T.R.
SAKARYA UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

# A SURVEILLANCE AND SECURITY ALERT SYSTEM BASED ON REAL-TIME MOTION DETECTION TO PROTECT SECRET AND VITAL PLACES

**MSc THESIS**

**Ahmed Shahab Ahmed AL-SLEMANI**

**Computer and Information Engineering Department**

**AUGUST 2023**

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**Thesis Advisor: Prof. Dr. Ahmet ZENGIN**

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The thesis work titled “A Surveillance And Security Alert System Based On Real-Time Motion Detection To Protect Secret And Vital Places” prepared by Ahmed Shahab Ahmed AL-SLEMANI was accepted by the following jury on 11/08/2023 by unanimously of votes as a MSc THESIS in Sakarya University Graduate School of Natural and Applied Sciences, Computer and Information Engineering Department, Computer Engineering Program.

**Thesis Jury**

| | | |
|---|---|---|
| **Head of Jury :** | **Prof. Dr. Ahmet ÖZMEN**<br>Sakarya University | .............................. |
| **Jury Member :** | **Prof. Dr. Ahmet ZENGİN (Advisor)**<br>Sakarya University | .............................. |
| **Jury Member :** | **Assist. Prof. Dr. A.F.M. Suaib AKHTER**<br>Sakarya University of Applied Sciences | .............................. |

**STATEMENT OF COMPLIANCE WITH THE ETHICAL PRINCIPLES AND RULES**

I declare that the thesis work titled "A SURVEILLANCE AND SECURITY ALERT SYSTEM BASED ON REAL-TIME MOTION DETECTION TO PROTECT SECRET AND VITAL PLACES", which I have prepared in accordance with Sakarya University Graduate School of Natural and Applied Sciences regulations and Higher Education Institutions Scientific Research and Publication Ethics Directive, belongs to me, is an original work, I have acted in accordance with the regulations and directives mentioned above at all stages of my study, I did not get the innovations and results contained in the thesis from anywhere else, I duly cited the references for the works I used in my thesis, I did not submit this thesis to another scientific committee for academic purposes and to obtain a title, in accordance with the articles 9/2 and 22/2 of the Sakarya University Graduate Education and Training Regulation published in the Official Gazette dated 20.04.2016, a report was received in accordance with the criteria determined by the graduate school using the plagiarism software program to which Sakarya University is a subscriber, I have received an ethics committee approval document, I accept all kinds of legal responsibility that may arise in case of a situation contrary to this statement.

(11/08/2023)

Ahmed Shahab Ahmed AL-SLEMANI

***And rely upon Allah, and sufficient is Allah as a disposer of affairs. Al-Quran Al-Ahzab (33:3)***

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Ahmed Shahab Ahmed AL-SLEMANI

**TABLE OF CONTENTS**

**Page**

## ABBREVIATIONS

| | |
|---|---|
| **CLR** | : Common Language Runtime |
| **COCO** | : Common Objects in Context |
| **CSC** | : C# Compiler |
| **DBMS** | : Database Management System |
| **DC** | : Direct Current |
| **ERD** | : Entity Relationship Diagram |
| **FTP** | : File Transfer Protocol |
| **GSM** | : Global System For Mobile Communication |
| **GUI** | : Graphic User Interface |
| **IMAP** | : Internet Message Access Protocol |
| **IT** | : Information Technology |
| **LAN** | : Local Area Network |
| **LCD** | : Liquid Crystal Display |
| **LED** | : Light Emitting Diode |
| **MSIL** | : Microsoft Intermediate Language |
| **PC** | : Personal Computer |
| **PDA** | : Personal Digital Assistant |
| **PIR** | : Passive Infrared Sensor |
| **POP** | : Post Office Protocol |
| **RDBMS** | : Relational Database Management System |
| **SBMA** | : Simple Background Modeling Algorithm |
| **SMS** | : Short Message Service |
| **SMTP** | : Simple Mail Transfer Protocol |
| **SQL** | : Structured Query Language |
| **TFDA** | : Two-Frame Difference Algorithm |
| **VOC** | : Visual Object Classes |
| **WCF** | : Windows Communication Foundation |
| **YOLO** | : You Only Look Once |

