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IoT-Based Sensor Technologies for Object Detection in Low-Visibility Environments: Development and Validation of a Functional Prototype

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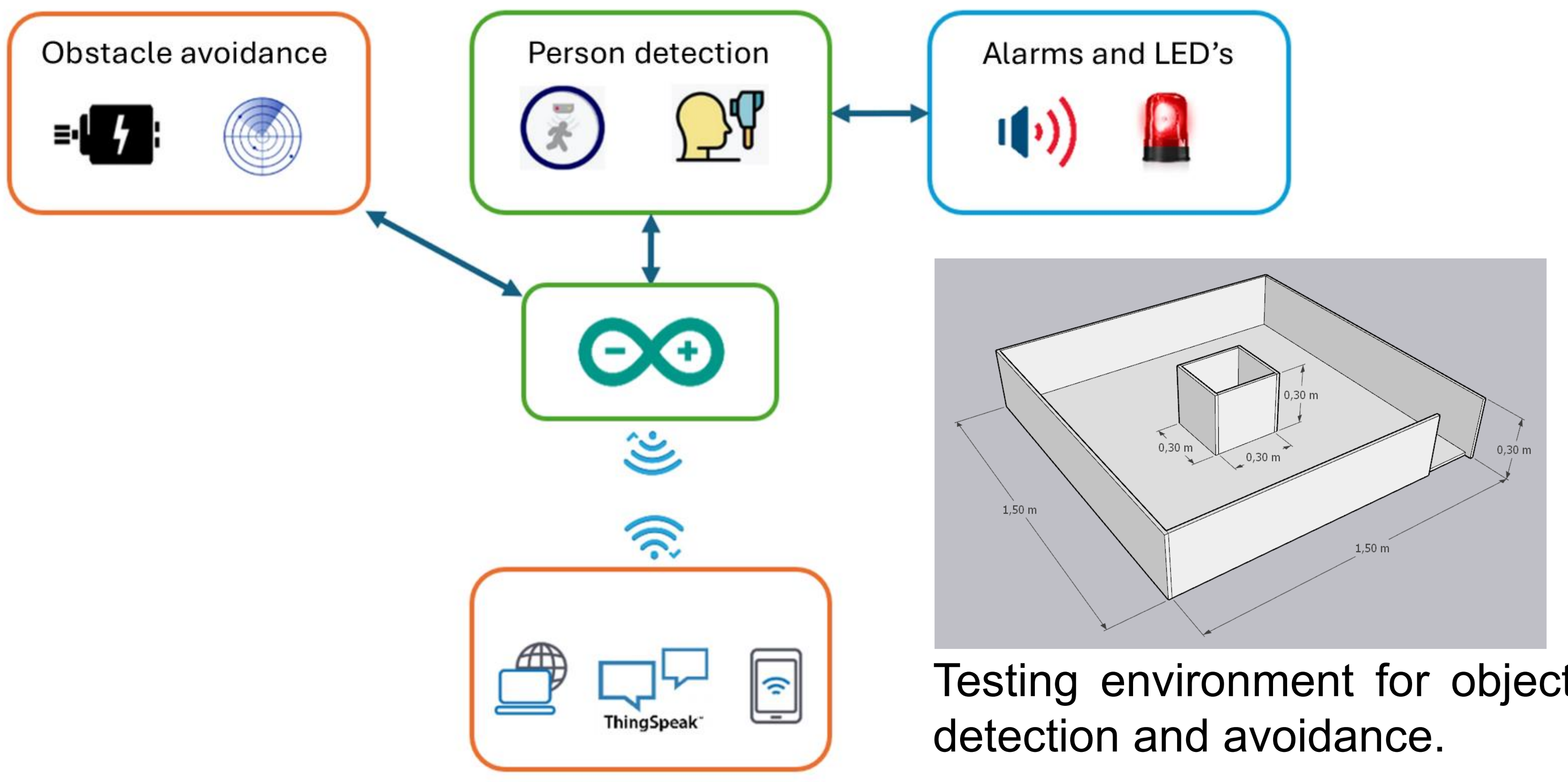
INTRODUCTION & AIM

In the last years, the rapid growth of smart cities and the Internet of Things (IoT) has transformed the way devices interact, enabling seamless connectivity not only between people but also among machines. These advances, together with significant progress in artificial intelligence and robotics, have strengthened the use of automated systems in critical environments. In particular, rescue and monitoring robots have become essential tools for improving safety and efficiency in hazardous situations such as earthquakes, landslides, mining accidents, or areas with low visibility. Equipped with cameras and specialized sensors, these platforms can enter spaces inaccessible to humans, detecting threats and identifying victims. Building on this technological evolution, the present work develops a sensored IoT-based prototype aimed at detecting objects and locating people in environments with reduced visibility.

