Invisiscan: Unveiling the Hidden Beyond Wall

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Abstract - Identifying humans behind walls is essential to tactical, surveillance, or search and locate missions: finding people in disaster area. The InvisiScan is an autonomous threat robotic system that mitigates human threat through using radar sensor and cameras and communicating with wireless devices. This paper communicates the design and development of InvisiScan by integrating ultrasonic radar sensing and video streaming to enable a constant and real-time response and encounter of humans in obstructed areas. The function of this system intentionally provides safety to operators and situational awareness for security and operators.

Keyword: Through wall detection, human presence, radar sensor, surveillance robot, wireless communications.

1. INTRODUCTION

In current military and surveillance missions, human detection behind walls or around obstacles is essential to mission success and personnel security. Conventional surveillance systems are hindered by the line-of-sight issue, which renders them inefficient in confined or obstructed environments. To overcome this, we introduce InvisiScan — a standalone robotic platform that combines dual radar sensing, live video streaming, and wireless communication for through-the-wall human detection.

The robot has a Doppler radar for NLOS detection, a sub-radar for precise distance measurement, and an ESP32-CAM module for real-time video feedback. Wireless communication is facilitated by an HC-05 Bluetooth module, with sensor data being sent to a distant operator. Powering the system are 100 RPM BO motors, an L298N motor driver, and a 2-cell Li-ion battery, which provide mobility on different terrain.

Built for use in military reconnaissance, search and rescue, and urban warfare, the robot ensures stable detection of concealed threats behind walls or rubble. Its modular structure enables future upgrades such as AI-classified detection, thermal vision, or 5G connectivity. The project presents a low-cost, scalable solution that unites robotics and defense, improving situational awareness in hostile and cluttered environments.

1.1 PROBLEM STATEMENT

In military operations, identifying human presence behind obstacles such as walls, barricades, or debris is a critical task for both operational success and safety. During combat or search and rescue missions in hostile environments, enemy personnel or hidden civilians can be concealed behind physical barriers, and failure todetect them can lead to significant risks. Traditional methods of detecting hidden humans, such as manual searches or basic visual reconnaissance, are often slow, dangerous, and prone to errors. Conventional techniques for finding hidden people, like manual searches or simple visual reconnaissance, are frequently laborious, risky, and prone to mistakes.

1.2 LITERATURE REVIEW

1) UWB Radar-Based Detection

Zhao Ying et al. (2016) proposed a wall-penetrating radar system using Ultra-Wideband (UWB) signals. The UWB radar provided high-resolution imaging capable of detecting human motion through obstacles. The system performed well in open environments but struggled with real-time data processing and high computational costs. Additionally, the complexity of signal interpretation limited its application in mobile systems.

Advantages: High-resolution radar imaging.
Can detect motion through walls and obstacles.

Disadvantages: Requires significant computational resources and is costly. Not suitable for mobile use or real-time applications.

Reference: Ying, Z., et al., "Wall-Penetrating Radar System Based on UWB," IEEE Sensors Journal, 2016.

2)Passive Wi-Fi-Based Detection

In 2020, R. Dinesh and team presented a system using passive radar techniques by analyzing variations in Wi-Fi signals for motion detection. This method used Channel State Information (CSI) and Doppler shift analysis to detect the presence of humans behind walls. Although non-invasive and low-cost, the system was heavily dependent on environmental stability and struggled in cluttered environments due to multipath interference.

Advantages: Low-cost and non-invasive. Works with existing Wi-Fi infrastructure.

Disadvantages: Very sensitive to changes in the environment. Struggles in cluttered or dynamic settings.

- Low-cost and non-invasive.
- Works with existing Wi-Fi infrastructure.

Reference: Dinesh, R., et al., "WiFi-based Through-Wall Motion Detection," IJERT, 2020.

3)Infrared and Thermal Imaging

Several systems like the one developed by Kumar et al. (2017) utilized thermal imaging sensors to identify human presence based on body heat. These sensors are effective for night surveillance and smoky environments. However, their performance is degraded by thick walls or materials with low thermal conductivity. Furthermore, they are more suitable for surface-level detection rather than deep penetration.

