.

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