Design and Implementation of a Solar-Driven Spy Security Motion Detector

Oyebamiji Hammed Lasisi, Salami Sulaimon Abiodun*, Oluwaseun Joel Olasunkanmi, Babatunde Mujeeb, and Ayobami Tewogbade

Department of Electrical and Electronics Engineering, Osun State University, Osogbo, Nigeria.

Email: sulaimon.salami@cset.uniosun.edu.ng

Article Information:

Received:
18 March 2025

Received in revised form:
21 May 2025

Accepted:
3 June 2025

Volume 7, Issue 1, June 2025
pp. 24 – 30

http://doi.org/10.23960/jesr.v7i1.216

Abstract

This project designs and implements a solar-powered spy security system with motion detection capability. The system integrates a solar panel, charge controller, battery, PIR sensor, 555 timer IC, buzzer, WiFi module, and a spy camera. The solar panel recharges the battery, providing a sustainable power source. The PIR sensor detects motion, triggering the 555 timer IC to activate the buzzer and spy camera. The system captures images or records videos only when motion is detected, conserving energy and memory space. The spy camera connects to a smart device via WiFi, enabling remote viewing of captured footage. Testing demonstrated the system's effectiveness as a reliable and efficient security solution. This project addresses the limitations of traditional CCTV cameras, providing a more efficient and sustainable solution for home security. The design leverages principles of electrical and electronics engineering, including circuit design, electronics, and control systems. Future enhancements can include integrating Artificial Intelligence to improve security and reduce false alarms.

Keywords: *Solar-Powered, Spy Security System, Motion Detection, Sustainable Security, Home Security*

I. INTRODUCTION

Motion detection is the process of sensing physical movement in a specific area. This can be achieved through mechanical or electronic devices. Mechanical devices, such as tripwires, detect movement through physical interaction but are vulnerable to tampering. Electronic devices, including motion detectors, offer enhanced security using optical or acoustical detection methods.

These devices employ sensors, infrared light, or laser technology to detect movement, triggering alarms, recording devices, or cameras. Motion detectors can be integrated with cameras and computer networks for remote monitoring. Applications include detecting unauthorized entry, occupancy sensing, and triggering cameras to record events, making motion detection a fundamental component of electronic security systems.

Motion detection methods utilize various approaches to track human movement and detect objects. Device-based solutions, such as those using accelerometers and gyroscopes, require users to carry smartphones or wear devices, providing accurate but potentially inconvenient data (Zhang et al., 2019).

Alternatively, CCTV security systems can effectively monitor areas like parking stations, helping to prevent crimes such as vehicle theft (Gossain & Gill, 2018). These systems can capture images, detect motion, and send remote notifications.

For real-time video object detection, methods include Frame Difference, Background Subtraction, and Block Matching (Tsai & Lai, 2018). These approaches enable accurate detection of moving objects in various environments.

Object detection is a crucial aspect of security systems, and various technologies are employed to achieve this. However, detectors may face problems due to several reasons (Kumar et al., 2017). To address this, researchers have proposed innovative approaches, such as integrating detection algorithms to enhance object detection (Gaussian & Gill, 2018).

The use of Raspberry Pi, a cost-effective hardware piece with an inbuilt camera module, has been explored for object detection (Kumar et al., 2017). This system, combined with Open CV libraries, enables intelligent surveillance. Development identification faculties can detect trespassing and send ready signals to the dashboard, while automated sensors can track and inform users of trespasser presence (Kumar et al., 2017).

Automated video surveillance systems have also been discussed, highlighting approaches to automation and effective data storage (Jadhav et al., 2017). Additionally, sensor-based systems can detect trespassers and alert clients, enhancing home security (Natraj et al., 2017). The ultimate goal of these systems is to prevent crime through remote supervision, saving time, lives, and resources.

Visible cameras are widely used in surveillance systems to monitor environments, people, and activities (Ibrahim, 2016). Computer vision techniques also aid in automated surveillance, with methods like background subtraction and temporal frame differencing used for object detection (Mishra & Saroha, 2016).

Various methods exist for detecting motion and objects in continuous video streams, including comparing frames against previous ones or the background frame (Vidhya et al., 2016). Other approaches include background subtraction, frame differencing, and on-body monitoring sensors.

Researchers have also proposed device-free solutions for detecting human motion without requiring individuals to carry devices (Wang, 2013). However, existing solutions using cameras, passive infrared (PIR), audio, or RADAR have limitations, such as limited coverage and ambient noise.

