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# SPHERESCUE: Design and Development of Search and Rescue Robot with Integrated First Aid Supply

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*Abstract*—**This study aimed to develop SPHERESCUE, a low-cost, remotely controlled spherical search and rescue robot with integrated first aid storage, live video, and GPS capabilities. Through remote operation and AI-enhanced human detection, the project seeks to address the danger rescuers face in hazardous terrain by providing a safer means to locate and assist survivors. The prototype was designed and constructed using Arduino Uno, ESP32-CAM, NEO-6M GPS, and a servo-controlled hatch for first aid deployment. Its spherical body, inspired by DOST's Project Sphere and Star Wars' BB-8, was made from papier-mâché reinforced with lightweight internal support. Programming was done in C++ via Arduino IDE to control movement, navigation, and detection systems. The prototype was tested on various terrains to measure stability, navigation efficiency, and accuracy of live video and GPS telemetry. The first aid delivery mechanism was also tested through multiple trials to assess success rates in opening, accessibility, and security of stored supplies. SPHERESCUE's results showed efficiency in navigating flat and uneven terrains. Although with minimal errors in identifying targets in transmitted live video using AI-assisted detection, it also lacks maintaining stability on inclined areas. The first aid hatch achieved a 60% success rate, indicating functionality with room for improvement. SPHERESCUE demonstrates strong potential as a low-cost, accessible robotic aid for safer and faster disaster response. As a prototype, limitations such as terrain adaptability and hatch precision are expected.**

*Index Terms*—**SAR Robot, First Aid Delivery, Spherical Robot.**

## 1. Introduction

Accidents together with nature's disasters keep putting people at risk, causing harm. Finding those missing or threatened – a job for experts or bystanders is where Search and Rescue (SAR) comes in to bring them back safely. Though settings differ with each crisis – earthquakes, landslides, or flood – the goal of rescuing people remains constant (FOCUSPOINT, 2023).

Since locating victims is the top priority for human responders, a common and unavoidable obstacle traditional search and rescue operations face is encountering dangerous terrain that puts responder's safety at high risk – leading to the need for more advanced equipment and technology. Recent innovations have proved the potential for rescue robots to improve search and rescue operations, particularly in disaster scenarios. Rescue robots are designed to their specific environments, and are deployed autonomously or remotely together with human responders. Equipped with artificial intelligence (AI), rescue robots can analyze data to complete their tasks or with minimal assistance from humans (Amprius, n.d.).

This study introduces a remote-controlled spherical search and rescue robot equipped with AI-enhanced human detection and integrated first aid supply. Unlike fully autonomous systems, this robot operates through human control but is supported by artificial intelligence to assist in human detection and navigating through complex environments. The prototype's spherical design enables it to roll and operate over uneven surfaces, which can improve mobility in disaster areas. Additionally, the integration of first aid supplies – although the robot doesn't perform the actual first aid, it still allows for immediate medical assistance while waiting for rescuers to arrive.

While the robot offers capabilities in mobility, detection, and first aid delivery, it also has limitations. The spherical body design, although efficient for rolling and protecting internal components, may be impractical in certain terrains, such as steep slopes or on mud – where traction and stability are compromised. Moreover, the robot's large body size may limit its ability to cross through tight spaces or debris-filled areas, which are common in disaster zones. These physical limitations emphasize the importance of further design improvements to enhance maneuverability and adaptability in various rescue scenarios.

Most of the existing studies on rescue robots emphasize autonomous navigation, search algorithms, or victim detection, but few focuses on remote-controlled designs equipped with both AI-based human detection and integrated first aid delivery. This research aims to fill that gap by developing and evaluating a robot that enhances human control with intelligent detection

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capabilities, supporting faster, safer, and more effective Search and Rescue operations in challenging environments.

## 2. Materials and Method

This research study developed and tested a remote-controlled, AI enhanced spherical search and rescue (SAR) robot capable of human detection and first aid supply delivery. The study consisted of seven (7) main phases: Phase I – Planning and Designing, Phase II – Component & Material Gathering, Phase III – Programming, Phase IV – Chassis Assembly, Phase V – Testing and Refining, Phase VI – Finalization, and Phase VII – Waste Disposal. The procedures were conducted at the researcher's home and nearby open test areas.

