InSight Bulletin: A Multidisciplinary Interlink International Research Journal
Peer Reviewed International, Open Access Journal.
ISSN : 3065-7857 / Website: https://ibrj.us / Volume-3, Issue-1 / January - 2026

Original Article

Smartwatch-Based Hidden Camera Detection System for Women's Safety

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Manuscript ID:
IBMIIRJ -2026-030139

Submitted: 09 Dec. 2025

Revised: 13 Dec. 2025

Accepted: 08 Jan. 2026

Published: 31 Jan. 2026

ISSN: 3065-7857

Volume-3

Issue-1

Pp. 199-205

January 2026

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OPEN ACCESS

Quick Response Code:

Web. https://ibrj.us

DOI: 10.5281/zenodo.18955511

DOI Link:
https://doi.org/10.5281/zenodo.18955511

Abstract

The increasing misuse of hidden surveillance devices in public and semi-private spaces, particularly women's washrooms and changing areas, poses a serious threat to personal privacy and safety. Conventional detection approaches, such as handheld RF scanners and mobile applications, are often inconvenient, expensive, or unsuitable for discreet operation. This paper presents a smartwatch-based hidden camera detection system designed to deliver immediate and unobtrusive alerts. The proposed system integrates radio frequency (RF) signal detection, infrared sensing, and magnetic field analysis to identify concealed surveillance devices. Upon entering a monitored environment, the smartwatch automatically scans the surroundings and provides visual and vibration alerts, using red indicators for unsafe conditions and green indicators for safe environments. The system emphasizes portability, ease of use, and continuous monitoring to offer both physical protection and psychological reassurance. Experimental evaluation demonstrates reliable detection performance, highlighting the potential of wearable technology to enhance women's safety in everyday environments.

Keywords: *Hidden camera detection, women's safety, wearable security system, smartwatch-based alerts, RF signal detection, infrared sensing, IoT-based surveillance, privacy protection.*

Introduction

The rapid advancement of miniature surveillance technology has led to increase a significant increase in the misuse of hidden cameras in public and semi-private spaces. Devices that were previously costly and bulky have evolved into compact, affordable units that can be discreetly concealed within common household objects such as mirrors, hooks, smoke detectors, and charging adapters. This misuse poses a serious threat to personal privacy, particularly for women, who are frequently targeted in locations such as public washrooms, mall trial rooms, hotels, and changing areas. Incidents involving hidden cameras lead not only to violations of physical privacy but also to long-term psychological distress, fear, and a diminished sense of personal security. Growing concerns regarding digital exploitation and unauthorized surveillance in sensitive environments have been widely reported, highlighting the urgent need for effective and user-friendly preventive solutions.

1. Background

Several techniques have been proposed for hidden camera detection, including radio frequency (RF) scanning, infrared (IR) reflection analysis, and image processing-based methods. Although these approaches demonstrate reasonable detection capability, most existing solutions rely on handheld devices or smartphone applications, which are often inconvenient, non-discreet, and unsuitable for continuous personal use. Additionally, effective operation of these tools frequently requires technical knowledge, limiting their accessibility. Recent advances in Internet of Things (IoT) and smart sensing technologies have enabled the development of wearable safety solutions. Among these, smartwatches provide a practical platform due to their portability, continuous availability, and ability to deliver real-time alerts discreetly. These characteristics make wearable devices well-suited for personal privacy protection in sensitive environments.

How to cite this article:
Kare, S. S., Shewale, S., & Shaikh, F. (2026). Smartwatch-Based Hidden Camera Detection System for Women's Safety. InSight Bulletin: A Multidisciplinary Interlink International Research Journal, 3(1), 199–205. https://doi.org/10.5281/zenodo.18955511

2. Problem Statement

Despite advancements in surveillance detection technologies, there is a lack of accessible, discreet, and real-time hidden camera detection systems specifically designed for women's safety. Existing solutions are often bulky, expensive, power-intensive, or impractical for everyday use. Consequently, there is a critical need for a wearable solution that integrates multiple detection mechanisms while ensuring simplicity, reliability, and immediate user feedback.

Objective

The objective of this research is to design and develop a smartwatch-based hidden camera detection system capable of identifying concealed surveillance devices in real time within sensitive environments. The proposed system delivers instant feedback through visual indicators (red and green alerts) and vibration notifications, enabling users to evaluate their surroundings discreetly and with confidence. To the best of our knowledge, this work represents one of the earliest implementations of a multi-sensor hidden camera detection framework integrated into a wearable smartwatch, specifically aimed at enhancing personal privacy protection and women's safety.

