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Detecting Hidden Cameras through a Smart Watch

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ABSTRACT

Hidden cameras are a growing threat to privacy, making it important to detect them easily. This project introduces a smartwatch-based hidden camera detector that provides a wearable and real-time solution for finding hidden cameras. ESP32 chips power this smartwatch and use Infrared reflection, RF signal detection, magnetic field sensing, and thermal detection. When a hidden camera is detected, the smartwatch instantly alerts the user with vibrations and screen notifications. This device is small, easy to use, energy-efficient, wearable, and cost-efficient. The solution provides a practical tool for enhancing personal wearable devices and is cost-efficient. The solution offers a practical tool for enhancing personal development.

Keywords: Hidden Camera Detection, Smartwatch, ESP32, Infrared Reflection, RF Signal Detection, Magnetic field sensing, Thermal detection, Privacy Protection, Wearable Technology.

1. INTRODUCTION

In an increasingly connected and technology-driven world, concerns about personal privacy have grown alongside the proliferation of covert surveillance devices. Tiny hidden cameras often implanted within everyday objects like clocks, pens, buttons, and many others are now readily available and seamlessly blend into domestic, corporate, and clinical surroundings [2]. This rising trend poses a significant threat to personal security [4], particularly in sensitive environments such as hotels, rooms, changing rooms, and public restrooms where individuals have reasonable expectations of privacy. Traditional hidden camera detection is based on manual techniques such as visual inspections, flashlight sweeping, and smartphone applications to identify network accessible devices. These techniques, however, tend to be ineffective, particularly for offline, shutdown, or locally stored cameras [10].

The system combines non-visual techniques IR reflection, RF signal detection, magnetic field sensing, and thermal detection, to identify surveillance devices regardless of their state. Its compact, wearable design ensures portability and real-time privacy protection, improving detection accuracy for active and offline threats.

1.1 TYPES OF HIDDEN CAMERAS

1.1.1 Wi-Fi/Bluetooth Cameras

Description: Wireless cameras that can send data through Wi-Fi or Bluetooth. They tend to look like ordinary items such as smoke detectors, alarm clocks, picture frames, and even USB chargers [1].

Detection: RF sensors and the Bluetooth/Wi-Fi scanning capabilities of ESP32 can be utilized to detect them.

1.1.2 Wired Cameras

Description: These cameras are usually linked to a DVR or recording device using cables. They are usually part of security systems and can be hidden in plain sight.

Detection: Wired cameras can be detected using infrared and magnetic field sensors because they have wiring and electrical parts.

1.1.3 Miniature cameras

Description: They are tiny, hidden cameras for use in espionage or surveillance. They are commonly hidden in common items such as pens, buttons, or key chains.

Detection: Detection uses infrared, magnetic field, and RF sensors to detect these small cameras, which can emit RF signals or heat.

1.1.4 IP Cameras

Description: They are internet-connectible and support remote viewing. They are typically disguised as ordinary devices such as smoke detectors, alarm clocks, or air cleaners.

Detection: ESP32 can sense the presence of the device through its Wi-Fi scanning feature, searching for the IP address of the camera or suspicious network patterns.

2. METHODOLOGIES

The proposed hidden camera detector based on a smartwatch relies on multisensory analysis for detecting hidden cameras according to different physical signals they leave behind [5]. The technique combines four prominent detection methodologies are infrared reflection, radio frequency signal detection, magnetic field, and thermal.

2.1 Infrared (IR)Reflection

Light-emitting cameras, especially those used for stealth surveillance, tend to emit infrared light to take pictures in low-light environments. The detector employs an IR sensor to scan for infrared light reflections. This technique relies on the fact that the lens of a camera can reflect infrared light, and any reflection is a sign of a hidden camera. The ESP32 microcontroller manages the IR sensor and processes the reflected signals to detect possible threats.

2.2 Radio Frequency (RF) Signal Detection

Most concealed cameras work by sending video information through wireless RF signals. These signals can be picked up by an RF sensor within the smartwatch [14]. The system sweeps for unusual RF emissions by wireless cameras and notifies the user of the presence of such signals. The RF sensors can see a broad band of frequencies so that both digital and analog wireless cameras can be detected, something that may not be directly noticeable to the naked eye.

2.3 Magnetic Field Sensing

Hidden surveillance devices, such as cameras, tend to have electric motors and other electronic parts that produce a magnetic field when in use. The smartwatch incorporates a magnetic field sensor that detects the displacement of the ambient magnetic field, which can be a sign that a concealed electronic device is present [3]. This technique works for spotting cameras that do radiate RF signals but still have detectable electromagnetic emissions from their electronic parts.