The system was programmed using C++ in the Arduino IDE, with the Arduino Uno serving as the main controller and the ESP32-CAM with AI Thinker module responsible for image processing and human detection. The ESP32-CAM transmitted live video and AI-based detections to a connected mobile device for monitoring. The robot's motion, controlled via Arduino Uno, allowed it to navigate through simulated environments to test its effectiveness in identifying human figures and delivering first aid supplies during search and rescue scenarios.

### *A. Phase I: Planning and Designing*

This phase focused on the conceptualization and design development of the SPHERESCUE prototype — a low-cost, remote controlled spherical search and rescue (SAR) robot equipped with AI enhanced human detection and an integrated first aid supply compartment. The goal of this phase was to design a robot capable of navigating through debris, detecting survivors, and delivering basic first aid supplies quickly and safely.

The spherical body design of SPHERESCUE was inspired by existing research of project SPHERE from the Department of Science and Technology (DOST) on spherical mobile robots, known for their ability to roll smoothly and protect internal components (DOST-PCIEERD, 2021). Meanwhile, the storage and payload system concept are adapted from delivery drone mechanisms, allowing efficient organization and secure transport of medical supplies within the robot's structure (Ayamga & Nyaaba, 2021). The 3D design and prototype layout were developed using TinkerCad and Cirkit Design IDE, drawing visual inspiration from BB-8, the spherical droid from Star Wars, to achieve a balance between aesthetics, stability, and compact internal arrangement.

Component placement was carefully planned to optimize space and performance. Inside the sphere, the Arduino Uno microcontroller serves as the central control unit – where it processes data from Bluetooth module motors. While the ESP32-CAM (AI Thinker) handles image capture and AI based human detection rests at the head of SPHERESCUE alongside a GPS Module for location mapping. Additional components include motor driver, servo motors, a battery pack, and the first aid storage compartment. Circuit schematics were drafted to ensure proper wiring, power management, and communication between modules. Finally, C++ was chosen as the programming language – since both Arduino Uno and ESP32-CAM can be programmed in Arduino IDE.