Advantages: Effective for nighttime surveillance and low visibility situations. Non-contact detection based on thermal radiation.

Disadvantages: Poor penetration through solid or insulated walls. Limited to detecting heat at the surface level.

Reference: Kumar, P., et al., "Human Detection using Thermal Imaging," IJEET, 2017.

4)Camera-Based Surveillance with Wireless Control

Smith and colleagues (2019) proposed a mobile robot equipped with a wireless camera module for real-time monitoring. The system was lightweight and used Wi-Fi to stream video footage to a remote device. While visually rich, the absence of wall-penetrating capability limited its application in obstructed environments. Also, visual-only data proved insufficient for accurate human detection behind barriers.

Advantages Effective for nighttime surveillance and low visibility situations. Non-contact detection based on thermal radiation.

Disadvantages: Poor penetration through solid or insulated walls. Limited to detecting heat at the surface level.

Reference: Smith, L., "Embedded System Techniques for Wireless Communication,"Springer,2019.

5)Combined Sensor Approach

Manoharan and Choudhury (2018) developed a hybrid ground sensor unit combining motion detection and RF sensors. Their system showed improved performance in detecting human presence from outside a closed room. Despite enhanced sensitivity, the design lacked mobility and had limited field-of-view, making it unsuitable for dynamic environments like urban search and rescue operations.

Advantages: High detection sensitivity. Works in obstructed or enclosed environments.

Disadvantages: Stationary design with no mobility. Limited area coverage and adaptability.

Reference: Manoharan, S., Choudhury, T., "Ground Sensor Units for Human Detection," Defence Technology, 2018.

6)Comparative Analysis Table

The below table 1 shows the comparative analysis of the Literature survey.

Paper	Technology Used	Advantages	Disadvantages	Application Suitability
Wall-Penetrating Radar System Based on UWB	UWB Radar	➢ High resolution imaging ➢ Good wall penetration	➢ High computational cost ➢ Not suitable for mobile systems	Stationary surveillance systems in open areas
WiFi-based Through-Wall Motion Detection	Passive Wi-Fi (CSI+Doppler)	➢ Low cost and power ➢ Non-invasive	➢ Affected by multipath interference ➢ Unstable in cluttered areas	Indoor environments with stable signal conditions
Human Detection using Thermal Imaging.	Thermal Imaging	➢ Works in darkness/smokeness ➢ Non-contact detection	➢ Poor penetration through walls ➢ Ineffective for deep detection	Nighttime surveillance, fire rescue
Embedded System Techniques for Wireless Communication	Camera +Wi-Fi	➢ Real-time video feed ➢ Portable and wireless	➢ Needs direct line of sight ➢ Cannot penetrate walls	Remote monitoring with visual verifications
Ground Sensor Units for Human Detection	RF+ Motion Sensors	➢ High sensitivity ➢ Works in obstructed zones	➢ No mobility ➢ Limited coverage area	Fixed installations for restricted access zones.

Table 1: Literature Survey

2. PROPOSED SYSTEM

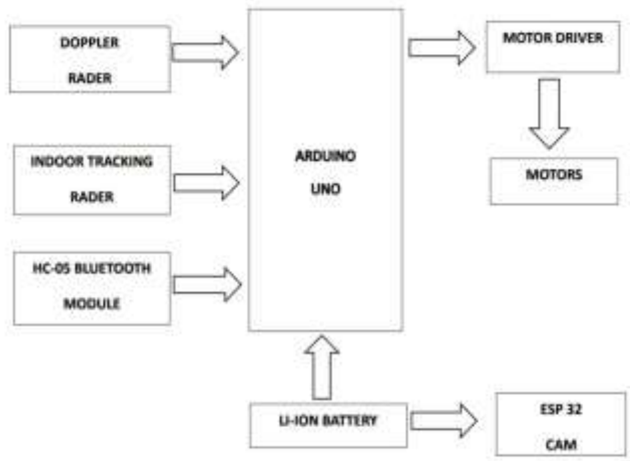

Figure 1: Block diagram of the proposed system

The proposed system is an indoor surveillance and tracking robot that works on its own. It uses several sensing and communication modules along with a microcontroller to detect motion, track objects, and monitor remotely in real time.