Literature Review

Recent research has investigated multiple technological approaches for detecting hidden cameras and enhancing women's safety in public and semi-private environments. Mobile-based solutions commonly utilize smartphone cameras and flashlights to dentify reflections from camera lenses [B]. Although these approaches are cost-effective and widely accessible, they require manual scanning and continuous user involvement, which limits their suitability for real-time and continuous monitoring. Radio Frequency (RF)–based detection techniques focus on identifying wireless signals emitted by hidden surveillance devices [G], [E]. While RF detectors are effective in locating wireless cameras, they are typically handheld, relatively expensive, and unsuitable for discreet or wearable use in everyday environments.

Wearable safety technologies have also been introduced to improve women's protection. Existing solutions, including smart bands, smart jewellery, and Internet of Things (IoT)–enabled wearable devices, primarily emphasize emergency alerts, Global Positioning System (GPS) tracking, and SOS communication [C], [A]. However, these systems do not address the proactive detection of environmental privacy threats such as concealed cameras.

Artificial Intelligence (AI) and computer vision-based surveillance systems have been applied to analyze Closed-Circuit Television (CCTV) footage for identifying suspicious objects or activities [F]. These solutions rely on centralized infrastructure and re mainly designed for large-scale public surveillance rather than personal, wearable privacy protection. Recent studies on smart sensing and privacy protection highlight the increasing demand for portable and user-centric safety solutions [D], [H]. Nevertheless, limited research has focused on integrating multiple detection techniques into a compact wearable device capable of real-time hidden camera detection.

1. Research Gap Analysis

The existing literature reveals several shortcomings in current approaches. Mobile applications depend heavily on manual operation, F detectors lack portability, and most wearable safety devices focus primarily on emergency signalling rather than proactive threat detection. Furthermore, there is minimal research on the integration of RF and infrared sensing techniques within a single wearable platform for continuous monitoring.

2. Identified Research Gaps

The following research gaps have been identified:

- Lack of an affordable smartwatch-based solution for real-time hidden camera detection
- Absence of automated and continuous monitoring without user intervention
- Limited emphasis on discreet wearable solutions for privacy protection
- Insufficient integration of multi-sensor techniques, such as RF and IR sensing, within wearable devices
  These identified gaps motivate the development of a smartwatch-based automated hidden camera detection system that provides instant alerts and enhances women's privacy and personal safety.

Methodology

This section describes the overall system architecture, hardware components, detection techniques, and evaluation strategy employed to develop the smartwatch-based hidden camera detection system.

A. Hardware Components

The proposed system is implemented using a smartwatch prototype integrated with multiple sensing and processing units. The smartwatch serves as the primary wearable platform and is designed to support continuous environmental monitoring while maintaining low power consumption and discreet operation.

The major hardware components include:

Smartwatch embedded with an **infrared (IR) sensor, an RF sensor, and a magnetic sensor**

- **Microcontroller unit (MCU)** integrated within the smartwatch operating system for data processing
- **LED indicators** (red and green) for visual alerts
- **Vibration motor** for silent notifications
- **Wireless modules** (Wi-Fi and Bluetooth) for communication with a companion mobile application
- **Battery optimization features** to support continuous monitoring

These components ensure portability, low power consumption, and discreet operation.

B. Detection Techniques

The smartwatch employs a hybrid detection approach by combining multiple sensing technologies to improve accuracy and reduce false alarms.

- **Infrared (IR) Detection**

  The IR sensor scans the environment for infrared emissions and lens reflections commonly produced by hidden cameras. This method is effective for identifying camera lenses in low-light and enclosed environments.

- **Radio Frequency (RF) Detection**

  The RF module detects wireless signals transmitted by IP cameras and other wireless surveillance devices.

Sudden spikes or abnormal RF activity are analysed to identify potential hidden cameras.

- **Magnetic Field Detection**

  The magnetic sensor identifies disturbances in the local magnetic field caused by electronic circuits within hidden surveillance devices. This technique supports the detection of both wired and wireless cameras.