Video surveillance security systems are effective in controlling theft in large indoor shopping malls, providing a safe and enjoyable shopping experience for customers (Bosman et al., 2007). However, device-based solutions that utilize contact sensors, such as accelerometers and gyroscopes, can be inconvenient and are not suitable for home security applications (Zhang et al., 2019).

To address specific security concerns, such as theft of motor vehicles in Ireland, CCTV security systems have been designed (Gossain & Gill, 2018). These systems consist of camera modes and base stations, enabling image capture, motion detection, and remote notifications. Real-time video object detection methods include Frame Difference, Background Subtraction, and Block Matching (Tsai & Lai, 2018).

Gossain and Gill (2018) proposed an innovative approach to enhance object detection using integrated detection algorithms. Image processing plays a crucial role in object detection, which is essential for various applications. However, object detection can be challenging due to several reasons.

Kumar et al. (2017) utilized Raspberry Pi to detect movement, identifying true elements such as face, audio, and pictures. Raspberry Pi, combined with Open CV libraries, enables intelligent surveillance. This system tracks people's utilization of the Raspberry Pi camera module, PIR sensor, and stores data in a database.

The system also features development identification faculties that detect trespassing and send ready signals to the dashboard. Programmed sensors begin working during the user's absence, tracking and informing them of trespasser presence in limited home areas.

Jadhav et al. (2017) discussed automated video surveillance, exploring approaches to automation and efficient data storage. This research contributed to the development of a project, adding functionality through textual data generation.

Natraj et al. (2017) developed a system that alerts clients when sensors detect trespassers, enhancing home security amidst rising crime rates. Existing security frameworks have limitations, such as restricted CCTV footage visibility.

Ibrahim (2016) highlighted the prevalence of visible cameras in surveillance systems, used to monitor environments, people, and activities. These cameras are widely available, ranging from low-cost IP cameras to high-performance professional CCTV systems, and have been extensively researched.

Mishra and Saroha (2016) highlighted the role of computer vision techniques in automated surveillance. Their research explored methods like background subtraction, statistical methods, and temporal frame differencing for object detection, as well as tracking methods like point tracking and kernel tracking.

Vidhya et al. (2016) discussed motion detection and object recognition in continuous video streams, noting that most approaches compare frames to detect motion. Various methods have been proposed, including background subtraction and frame differencing.

Khalid and Majeed (2016) introduced a GSM-based innovation using web cameras to capture images and send SMS alerts to owners in case of emergencies. Wang (2013) proposed device-free solutions for detecting human motion, but noted limitations in existing camera, PIR, audio, and RADAR-based systems.

Bosman et al. (2007) found that video surveillance security systems effectively control theft in large indoor shopping malls, benefiting both customers and owners. Effective surveillance systems can provide a better shopping experience for customers.

II. Literature Review

A. House Security System

A security system is a network of interconnected devices that work together to protect against potential threats. In the context of home security systems, these devices integrate with a central control panel to safeguard against burglars and other intruders.

Home security systems often include burglar and safety alarms, which are typically electronic. These systems consist of sensors connected to a control unit, which triggers an alarm response. Some systems can handle multiple missions simultaneously, such as fire, intrusion, and safety alarms.

Common features of home security systems include motion-triggered lights, which deter burglars by making it seem like someone is home. Infrared motion detectors are also used to detect and alert homeowners or police to potential intruders.

B. Solar System

Solar power converts sunlight into electricity through photovoltaic (PV) cells, concentrated solar power, or a combination of both. Concentrated solar power systems use lenses or mirrors to focus sunlight, while PV cells convert light into electric current.

A typical solar power installation requires the following components: Solar panels or modules, Solar charge controller, DTL Cable, Power Inverter and Solar Battery (for storage)

Solar panels produce electricity by converting sunlight into direct current (DC) electricity. PV cells, made from semiconductor materials, are the building blocks of solar panels. Each panel has a rated power output, determined by its voltage and current production, typically at 12 or 24 volts. The amount of current produced determines the panel's power output.

C. Motion Detector

A motion detector is a device that uses a motion sensor to detect movement and trigger an alert. Electronic motion detectors convert the detection of motion into an electric signal, which can be connected to a burglar alarm system to alert homeowners or security services.