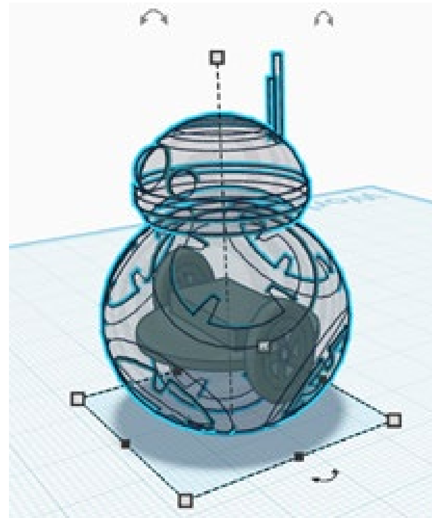

Fig. 1. Prototype's 3D Design

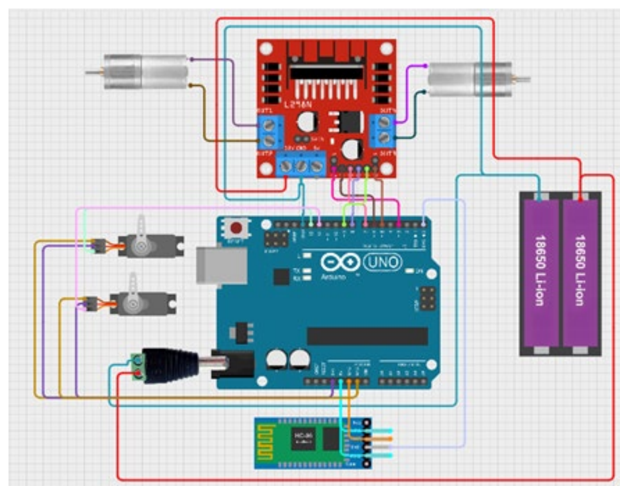


Fig. 2. Mobility components

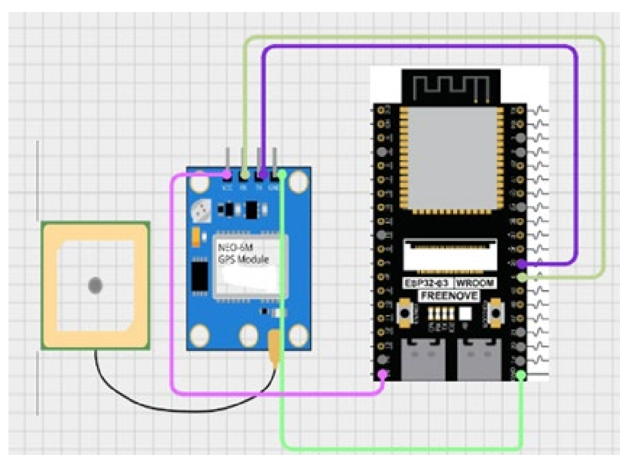

Fig. 3. Navigation components

### *B. Phase II: Component and Material Gathering*

The researcher gathered materials both online and in-store, specifically from Makerlab Electronics online and CreateLabz located at Davao City. The study utilized various electronic and structural components essential for the construction and functionality of the robot prototype. These include an Arduino Uno microcontroller, an expansion board, Metal Geared DC Motors (12V–531 RPM), an L298N motor driver, 18650 Li-ion batteries with a battery case, a servo motor for the hatch mechanism, and an HC-06 Bluetooth module for wireless control.

Additional components integrated into the system include an ESP32 S3 WROOM N16R8 development board, an OV5640 camera module for image capture and AI-enhanced human detection, and a NEO-6M GPS module for real-time geolocation tracking. Various jumper wires (male-to male, male-to-female) were used to establish stable circuit connections between all components.

The prototype's body was constructed using paper-mâché made from recycled scratch papers and a beach ball as mold – forming a 50 centimeters diameter sphere reinforced with multiple layers, and a layer of wood putty for added strength and durability. The upper portion, or "head," was created from Styrofoam, which houses the ESP32-CAM module and GPS Module. This design provides lightweight protection for internal components while maintaining visual appeal.

### C. Phase III: Programming

This phase focused on the programming and system integration of the SPHERESCUE prototype, ensuring that all electronic components functioned properly to carry out search and rescue operations. The researcher used Arduino IDE as the main programming platform, written in C++ – to develop and upload codes for both the Arduino Uno and ESP32 S3 WROOM N16R8 development board (Hertz, 2023).

Similar to an Arduino remote-control car – the HC-06 was programmed to control the DC motors via L298N driver for basic mobility functions like forward, backward, and directional turns (Shahid, 2025). For the prototype to release and store supplies, the servo motor is set to open and closed the hatch. Additionally, the HC-06 Bluetooth module was calibrated to establish wireless communication between the robot and a mobile device, allowing for remote-controlled navigation and operation (Technetron, 2021).

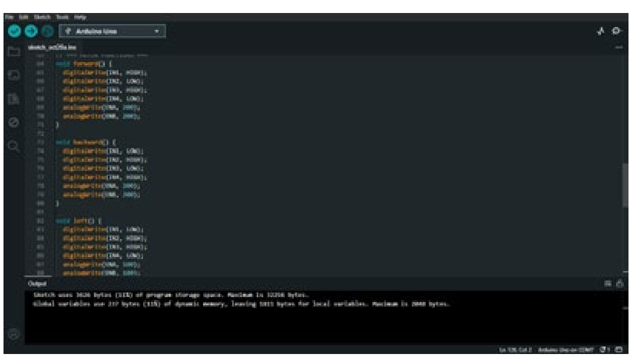

Fig. 4. Remote-control mobility code

The ESP32-S3 WROOM N16R8 module managed the robot's AI enhanced human detection system, using the OV5640 camera module and modified AI Thinker libraries for identifying human presence within its visual range (Espressif Systems, 2023). To secure the precise location of the prototype during the simulated operation, NEO-6M GPS Module provided real-time data on its location (Electroscope Archive, 2025). Multiple programming and debugging iterations were conducted to ensure stable data flow and reliable Bluetooth communication. Final code optimizations focused on improving movement precision, response time, and coordination between subsystems, ensuring SPHERESCUE's readiness for real-world application testing.