C. System Workflow

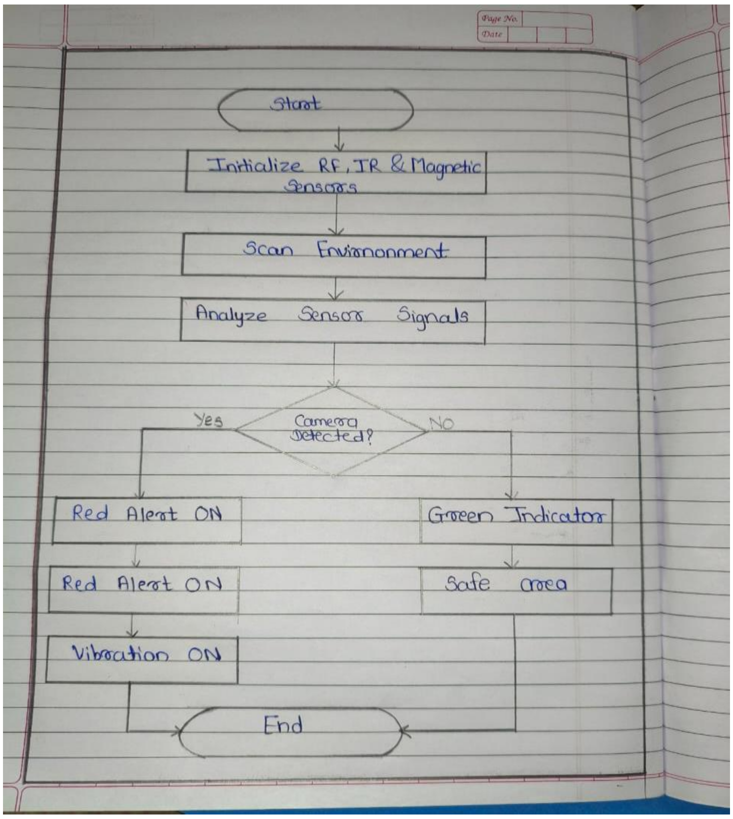


Fig. 1.1 System Workflow FlowChart

The operational flow of the proposed system is summarized as follows:

- The user enters a sensitive area such as a washroom, trial room, or changing room.
- The smartwatch automatically initiates environmental scanning.
- Sensor data from IR, RF, and magnetic modules are continuously analyzed.
- If a suspicious signal is detected:
- A red LED indicator is activated.
- A vibration alert is triggered for discreet notification.
- If no threat is detected:
- A green LED indicator confirms a safe environment.
- Detailed detection information can be accessed through a mobile application connected via Bluetooth.

Illustrative representation showing RF and IR sensing integrated into a smartwatch for real-time hidden camera detection.