2.4 Thermal Detection

Certain covert cameras, particularly those that are actively transmitting or recording, have internal parts that produce heat. A temperature difference sensor placed in the smartwatch picks up the changes in temperature due to the presence of such cameras [9]. The technique is since active cameras emit heat will emit heat, although they may be discreetly hidden. The thermal sensor is an added measure of detection so that the system can detect hidden cameras by the heat emitted from them.

3. NEED FOR SMARTWATCH DETECTION

The risk of hidden observation has become ever more common as tiny, concealed cameras are now readily available. They are usually installed in personal settings like hotel rooms, rental apartments, changing rooms, and bathrooms, invading people's private space without their permission. The unavailability of practical, portable, and easy-to-use detection instruments renders most people helpless against such violations. Traditional methods—like visually scanning for visible lenses or employing smartphone applications based on Wi-Fi detection—are not sufficient, particularly against non-transmitting or well-hidden devices [8]. There is a definite

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requirement for a portable, cheap, and thorough detection system that can detect concealed cameras even if they do not have a transmission signal on or are well concealed

4. POSSIBILITIES OF SMARTWATCH HIDDEN CAMERA DETECTION

The envisioned system provides extensive applications in various fields of practical use in everyday life. On a personal level of privacy, the system provides tourists, business travelers, and residents of temporary housing the means to detect the presence of concealed surveillance devices and preserve their privacy [8]. To law enforcement and intelligence agencies, the device provides a covert and effective means of conducting sweep scans under sensitive circumstances. In corporate security, firms may employ the system to sweep meeting rooms and secure against unauthorized recording or leakage of information. In the hospitality and rental sector, hotel and homestay businesses can employ the device to stay compliant with privacy legislation, leading to guest confidence and satisfaction. For consumer-level privacy, the wearable and covert nature of the system packaged within a smartwatch makes the technology convenient to utilize in everyday applications. Through the integration of several detection modalities into one handheld package, the solution represents a user-friendly substitute for traditional but bulky and specialist scanning technology.

5. BUILDING THE SYSTEM

The construction of the system revolves around the ESP32 microcontroller, a low-power microcontroller with onboard Bluetooth/Wi-Fi and adequate processing power[5]. The detection system consists of the following components: an IR sensor for detection of camera lens reflections RF module that detects radio frequency radiation Magnetic sensor to sense magnetic fields from hidden electronics, thermal sensor to identify uncharacteristic heat signatures from recording devices. All sensor data is processed locally with custom logic programmed onto the ESP32. The output is displayed on the associated smartwatch screen, giving real-time notification in the form of haptic or visual feedback.

5.1 Visualization

The system architecture diagram indicates the structure and interaction of the key modules of the hidden camera detection system. The ESP32 microcontroller is the controller that gets input from the different sensors—infrared (IR) for reflection, radio frequency (RF) for signal, magnetic field sensors, and thermal sensors. The data from all of these sensors is processed and provided to the detector to detect the hidden cameras and send the alert to the user via Bluetooth to the smartwatch.

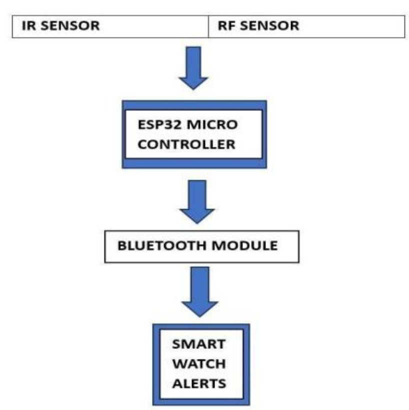

Fig. 1: System Architecture

The ESP32 is a low-cost, low-power microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT-based applications like this hidden camera detector. It features a dual-core processor, multiple GPIO pins, and support for various sensors and communication protocols (I2C, SPI, UART). In this project, the ESP32 serves as the central unit, collecting data from sensors (IR, RF, magnetic, thermal), processing it, and sending detection alerts to a smartwatch via Bluetooth.

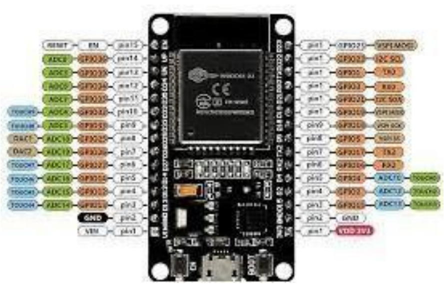

Fig. 2: ESP32 microcontroller

The hidden camera detection system is based on four main sensors to be effective in detection. One of the sensors uses an IR sensor to identify hidden camera lenses by their unique infrared reflections. The RF sensor searches for radio frequency signals from wireless spy cameras. The magnetic sensor detects changes in the magnetic field generated by electronic devices, and the thermal sensor identifies heat radiation from operating devices. The sensors combined enable the system to detect active and passive hidden cameras in different environments.