Active sensors are commonly used in motion detectors, emitting optics or sound waves to detect motion. These sensors are often used in home security systems and can be purchased as inexpensive devices to add extra security and peace of mind for homeowners.

A simple example of an active motion detector is a doorway sensor that triggers a doorbell when someone enters. This type of sensor uses a beam of light that is broken when someone passes through the doorway, triggering the alarm.

Motion detectors are commonly used in security systems to monitor areas around exterior doors and windows. They offer a sense of protection and security for homeowners and commercial organizations. Electronic motion detectors transform physical movement into an electric signal, which can trigger various devices such as security systems, lighting, and audio alarms.

Motion sensors have diverse applications, resulting in various types, including infrared sensors. Infrared sensors are widely used in intrusion detection, fire/smoke detection, automatic light switches, and security systems. They have two forms: active and passive.

Active infrared detectors consist of a radiation source and an infrared sensor that detects interruptions in the radiation. These detectors are used as intrusion detectors, providing a path of radiation that an intruder is likely to interrupt.

Active infrared motion detection offers several advantages, including fast speed response, simpler optical system design, insensitivity to mechanical and acoustic noise, and low production cost.

In contrast, passive infrared motion detection detects heat energy radiated by objects, using an optical collection system and multiple sensing elements. However, PIR detectors can be falsely triggered by warm air movement or other disturbances.

Ultrasonic motion detectors are sensitive and fast-acting but can be triggered by environmental vibrations and have limited installation options due to easily blocked ultrasonic beams.

To address false triggering issues, newer PIR systems use two infrared sensors monitoring different zones, triggering the alarm only when both zones are activated in sequence, indicating a person's movement.

Given these considerations, active infrared sensors are chosen for this project due to their advantages. The image of an active and passive infrared sensor is shown in Figure 1 and Figure 2 respectively.

D. Hidden camera or spy camera

Spy cameras are typically disguised as ordinary objects and come in various types, suitable for different environments. They can be wired or wireless, with wired cameras connected to a storage device and wireless cameras transmitting recordings to a receiver. Spy cameras are valuable for protection, safety, and investigations, often used by law enforcement and businesses to gather evidence of theft or misconduct.

Security officers utilize spy cameras to monitor activities that cannot be captured with standard audio/video equipment. Figure 3 shows an image of a spy camera. Hidden cameras or spy cameras record individuals without their knowledge, often used in TV shows when subjects are unaware of being recorded. The term "spy camera" refers to situations where the subject would object to being recorded if they knew about the camera.

In contrast to spy cameras, "security cameras" are visible and often accompanied by warning notices. Hidden cameras, on the other hand, are not visible to the subject being filmed or are disguised as everyday objects. These cameras can be equipped with long-focus lenses or placed behind two-way mirrors to remain undetected.

Hidden cameras can be cleverly concealed within common objects such as TVs, smoke detectors, alarm clocks, motion detectors, pens, plants, and even mobile phones. They can be used for household surveillance, as well as for commercial or industrial purposes, including spying.

Figure 1. Active Infrared Sensor

Figure 2. Passive Infrared sensor

Figure 3. Spy Camera

III. Materials and Methods

The design comprises various units of electronic circuit operations, which include the Power Supply Unit, Switching and Sensing Unit, Controlling Unit, and Alarm and Capturing Unit. These units are illustrated in the block diagram shown in Figure 4.

A. Circuit Operation

We have two circuit boards with the same operational system but different functions. One circuit is designed to keep a buzzer sounding with a 5-second delay, while the other circuit powers a spy camera to capture footage for less than a minute, as illustrated in Figure 5. The circuit diagram shows that the current from the power supply enters the PIR sensor through the Vcc and GND terminals and also enters the IC 555 timer through pins 1 and 8. The output signal from the sensor is stepped down with a 1K resistor (R3) and amplified by a BC547 transistor (T1) before entering the IC 555 timer through pin 2. An output signal from pin 3 of the IC is connected to a 1K resistor (R5) and a transistor (T2) that serves as a switch for the spy camera. Additionally, C3 and R4 are connected to pins 6 and 7 of the IC.