### D. Phase IV: Chassis Assembly

This phase focused on the construction and integration of the SPHERESCUE robot's physical framework – following the 3D designed model. The researcher followed a step-by-step chassis assembly process inspired by existing BB-8 builds available on Instructables (Ascas, 2020; Casimero, 2016), adapting the design to fit the spherical body structure and internal hardware arrangement of the prototype.

The main body of the robot was handcrafted using papier-mâché made from recycled scratch papers, molded into a 50 cm diameter sphere using a beach ball, and reinforced with multiple layers for durability and protection of the internal components. The internal platform is made out of cardboard with a 20-centimeter diameter to mount it mobility components and storage box for the first aid system. The ESP32-S3 WROOM N16R8 module and OV5640 camera, alongside the GPS module are mounted in the upper section (head) of the robot constructed from Styrofoam, which served as a lightweight addition for mounting. The servo motor was positioned near the access hatch to enable smooth opening and closing during first aid delivery.

While the general chassis assembly was based on the Instructables guide, the researcher made several customizations to incorporate advanced components such as the camera and GPS module, which were not part of the inspired build. These integrations required additional structural supports and internal wiring adjustments to ensure functionality and balance within the spherical enclosure. Proper alignment and secure placement of all electronic components were ensured to prevent internal shifting during motion.

### E. Phase V: Testing and Refining

After assembling the SPHERESCUE prototype, the researcher conducted a series of tests to verify its movement, detection, and tracking capabilities. The robot's mobility was tested using Bluetooth control through the HC-06 module via a mobile device, operating similarly to an Arduino RC car. Adjustments were made to improve motor alignment and rolling balance.

During simulated first aid delivery, the servo motor for the hatch was calibrated to open and close smoothly. While the NEO-6M GPS verified accurate location tracking – the ESP32-CAM (OV5640) was tested for AI enhanced human detection.

Troubleshooting focused on fixing power inconsistencies, weak connections, and accuracy of AI recognition. After several trials, the robot demonstrated stable operation, though movement on inclined and narrow spaces remained limited due to its spherical body design.

### *F. Phase VI: Finalization, Data Collection and Analyzation*

In this phase, the researcher finalized the SPHERESCUE prototype by ensuring all electronic components and mechanical systems were securely integrated and fully functional. The system was refined to enhance responsiveness during trials.

Data collection involved observing and recording the robot's movement accuracy with 3 different environments replicated 3 times. AI human detection efficiency, and GPS tracking precision, and hatch operation are tested with 5 trials. Each test was replicated multiple times to ensure reliability, with performance data analyzed based on consistency and responsiveness.

Although its large spherical body presented challenges in uneven terrain and narrow spaces, the results showed that the robot performed well in detecting human presence and basic mobility tests. The results were used to assess the prototype's effectiveness and identify areas for future improvement.

### *G. Phase VII: Waste Disposal*

All materials used in constructing the SPHERESCUE prototype – paper mâché, wires, and electronic components, were properly handled and disposed of according to environmental safety guidelines. Excess materials such as adhesives and damaged components, and other non-recyclables were segregated and discarded responsibly. The paper mâché shell, made from recycled scratch papers, was also reused for testing and educational display purposes to minimize waste. This ensures that the study followed proper waste management and sustainability practices throughout its completion.

## 3. Results

The navigation and stability performance of the SPHERESCUE sphere-shaped prototype were evaluated across three controlled terrains: flat surface, uneven ground, and inclined plane. Each test was conducted through three (3) trials replicated three (3) times, and data were gathered on stability (number of tips or stalls), navigation success rate, and average travel time.