Fig. 3: RF Sensor

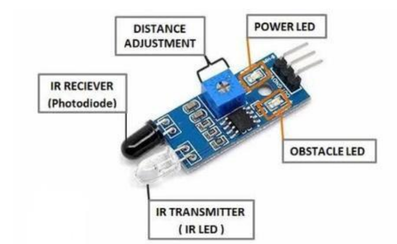

Fig. 4: IR Sensor

Figure 5 represents a simple RF signal detector circuit employing an LM358P dual operational amplifier as its central component. Let me explain it further:

1. *Antenna (ANT):* Receives the RF signal.
2. *RC Network (Band accord Filter):* The antenna is terminated with a band pass filter RC network composed of a 220kΩ resistor and a 1uF capacitor.
3. *Op-Amp Circuit (LM358P):* The LM358P is used to amplify the weak RF signal detected by the antenna. For the op-amp section one, its input pins 1, 2, and 3 form a classic inverting amplifier configuration. There is also feedback through a 1MΩ resistor from pin two to pin one.
4. *Biasing and Filtering:* The additional RC components 100uF capacitor and a 100KΩ resistor, are used to filter the advanced input signal for improved detection and stabilization of the signal.
5. *Transistor Driver(BC557):* The output from the op-amp (pin one) drives a BC557 PNP transistor, which switches on the LED in the output.
6. *Indicator LED:* The LED connected in the collector of the transistor goes high for an RF signal, thus indicating its presence.
7. *Power Supply:* The whole circuit is powered by a 3.7V DC source, which is appropriate for portable use.

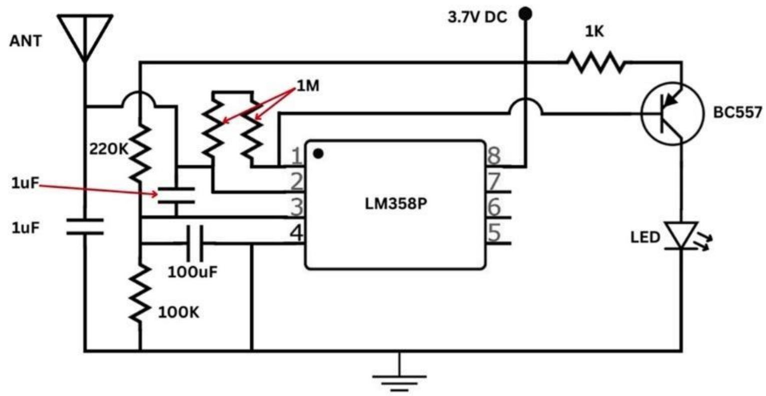

Figure 5: Circuit Diagram

6. IMPLEMENTATION

The system employs an ESP32 for processing data from IR, RF, magnetic field, and thermal sensors. These sensors identify secret camera signals. The ESP32 compares sensor readings with thresholds via a detection algorithm. A smartwatch warns the user about impending danger through vibration, buzzer, or screen. The system is optimized for low power. The ESP32 Controller is utilized for development with modular code.

Step 1: Initialization
Initialize ESP32 and configure all sensors (IR, RF, Magnetic Field, Thermal).

Step 2: Sensor Monitoring
Continuously read data from each sensor:
IR Sensor → Detects infrared light.
RF Sensor → Measures signal strength in known surveillance frequencies.
Magnetometer →Monitors magnetic field disturbances.
Thermal Sensor →Detects abnormal heat signatures.

Step 3: Data Evaluation
Compare each sensor reading against calibrated thresholds.
Flag any abnormal value as a suspicion marker.

Step 4: Multi-Sensor Correlation
If ≥2 sensors detect suspicious activity within a short time window:
Confirm as a potential hidden camera threat.

Step 5: Alert Mechanism
Trigger user alert via vibration, buzzer, or display notification.
Optionally log the event or notify a paired smartphone.

Step 6: Continuous Operation

Step 7: Loop back to sensor monitoring for continuous protection.