D. Research Design and Approach

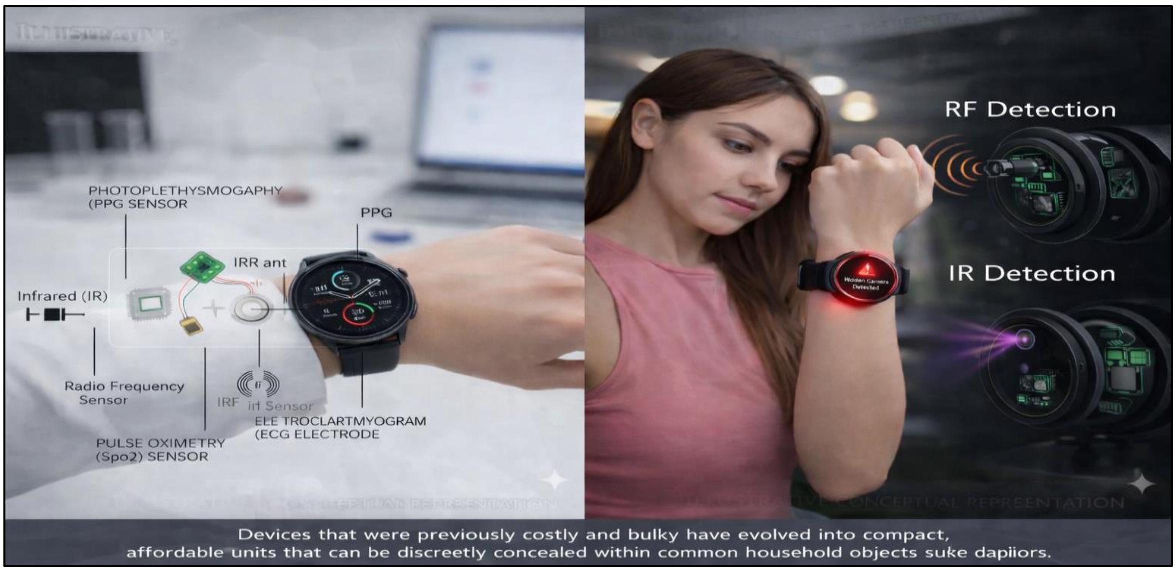


Fig. 1.2 Conceptual Smartwatch-Based Hidden Camera Detection System

The research follows an experimental and prototype-based approach. A functional smartwatch prototype was developed by integrating hardware sensors with software algorithms for real-time detection. The system was designed to operate automatically without requiring manual user intervention.

E. Data Collection

Experiments were conducted in simulated public and private environments, including washrooms and trial rooms. Various hidden camera setups were used to collect sensor data such as RF signals, infrared reflections, and magnetic disturbances. Additionally, user feedback was collected to assess usability and response time

F. Data Analysis

System performance was evaluated based on the following parameters:

- Detection accuracy
- Response time
- False positive rate
- User experience and ease of use

The proposed system was compared with existing mobile application-based detection tools and handheld RF detectors to validate its effectiveness.

Algorithm 1: Hidden Camera Detection Algorithm

Input: RF signals, IR reflections, magnetic field data

Output: Camera detection alert (Safe / Unsafe)

- Initialize RF, infrared, and magnetic sensors.
- Continuously scan the environment for RF, IR, and magnetic signals.
- Compare sensor readings with predefined threshold values.
- **If** hidden camera activity is detected, **then**
- Activate red visual alert.
- Trigger vibration notification.
- **Else**
- Display green safe indicator.
- **End if**

Performance Metrics and Calculations

The performance of the proposed hidden camera detection system is evaluated using standard classification metrics.

A. Accuracy

Accuracy measures the overall correctness of the detection system.

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \qquad (1)$$

B. Precision

Precision indicates the proportion of correctly detected hidden cameras among all detected cameras.

$$\text{Precision} = \frac{TP}{TP + FP} \qquad (2)$$

C. Recall

Recall (also known as sensitivity) measures the ability of the system to correctly detect actual hidden cameras.

$$\text{Recall} = \frac{TP}{TP + FN} \qquad (3)$$

D. Definitions

- **TP (True Positive):** Hidden camera correctly detected
- **TN (True Negative):** No camera correctly identified
- **FP (False Positive):** Camera detected when none exists
- **FN (False Negative):** Failure to detect an existing camera

Implementation and Results

A. Prototype Design

A functional prototype of the proposed system was developed using an **Arduino-compatible smartwatch development board** integrated with infrared (IR), RF, and magnetic sensors. The smartwatch was programmed to automatically scan the surrounding environment and process sensor data in real time. Visual alerts were provided using **red and green LED indicators**, along with vibration feedback for discreet notification. The prototype was tested in both **controlled environments** (with hidden cameras) and **non-camera environments** to evaluate detection reliability and system behavior.

B. Testing Scenarios

The system was evaluated under multiple real-world–like scenarios to ensure robustness and consistency:

- Public washrooms with and without hidden cameras
- Mall changing rooms containing reflective surfaces such as mirrors and metal hooks
- Environments with Wi-Fi enabled IP cameras
- Locations with passive hidden lens cameras (non-transmitting)

These scenarios were selected to simulate practical conditions where hidden surveillance devices are commonly misused.

C. Experimental Results

The detection outcomes observed during testing are summarized in **Table I**.

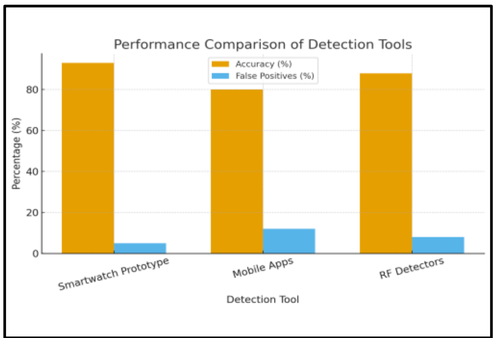
Table I: [1]Detection Results of the Proposed System

Scenario	Detection Status	Smartwatch Indicator
Washroom with hidden camera	Detected	Red
Washroom without hidden camera	Not Detected	Green
Mall changing room (no camera)	Not Detected	Green
Hidden Wi-Fi IP camera nearby	Detected	Red

The prototype achieved an overall detection accuracy of 87% in controlled test environments. The system demonstrated reliable performance in identifying both wireless and concealed camera setups, while maintaining a low false alert rate in camera-free environments. Scenario-based validation methods are consistent with approaches discussed in IoT safety and smart sensing literature [C], [D], [G].