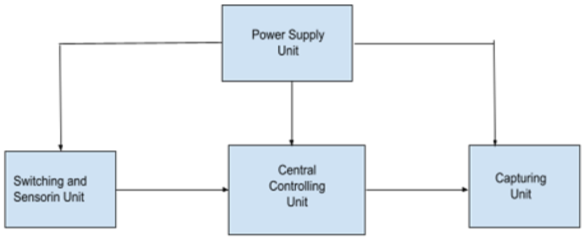

Figure 4. Block Diagram of the Circuit

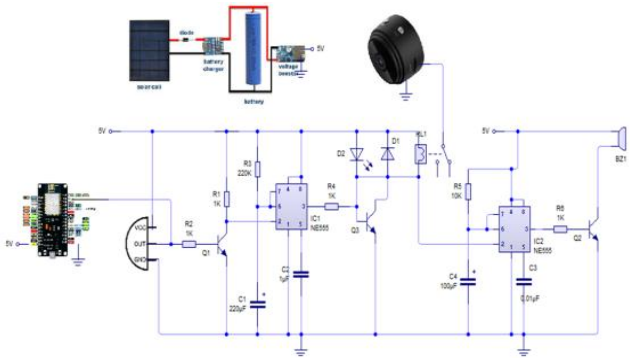

Figure 5. Camera and Buzzer Timer Circuit diagram

B. Power supply unit

Figure 6 illustrates the connection of the Power Supply Unit. The unit consists of a solar system, featuring a 1-watt solar panel connected to a charge controller. The charge controller stabilizes the direct current from the panel to charge a 3-volts lithium iron battery. The battery is then connected to a boost converter, which amplifies the voltage to 5 volts before supplying it to the circuit, as shown in Figure 5.

C. Switching and Sensing unit

The sensing unit comprises an infrared sensor that detects moving objects or people through vibration. When motion is detected, the PIR sensor outputs a HIGH signal on its output pin, which is read by the

555 timer IC, triggering a transistor to switch a higher current load. The PIR sensor has a detection range of 7 meters with a 140-degree conical angle, a delay time of 16 seconds (adjustable), and an operating ambient temperature of 253K-323K. The sensor is powered directly from the 5V DC supply pin, and its output is connected as the input to the 555 timer IC, as illustrated in Figure 5.

D. Controlling unit

The controlling unit's circuit diagram is shown in Figure 7, featuring the 555 timer IC as the primary component. This IC is versatile, used in applications like oscillation, pulse generation, and timing. It can be designed using various components, including transistors, resistors, diodes, and flip-flops. The IC operates within a 4.5V-15V DC supply range.

The 555 timer IC's functional parts include a flip-flop, voltage divider, and comparator, with its primary function being to generate accurate timing pulses. In monostable mode, the delay is controlled by external components like resistors and capacitors. In astable mode, the duty cycle and frequency are controlled by two external resistors and one capacitor. Figure 8 illustrates the graphical method for determining the capacitor and resistor values based on the desired delay time.

The 8-pin 555 timer IC has specific functions for each pin. The pin configuration is shown in Figure 9. Pin 1 is the GND pin, supplying zero voltage to the IC. Pin 2 is the trigger pin, converting the flip-flop from set to reset. The output depends on the external trigger pulse's amplitude. Pin 3 is the output pin, while pin 4 is the RST pin, which disables or resets the IC when a negative pulse is applied. Pin 5 is the control voltage pin, controlling the output waveform's pulse width and threshold and trigger levels. Pin 6 is the threshold pin, contrasting with a reference voltage to determine the flip-flop's set state. Pin 7 is the discharge pin, discharging a capacitor between intervals to toggle the output from high to low. Pin 8 is the voltage supply pin, supplying voltage to the IC relative to the ground terminal, as shown in Figure 9.

E. Alarm and Capturing Unit

The alarm and capturing unit consists of a buzzer, a WiFi module, and a spy camera attached to the circuit as the load. The camera is capable of capturing clear images with a 5MP resolution and recording videos in 1080HD quality. It supports multiple video resolutions, including 4K, 2K, 1080P, and 720P, with videos saved in ASF format and images in JPEG format. The camera records at a frame rate of 25 frames per second and offers a wide visual angle of 150 degrees, covering a recording range of up to 5 square meters. It utilizes the H.264 compression format and connects via a Micro USB interface. These specifications enable the camera to provide high-quality visual evidence.