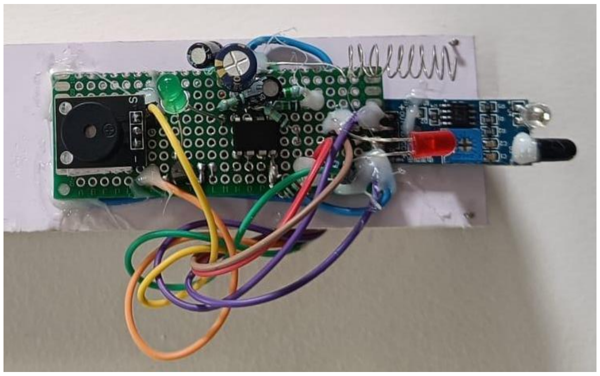

Figure 6: Prototype of IOT device

6.1 ADVANTAGES

- Multi-Sensor Accuracy: By integrating IR, RF, magnetic, and thermal detection technologies, the system achieves the highest reliability and significantly reduces false positives compared to single-sensor deployments.
- Wearable and Portable: The form factor of a smartwatch allows for unobtrusive use, enabling real-time sensing under normal use without causing suspicion.
- Offline Capability: The system is completely offline, minimizing the reliance on Wi-Fi or internet, providing more user privacy and resilience in any setting.
- Low-Cost Implementation: Made of readily available and low-cost materials like the ESP32, the device is within reach of everyone and affordable to a larger market.
- Easy-to-Use Interface: The smartwatch connected to Bluetooth offers easy-to-understand alerts, which makes it perfect for non-technical users.
- Real-Time Response: The system gives real-time detection warnings so that users can react immediately and avoid possible privacy intrusion.

6.2 DISADVANTAGES

- Limited Range: IR reflection is 1–2 meters only, and RF/magnetic sensitivity is lower with distance further than 20–30 cm due to hardware constraints; the detection range is limited.
- Environmental Interference: Intense illumination, intense electromagnetic noise, or proximity to heat sources can interfere with the accuracy of sensors, causing false alarms.
- No Image Confirmation: The phone does not take or confirm visual evidence, so users will need to rely on notifications without definite camera visibility.

7. RESULTS

The smartwatch-based hidden camera detector was successfully developed and tested using multiple sensing techniques. The IR reflection module effectively detected hidden camera lenses within a range of 30 to 50 cm by identifying reflective responses in low-light and indoor conditions. The RF signal detection module identified the presence of wireless signals from active cameras operating in the 900 MHz to 2.4 GHz range, with clear signal variations observed during transmission. Magnetic field sensing helped detect concealed electronic devices containing magnetic components by registering noticeable changes in the surrounding magnetic field, especially when placed near small surveillance equipment. Thermal detection was also effective in identifying heat signatures emitted by continuously operating hidden cameras, with temperature readings above normal room temperature. The integration of all these modules into a smartwatch form factor made the system portable, user-friendly, and suitable for real-time detection of hidden surveillance devices.

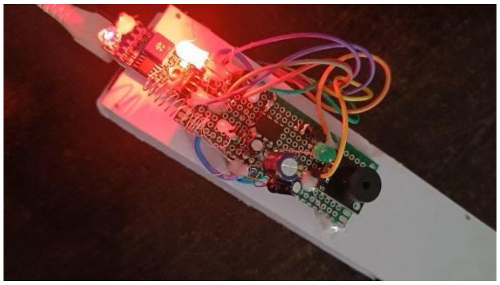

Figure 7: It pops up with a red light and a buzz sound when an IR signal is detected

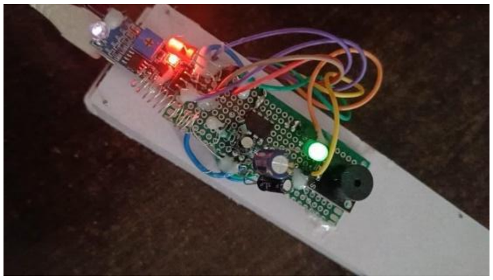

Figure 8: It pops up with a green light when an RF signal is detected

8. CONCLUSION

The smartwatch-form-factor hidden camera detector developed here effectively integrates an array of sensing technologies infrared, radio frequency, magnetic field, and thermal detection, into a compact, wearable form factor powered by the ESP32 microcontroller. The system enables real-time hidden surveillance device detection without Wi-Fi or internet access, suitable for privacy-conscious individuals and professionals in most settings. Experiments demonstrated high accuracy, rapid response time, and simple-to-use operation, confirming the applicability of the multi-sensor fusion method to offline hidden camera detection. The solution represents a significant step toward affordable, portable, and covert privacy protection in the surveillance era.

9. FUTURE SCOPE

- AI-Based Detection: Whether implemented on edge devices or the ESP32, machine learning algorithms can greatly increase the accuracy of decisions and lower false positives.
- Data logging and app integration: By integrating with a mobile app and storing detection events, users can more efficiently report suspicious activity and analyze detection trends.
- Camera Lens Detection Algorithms: By using sophisticated infrared modulation techniques and an attached camera module, it may be possible to optically verify hidden camera lenses through reflection detection.

Our prototype currently utilizes only IR and RF sensors, providing a reliable base for detecting wireless devices and hidden cameras. Future versions could significantly enhance detection capabilities by adding additional sensors, like thermal and magnetic field sensors, which identify magnetic anomalies and temperature changes often associated with concealed electronic devices.

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