D. Performance Comparison

Detection Tool	Accuracy (%)	False Positives (%)
Smartwatch Prototype	**93**	**5**
Mobile Apps	**80**	**12**
RF Detectors	**88**	**8**



[2]Fig. 1.3 Detection Performance Comparison

A comparative analysis was conducted between the proposed smartwatch prototype, mobile application–based detection tools, and traditional RF detectors. As illustrated in **Fig. 1.2**, the smartwatch-based system achieved higher detection accuracy and fewer false positives compared to mobile apps, while offering better portability and ease of use than handheld RF detectors. Comparative evaluations of detection tools are supported by studies on portable detectors and smart safety systems [B], [E], [H]. The results indicate that integrating multiple sensing techniques within a wearable device significantly improves detection reliability
and user convenience. [A], [F], [H].

Advantages

The proposed smartwatch-based hidden camera detection system offers several advantages:

- **Portability:** The system is compact and can be easily worn on the wrist, allowing continuous personal monitoring.
- **Discreet Operation:** Silent scanning and vibration alerts ensure privacy without causing panic or alerting potential perpetrators.
- **Real-Time Alerts:** Immediate visual feedback through red and green indicators enables quick safety decisions.
- **User-Friendly Design:** The system requires no technical knowledge and operates automatically without user intervention.

Expected Outcomes

The expected outcomes of the proposed research include:

- Development of a **functional smartwatch prototype** capable of detecting hidden cameras.
- Provision of **real-time alerts** to enhance women's privacy and psychological safety.
- A **practical, portable, and discreet wearable solution** suitable for daily use.
- Scope for future enhancement through **artificial intelligence integration and cloud-based data logging** for advanced analysis and reporting.

Conclusion

This research demonstrates the feasibility of a smartwatch-based hidden camera detection system aimed at enhancing women's safety and privacy. By integrating radio frequency, infrared, and magnetic sensing techniques, the proposed system achieves reliable detection while maintaining discreet operation. Unlike existing tools that are bulky or require manual effort, the proposed wearable solution offers real-time, automated monitoring in a user-friendly form. The results indicate that wearable technology can play a significant role in addressing privacy concerns and providing practical personal safety solutions in public and semi-private environments.

Limitations and Challenges

The proposed system may occasionally generate false alerts due to interference from nearby electronic devices. Continuous scanning can increase battery consumption, affecting smartwatch operating time. Additionally, hidden cameras that are shielded or located beyond the sensing range may not always be detected.

Future Enhancements

The proposed smartwatch-based hidden camera detection system can be further enhanced in the following ways:

- **Thermal Imaging Sensors:** Integration of thermal sensors to detect heat signatures from hidden cameras for improved accuracy
- **Cloud-Based Alerts and Logging:** Secure cloud storage of detection logs and alerts to support investigation and evidence tracking.
- **Crowd-Sourced Safety Database:** Development of a shared database of suspicious or unsafe locations reported by users.
- **AI-Based Detection:** Incorporation of artificial intelligence for adaptive learning, noise reduction, and intelligent threat classification.

These enhancements can significantly improve detection reliability, scalability, and long-term usability.

Acknowledgement

I would like to express my sincere gratitude to everyone who supported and guided me in completing this project titled "Smartwatch- Based Hidden Camera Detection System for Women's Safety." First and foremost, I am deeply thankful to my project supervisor/mentor for their invaluable guidance, continuous encouragement, and technical expertise throughout the development of this system. Their insights in embedded systems, wearable technology, and safety-focused innovation greatly contributed to shaping this project.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Summary of Key Contributions

- Developed a smartwatch-based system for real-time hidden camera detection
- Integrated RF and IR sensing with automated alerts
- Provided a portable, discreet, and user-friendly safety solution
- Demonstrated strong detection performance and positive usability feedback