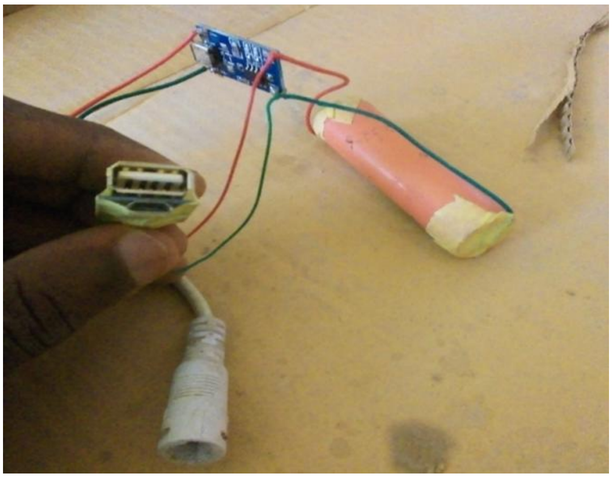

Figure 6. Connection of the Power Supply Unit

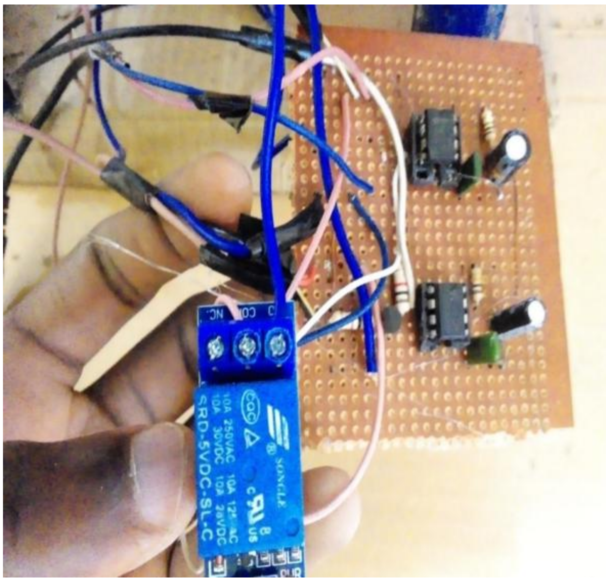

Figure 7. Controlling unit circuit.

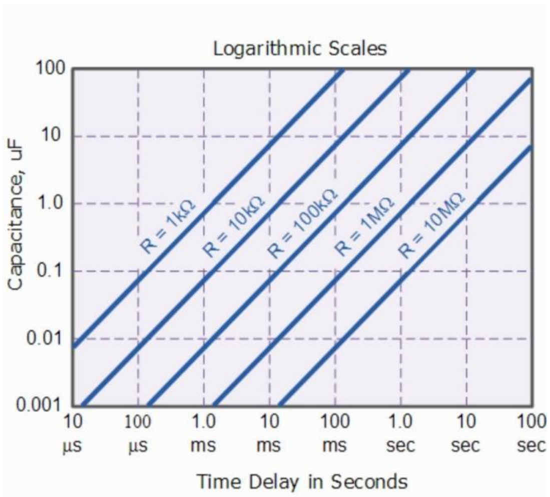

Figure 8. Basic 555 Mono-stable Nomograph

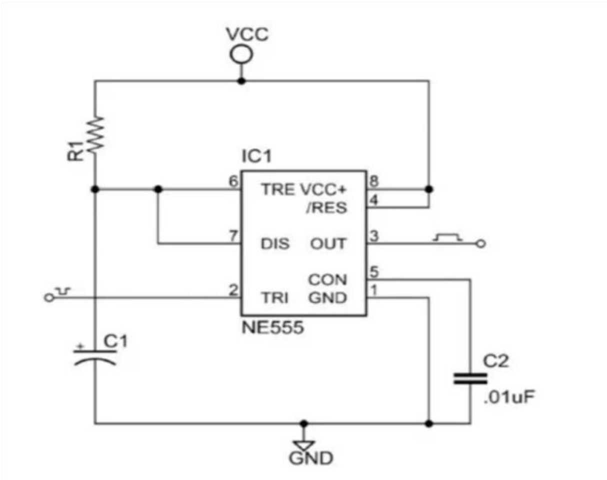

Figure 9. Basic 555 Monostable Multivibrature Circuit

F. Packaging and Casing

Figure 10 and 11 illustrate the packaging and casing of the project, showcasing its appearance before and after installation. The packaging unit was crafted using various materials, including carton, electronic hot glue, top bound, A2 white paper, paint, and others, to create a secure and visually appealing enclosure for the project.