METHOD

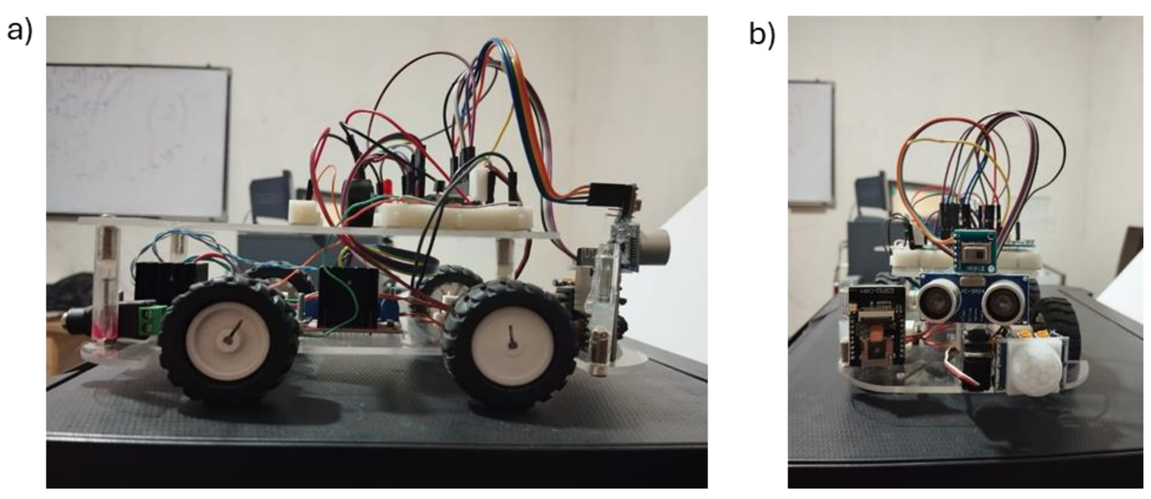
This section presents the design of the four modules that make up the mobile platform: obstacle avoidance, person detection, rescue confirmation, and monitoring. It also describes the interconnection of the devices and the overall architecture of the project.



Testing environment for object detection and avoidance.

RESULTS & DISCUSSION

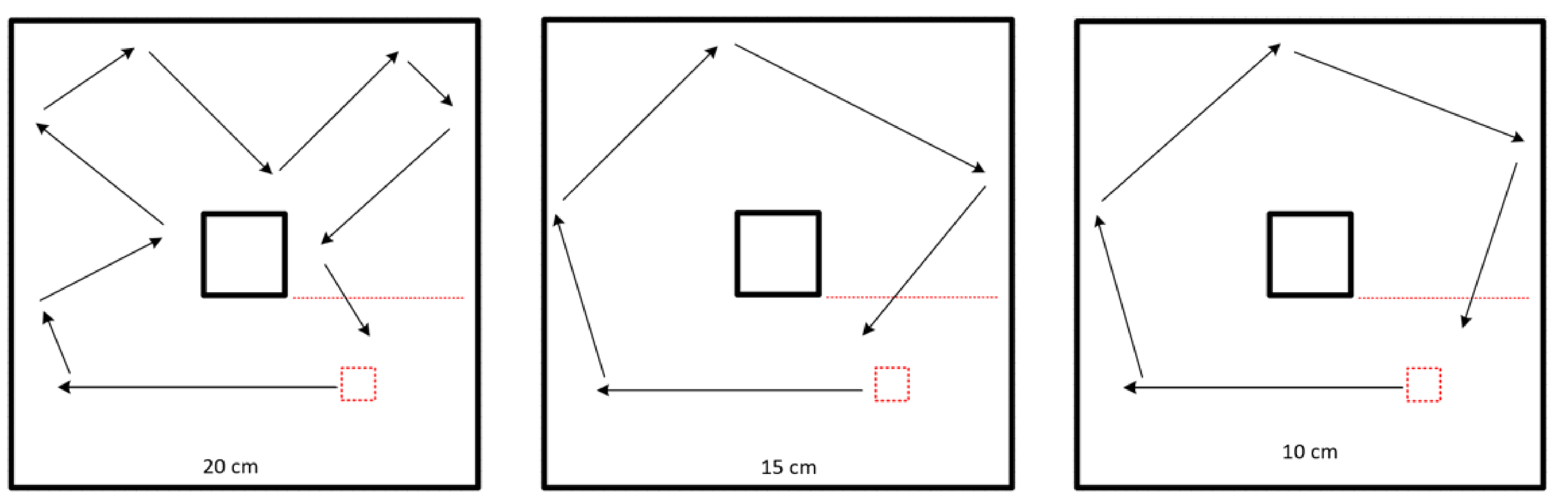
This section presents the system evaluation through tests conducted under different visibility levels and terrain conditions. It analyzes the performance of the sensors, the robot's navigation paths, and its ability to search for and identify the target.