At its core is an Arduino Uno, which serves as the main processing unit. The system uses Doppler radar and an Indoor Tracking Radar to detect moving objects, as well as estimate their speed and location indoors. This feature allows the robot to identify possible targets or intrusions without depending only on optical sensors. As a result, it performs well in low-light conditions or areas where visibility is limited.

An ESP32-CAM module provides a live video feed for monitoring and gathering evidence. Users can access the camera stream remotely through Wi-Fi, which improves their situational awareness. An HC-05 Bluetooth module also allows wireless control and communication between the robot and a mobile app or computer interface for manual intervention when needed.

For movement, the system uses DC motors controlled by a motor driver module. This setup enables the Arduino to navigate the robot automatically based on sensor input or user commands. The entire system runs on a rechargeable Li-Ion battery, which makes it portable and ensures continuous operation during use.

By combining radar-based sensing with visual feedback and wireless communication, this system offers a strong and adaptable solution for indoor surveillance. It can carry out real-time motion detection, track objects automatically, and monitor remotely in various settings like offices, warehouses, and homes.

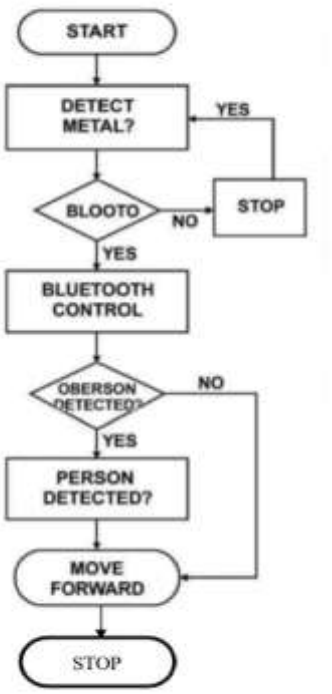

Figure 2: Flow Chart

Description of Flow Chart:

1. Begin

It starts up.

2. Can You Find Metal?

The system looks for metal.

If so, it proceeds to the following phase.

If not, the system shuts down.

3. The Bluetooth

The device looks for a Bluetooth connection or availability.

It moves on to Bluetooth control if it does.

If not, the system shuts down.

4. Bluetooth Management

The device switches to Bluetooth-controlled mode of operation.

5. Person Found

The system looks for human presence.

It moves on to the next check if it does.

If not, it goes back (perhaps carrying on the check until someone is found).

3. CONCLUSIONS

This project makes a big step forward in military robotics by combining obstacle-penetrating radar, real-time video, and wireless control into a single deployable unit. It overcomes the limits of traditional surveillance methods and provides a tactical edge in finding hidden targets. This makes it vital for defense and security operations. Future upgrades could include swarm robotics, 5G connectivity, and AI-driven analytics, which would further improve its performance on the battlefield.

A major breakthrough in counterterrorism technology is the robot controlled by Wi-Fi. It offers a dependable solution for detecting motion secretly and for remote control, due to the seamless integration of sensors, microcontrollers, and robotics. In high-risk situations, this project enhances efficiency and security. Such initiatives are crucial for developing technologies that safeguard the lives of workers in complex and evolving environments, especially as safety concerns increase.

Doppler radar technology is part of an automated system designed to detect people behind building walls in real time. Tests indicate that the detection speed is sufficient and can be adjusted based on the system's requirements for real-time performance. The proposed detection method may trigger false alarms when animals are nearby, as they might be mistaken for people. We can partially reduce this issue by remembering that most common pets, like dogs and cats, are smaller than humans.

4. FUTURE SCOPE

Traditional surveillance tools like optical cameras, IR sensors, acoustic devices, and bulky radar systems face challenges such as limited visibility, line-of-sight dependence, and environmental interference. These shortcomings are critical in scenarios like urban warfare, hostage rescue, and forest combat, where targets are hidden or obscured.

Doppler radar detects motion through barriers like wood and drywall by sensing shifts in radio waves. Unlike optical systems, it doesn't require visibility, enabling real-time tracking of hidden targets. This project utilizes DF Robot's low-power Doppler radar module, ideal for compact, portable robotic applications.

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