## LIST OF TABLES

**Page**

**LIST OF FIGURES**

**Page**

**A SURVEILLANCE AND SECURITY ALERT SYSTEM BASED ON REAL-TIME MOTION DETECTION TO PROTECT SECRET AND VITAL PLACES**

## SUMMARY

In the modern world, surveillance systems are crucial to the security sector. Video surveillance systems have traditionally employed moving object detection extensively. In computer vision, surveillance systems have grown in popularity recently. In this study, we have developed a system to protect vital and secret places from thieves. It should also facilitate the work of areas that require monitoring systems because security concerns have exploded in the current environment. The system relies on human motion detection.

The main objective of the research is to create a system that can be part of reducing and eliminating theft and evil and provide an easy system with a user-friendly interface at a low cost.

Cameras have been used to detect human movement and monitor areas, allowing observers to monitor areas directly through the system. Whenever the system detects human movement through a camera, it directly notifies the observers of the presence of human movement in areas where there should be no human movement through sound alerts, LED alerts, and emails to the observer. It starts videotaping the area, as well as recording and storing the time, place, and photo of the movement to make it easier for observers to follow up.

The system consists of two main parts: software and Arduino hardware. In the software part, the types of algorithms used were the two-frame difference and simple background modeling for movement detection with the assistance of AForge.NET and C# and Tiny YOLOv2 for human detection. In the Arduino hardware section, Arduino is used to create an LED alert.

Evaluation and testing of the system show that it can be used indoors and outdoors and detect human movement in all four directions, such as the back, forward, right, and left. In low light, the system has the ability to determine human movement. The experiments tell us that the system's accuracy in determining human motion was 95%, and depending on this result shows that the system can preserve vital and secret locations and correctly surveil zones.

Future work includes adding alerts, such as mobile calls to observers through the system, which will help control incidents as soon as possible. Adding a mobile application to the system, where observers will be able to monitor the areas via their mobile phones, may allow them to monitor the areas from anywhere. Also, it will be possible to detect fire and smoke in areas where surveillance cameras are installed. And it is possible to use other Yolo models for human detection and other motion detection methods in the surveillance and security alert systems.

# KRİTİK ÖNEMDEKİ YERLERİ KORUMAK İÇİN GERÇEK ZAMANLI HAREKET ALGILAMAYA DAYALI BİR GÖZETİM VE GÜVENLİK UYARI SİSTEMİ

## ÖZET

Güvenlik, risk, kayıp ve suç faaliyetlerine karşı savunma düzeyidir. İnsanlar her zaman hayatlarını, mallarını ve iş kollarını korumak için çalıştılar. Özellikle şirketler, bankalar ve devlet kurumları gibi yüksek riskli alanlarda güvenlik ve koruma sistemlerine olan ihtiyaç hızla artmıştır. Modern teknolojinin kullanımıyla, ev sahipleri ayrı yerlerde olsalar bile evlerini suçlulardan koruyabilirler. Günümüzde güvenlik, hayatımızda çok önemli bir konu olarak görülebilir. Güvenlik sistemi, insanları ve mülkü korumak için sızmalara karşı koruma sağlayan bir donanım ve yazılım sistemidir. Uzun süredir koruma ve güvenliğe ihtiyaç duyulduğu için güvenlik sisteminin gelişimi ilginç bir geçmişe sahiptir. Kamu güvenliği sektörü daha modern zorluklarla uğraşırken güvenlik endişeleri önemli ölçüde artmıştır. Geleneksel güvenlik önlemleri, sayıları hızla artan suçlar ve terör tehditleriyle yeteri seviyede mücadele edememektedir. İnsanın i.inde olduğu emek yoğun güvenlik kullanımı azalmaktadır ve bunun yerine otomatik izlemenin kullanımı yaygınlaşmaktadır.