After designing and implementing the solar spy security motion detector, the desired goals were successfully achieved. The solar panel effectively charged the battery, indicated by the charging indicator light changing from red to blue, as shown in figure 12. The sensor detected motion within a 180-degree range and triggered the two controlling unit electronic circuits.

One controlling unit circuit activated the buzzer, which sounded with a 5-second delay. The other controlling circuit powered the spy camera, which captured footage for less than a minute. The camera responded to signals from the relay module based on object detection by the PIR sensor.

Furthermore, the camera established a Wi-Fi connection with a smart device, enabling the viewing of captured images. Overall, the solar spy security motion detector functioned as intended, demonstrating its effectiveness in detecting motion and capturing images.

IV. RESULTS

This project focuses on designing an electronic circuit that controls the capturing period of a spy camera and the alarming period of a buzzer when motion is detected by a PIR sensor, utilizing an IC555 and other electronic components as outlined in the methodology.

Figure 10. Packaging before Installation

Figure 11. Packaging after Installation

Figure 12. Charging System

During the construction of the device, the major challenge encountered was the damage of various components and materials, including capacitors, resistors, the spy camera, and the boost converter. Additionally, during the testing phase, a significant issue arose when the live streaming video of captured footage was interrupted due to network problems.

V. CONCLUSION

In recent times, electronic security systems have emerged as the most effective solution to combat house intrusion issues. Among various types of house security systems, such as CCTV cameras, most capture and record everything continuously, consuming excessive energy and memory space. To address this limitation, this project has successfully developed an energy-efficient and memory-space-managed house spy security system. This innovative system captures images or records videos only when motion is detected, thereby conserving energy and memory. Furthermore, the system utilizes renewable energy from a solar energy system to recharge the battery, making it a sustainable and efficient solution for home security.

This project has vast potential for application in various situations and areas. To further enhance its capabilities, incorporating Artificial Intelligence (AI) can be a significant upgrade. By integrating AI, the system can be trained to recognize and distinguish the owner from a stranger, thereby reducing false alarms and improving overall security. This advanced feature can be achieved through machine learning algorithms and facial recognition technology, making the system even more intelligent and effective.

REFERENCES

[1] Ayyasamy, P., Kumar, P., and Meyyagoundan, J. (2015). Real Time Power and Memory Efficient CCTV Surveillance Recording System.

[2] Bosman, J. A., Olivieri, S., Ozil, I., and Steacy, B. (2007). Design of a completely wireless security camera system. A Major Qualifying Project Report, University of Limerick, Faculty of Worcester Polytechnic Institute, Worcester, Massachusetts.

[3] International Journal of u- and e-Service, Science and Technology, 8:47–54

[4] Gossain, S. and Gill, J. (2018). A novel approach to enhance object detection using integrated detection algorithms. International Journal of Computer Science and Mobile Computing, 3:1018–1023.

[5] Ibrahim, S. W. (2016). A comprehensive review on intelligent surveillance systems. Communications in science and technology, 1(1).

[6] Jadhav, M. P., Suryawanshi, M. S., and Jadhav, M. D. (2017). Automated Video Surveillance.

[7] Khalid, M. and Majeed, S. (2016). A smart visitors' notification system with automatic secure door lock using mobile communication technology. IJCSNS International Journal of Computer Science and Network Security, 16(4):97–101

[8] Kumar, K. K., Natraj, H., and Jacob, T. P. (2017). Motion activated security camera using Raspberry Pi. In 2017 International Conference on Communication and Signal Processing (ICCSP), pp. 1598–1601. IEEE.

[9] Mishra, P. K. and Saroha, G. (2016). A study on video surveillance system for object detection and tracking. In 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom), pp. 221–226. IEEE.

[10] Parveen, S. and Shah, J. (2021). A motion detection system in python and Opencv. In 2021 third international conference on intelligent communication technologies and virtual mobile networks (ICICV), pp. 1378– 1382. IEEE.

[11] Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 3(3):1–24.

[12] Vidhya, M., Aji, S., and Beniam, M. (2016). A classical method for detecting overlapping faces in images. In 2016 International Conference on Computer Communication and Informatics (ICCCI), pp. 1–5. IEEE.

[13] Wang, X. (2013). Intelligent multi-camera video surveillance: A review. Pattern recognition letters, 34(1):3–19.

[14] Zhang, F., Wu, C., Wang, B., Lai, H.-Q., Han, Y., and Liu, K. R. (2019). WiDetect: Robust motion detection with a statistical electromagnetic model.