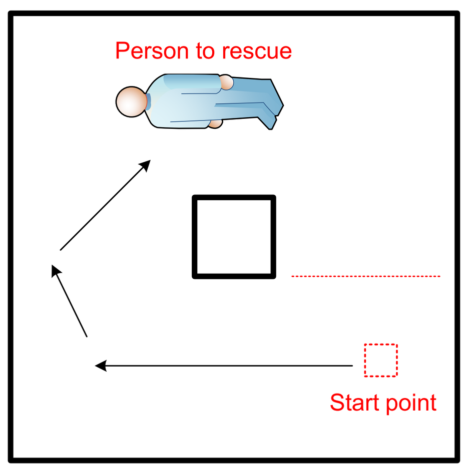


Completed mobile platform: (a) side view, (b) front view.

Tests

The analysis of the robot's routes shows that at 20 cm it struggled to complete the circuit due to limited space, often turning back before midpoint. At 15 cm and 10 cm the paths were similar, though at 10 cm the platform experienced repeated collisions due to sound reflection in the reduced space.





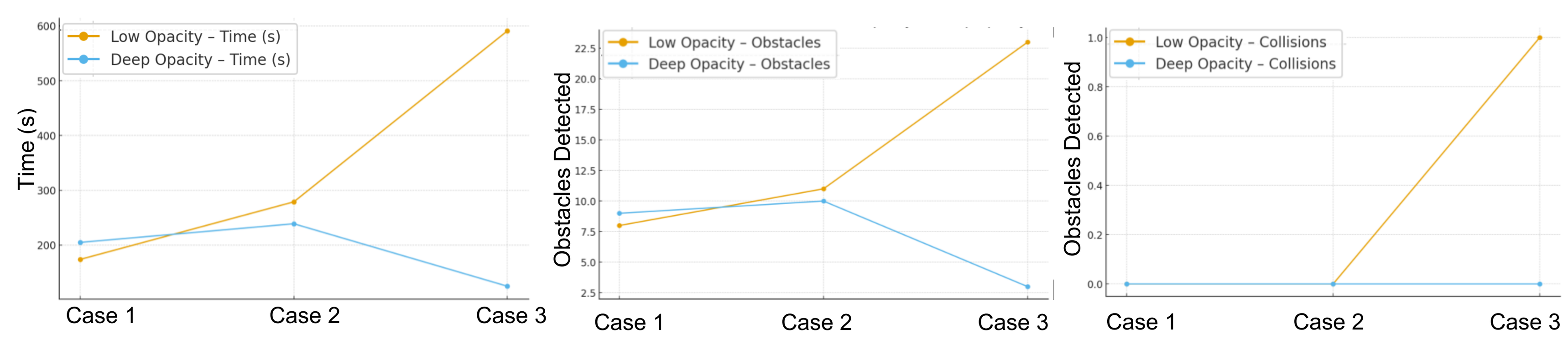
Tests were conducted in three environments—light, shadow, and darkness—to evaluate the platform's behavior under different visibility conditions. Two dimmable lamps were used: both at 100% for light, one at 10% for shadow, and both off for darkness, with trials performed after 22:00 hours. An Ezviz C6N infrared camera captured images in all conditions. A fixed starting point and a designated location for the person were marked to ensure consistent reference across tests. The routes obtained in these environments were similar, with only small variations caused by sound angle differences.

Evaluation

A 3×2 m test track with varied obstacles was built to simulate realistic conditions. Three trials were performed in darkness and deep opacity to evaluate the platform's behavior under low-visibility scenarios.

The evaluation show that the mobile platform successfully fulfills its objective, continuously moving and avoiding multiple obstacles without errors or loop failures. Although one collision occurred due to an irregular obstacle, the platform recovered and continued its route. Temperature and motion data clearly indicated when a human target was detected, with readings rising above 30 °C and the motion sensor activating accordingly.

Results show shorter victim-detection times compared to the darkness tests, mainly due to the platform's sharper turning angles. No collisions occurred, and the alarm activated immediately. The AMG8833, HC-SR04, and HC-SR501 sensors were unaffected by zero visibility, and temperature data were transmitted correctly, remaining below 30 °C before detection.



Comparison values for time, obstacles and collision for the 3 cases

CONCLUSION

The project demonstrated the implementation of an IoT-based mobile robotic platform capable of detecting obstacles and identifying people in environments with low visibility. The integration of ultrasonic sensing, thermal imaging, motion detection, and cloud connectivity through ThingSpeak enabled effective navigation, data transmission, and remote decision-making. Tests conducted under different lighting and opacity levels confirmed that the system operated with acceptable accuracy, achieving reliable obstacle avoidance at a 15 cm threshold and consistent detection of thermal patterns associated with human presence. Although the prototype is functional, its performance can be improved by refining sensor calibration, strengthening mechanical stability, and reducing communication delays. Overall, the system proved viable as a support tool for rescue tasks, providing real-time monitoring and autonomous search functions in restricted-visibility environments.

FUTURE WORK / REFERENCES

Future work includes adding an anti-collision system using elastomer coating, incorporating a tracked locomotion system, and implementing a rollover-recovery mechanism to improve operation on irregular terrain. It also proposes integrating a GPS module with cloud connectivity to obtain the precise location of both the detected object and the robotic platform.