Table 1
Navigation test results (Time in seconds)

| Terrain Type | R1 | R2 | R3 | Average Time (s) |
|---|---|---|---|---|
| T1: Flat | 10.86 | 9.47 | 12.52 | 10.95 |
| T2: Uneven | 13.12 | 15.24 | 17.16 | 15.17333333 |
| T3: Inclined | 26.79 | 23.9 | 25.81 | 25.5 |

The results showed that the robot maintained excellent stability on flat terrain, with no tipping incidents and an average of 10.95 seconds travel time. On uneven ground, the robot displayed moderate instability, tipping or becoming stuck twice during the duration, resulting in an 77.77% success rate. On inclined planes, the spherical body faced traction difficulties, reducing navigation success to 44.44% and increasing travel time significantly due to reduced grip.

The live video and GPS telemetry performance of SPHERESCUE were tested to determine its effectiveness in identifying simulated survivors and locating their positions using GPS data. The robot was remotely controlled through the ESP32-CAM for human detection and the NEO-6M GPS module for real-time positioning.

Table 4
Live video and GPS Telemetry

| Trial | Target Detection | GPS Location |
|---|---|---|
| 1 | Inaccurate | Accurate |
| 2 | Accurate | Accurate |
| 3 | Accurate | Inaccurate |
| 4 | Inaccurate | Accurate |
| 5 | Accurate | Accurate |

The robot's live video detection system showed a lower consistency rate (60%) compared to its GPS module (80%). While both systems effectively aided in remote operation, occasional signal interference and camera positioning errors reduced overall precision.

To evaluate the effectiveness of the first aid delivery system, the prototype was subjected to five (5) controlled trials simulating deployment scenarios. Each trial assessed three parameters: (1) hatch operation, (2) accessibility of supplies, and (3) condition of the supplies after movement. Results were categorized as Successful, Partial, or Failed, depending on whether all three criteria were met.

The data show that the prototype achieved a 40% success rate, with the hatch consistently opening fully and the supplies

Table 2
Stability test result (No. of stalls)

| Terrain Type | No. of stalls in R1 | No. of stalls in R2 | No. of stalls in R3 | Average No. of Stalls |
|---|---|---|---|---|
| T1: Flat | 0 | 0 | 0 | 0 |
| T2: Uneven | 1 | 0 | 1 | 0.6 |
| T3: Inclined | 2 | 1 | 1 | 1.33 |

Table 3
Summary of navigation and stability test result

| Terrain Type | Average No. of Stalls | Average Travel Time (s) | Success Rate (%) | Remarks |
|---|---|---|---|---|
| Flat | 0 | 10.95 | 100% | Stable and consistent |
| Uneven | 0.6 | 15.17333333 | 77.77% | Moderate instability |
| Inclined | 1.33 | 25.5 | 44.44% | Slower navigation |

Table 5
Live video and GPS Telemetry percentage

| Parameter | Accurate (trials) | Inaccurate (trials) | Accuracy Percentage |
|---|---|---|---|
| Target Detection (ESP32-CAM) | 3 | 2 | 60% |
| GPS Location | 4 | 1 | 80% |

Table 6
Hatch operation trial

| Trial No. | Hatch Opens Fully | Supplies Accessible | Supplies Undamaged | Overall Result |
|---|---|---|---|---|
| 1 | Yes | Yes | Yes | Successful |
| 2 | Partial | Partial | Yes | Partial |
| 3 | Partial | Yes | Yes | Partial |
| 4 | No | No | Yes | Failed |
| 5 | Yes | Yes | Yes | Successful |

remaining intact and accessible. A 40% partial success rate was recorded when the hatch partially opened and the remaining 20% of trials failed, primarily due to servo motor response delay or obstruction within the mechanism.

## 4. Discussions

The overall results of the study indicate that the SPHERESCUE prototype, a remotely controlled sphere-shaped search and rescue robot, demonstrated a partially success to its primary functions of navigation, victim detection, and first aid supply delivery. Each phase of testing contributed to evaluating the system's effectiveness in real-world disaster simulation environments.

In terms of navigation and stability, the robot performed efficiently on flat and slightly uneven terrains, completing most runs without external assistance. However, as observed in the trials, the spherical body design posed challenges in steep environments where traction and control were reduced. These findings align with previous research emphasizing that spherical mobile robots often experience instability when navigating on highly irregular surfaces (Chase, 2022). Despite these limitations, the sphere configuration provided significant advantages in protecting internal components and allowing multidirectional movement with minimal mechanical complexity.

For live video and GPS telemetry, the integration of the ESP32-CAM and NEO-6M GPS module proved effective in enhancing remote situational awareness. The robot consistently transmitted live footage with minimal delay and accurately identified simulated targets using its AI-assisted human detection feature. The GPS module also provided coordinates with reliable accuracy across multiple trials, confirming the viability of GPS based localization in real-time rescue operations. These results demonstrate the potential of combining low-cost embedded systems with AI to support search and rescue activities, consistent with findings from emerging robotic vision studies (Amprius, n.d.).

The first aid storage and delivery system also achieved a considerable success rate in delivering medical supplies to the simulated recipient. The servo-controlled hatch mechanism functioned effectively during most trials, securely holding and releasing the contents as intended. However, mechanical interference during movement occasionally caused partial failures in hatch opening. These limitations highlight the need for refining the servo calibration and improving the compartment's structural balance. Nevertheless, the mechanism successfully demonstrated how simple automation can contribute to timely and contactless aid delivery in hazardous environments.

Collectively, these findings validate the potential of the SPHERESCUE prototype as a cost-effective robotic assistant for search and rescue operations. The combination of mobility, live monitoring, and supply deployment suggests that such designs can supplement human responders during emergencies, particularly in areas unsafe for direct human access. However, the prototype's relatively large and spherical body limits its adaptability to certain terrains, which must be addressed in future redesigns through material optimization or hybrid locomotion systems.

## 5. Conclusion

The results from the conducted tests demonstrate that the prototype can efficiently navigate controlled flat or uneven terrains, transmit live visual data, locate simulated victims, and perform medical supplies delivery. These results confirm the feasibility of combining low-cost electronics, remote communication modules, and artificial intelligence to support search and rescue operations in hazardous or hard-to-reach areas.

Although, the robot's large, spherical body is capable of storing materials – it's also the prototype's primary problem. It's impractical to steep and narrow spaces which are highly possible in a post disaster area. Minor inconsistencies in the servo-controlled hatch during supply deployment also indicate the need for refinement in calibration and mechanical design.

SPHERESCUE naturally presents certain limitations – as a prototype; however, it effectively demonstrates the potential of accessible, adaptable, and sustainable robotics in improving emergency response operations and minimizing risks for human rescuers. The integration of live video monitoring, AI-enhanced human detection, and first aid storage highlights its innovative approach to supporting search and rescue missions. While its current design may face challenges in terrain adaptability – future refinement to automation, and waterproofing, and overall design could solve these.

Overall, the SPHERESCUE project contributes to global efforts to utilize technology for humanitarian and life-saving applications. It proves that even small-scale, low-cost innovations can play a vital role in developing for better systems that support both rescuers and victims in times of crisis.

## 6. Recommendations

Based on the performance of the prototype during the testing, the researcher recommends several improvements to reach the full potential of the rescue robot prototype. The large size of SPHERESCUE limits its navigation access through narrow spaces – that are usually present in disaster affected areas. Its AI recognition library also lacks precision when it comes to identify humans with low visibility.

In terms of hardware, the researcher recommends to change the material used to reinforce the paper-mâché and to add more layers for more durability and to protect the internal components. Changing to wheels with more tread designs for high tractions to optimize performance and faster rotations for mobility is also highly suggested by the researcher.

To address its limitation for narrow spaces, the researcher suggests having the magnetic head to be also capable of roaming around by adding a set of wheels. Since the head's primary function is for human detection – the goal of searching victims can still be reach.

Shifting to a camera with more advance AI library to recognize humans for more precision in detecting is also highly recommended by the researcher. Optimizing the control system of the robot to return to its controller when maximum distance has been reached to also secure the robots location.

In conclusion, the results of this study demonstrate that a low-cost, remote-controlled rescue robot can effectively assist in post-disaster operations by providing live situational awareness and immediate first aid delivery. With the recommended enhancements in design, material, and control systems, future iterations of this prototype could serve as a reliable and deployable tool for actual search and rescue missions, promoting both safety and innovation in humanitarian technology.

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