Video gözetim sistemlerinde hareket algılama, özellikle video sıkıştırma, insan algılama ve davranış analizi için çok önemlidir. Gerçek zamanlı bir video gözetim sistemi için, güvenilir algılama sağlayabilen sağlıklı bir hareket algılamaya ihtiyacımız var. Sürekli bir video akışındaki hareketi algılamak için çeşitli yöntemler kullanılmıştır. Gelişmiş güvenlik önlemleri sunduğu ve bir izleme sisteminde kullanılabildiği için, hareket algılama bir güvenlik sisteminde çok önemlidir. Bankalar, müzeler, nadide tarihi kitaplar, devletin gizli belgelerinin tutulduğu merkezler vb. gibi devletin ve devlet kurumlarının korumaya çalıştığı ve zarar görmek istemediği birçok önemli mekan vardır. Bu önemli mekanların sıı bir şekilde korunması gerekir dolayısıyla buraları kontrol edecek bir sistem olmalıdır.

Bu araştırmayı gerçekleştirmemizin ana motivasyonu, insanların hayatlarını koruyarak daha rahat ve güvenli yaşamalarını sağlamak için topluma ve insanlığa hizmet edebilmektir. Hırsızlığın azaltılması ve bu çirkin olgunun ortadan kaldırılması konusunda da katkı sağlamak amacındayır. Bu nedenle insan girişime izin vermeyen bir gözetleme sistemine ihtiyaç duyan önemli mekanları korumak için kullanılabilecek bir sistem geliştirdik. Bu sistemde gözlemciler ilave olarak insan hareketi hakkında bilgi edinmektedirler.

Tezin amacı, insanlar için daha fazla güvenlik ve koruma sağlamaktır. Önemli ve gizli mekanlarda hırsızlık ve vandalizm nedeniyle güvenlik talebi artmıştır. Bu tür harekete izin verilmemesi gereken alanlarda insan hareketini tespit edebilen bir güvenlik sistemine ihtiyaç vardır. Modern dünyada, izleme sistemleri güvenlik sektörü için çok önemlidir. Video izleme sistemleri geleneksel olarak hareketli nesne algılamayı yaygın olarak kullanır. Bilgisayar kullanılarak izleme sistemlerinin popülaritesi son zamanlarda artmıştır. Bu çalışmada hayati derecede gizli mekanları

hırsızlardan korumak için bir sistem geliştirilmiştir. Sistem hareket algılamaya dayanır. Araştırma, hırsızlığı ve kötülüğü azaltmanın ve ortadan kaldırmanın bir parçası olabilecek ve düşük maliyetle kullanıcı dostu bir arayüzle kullanımı kolay bir sistem oluşturmak için çalışır. İnsan hareketini algılamak ve mekanları izlemek için kameraları kullanılmış ve gözlemcilerin alanları doğrudan sistem aracılığıyla izlemesine olanak sağlanmıştır. Sistem bir kamera aracılığıyla insan hareketini algıladığında, gözlemciye sesli uyarılar, LED uyarılar ve e-postalar aracılığıyla hareketin varlığını doğrudan bildirir. Gözlemcilerin takip etmesini kolaylaştırmak için mekanın videosunu çeker ve hareketin zamanını, yerini ve fotoğrafını kaydetmeye ve saklamaya başlar. Sistem yazılım ve donanım olmak üzere iki ana bölümden oluşmaktadır. Yazılım kısmında AForge.NET ve C# yardımıyla hareket tespiti için iki kare fark algoritması ve basit bir arka plan modelleme algoritması kullanılmıştır. İnsan tespiti için ise, Tiny YOLOv2 kullanılmıştır. Donanım kısmında Arduino bir LED uyarısı oluşturmak için kullanılır.

Sistemin değerlendirilmesi ve test edilmesi, iç ve dış mekanlarda da kullanılabileceğini ve insan hareketini algılayabildiğini göstermektedir. Sistem, dış veya iç mekanlara kurulan kameraların önündeki herhangi bir insan hareketini algılayabilir. Güvenli olması için insan girişinin yasak olduğu bankalardaki para odaları gibi bazı iç mekanlarda harekete izin vermez. Ayrıca dış mekanlarda insan hareketine izin verilmeyen bazı yerler vardır. Bu sistemin kullanılması her iki durumda da önemli bir etkiye sahip olacaktır.

Sistem, insan hareketini dört farklı yönde algılama yeteneğine sahiptir: ileri, geri, sağ ve sol. İnsan hareketinin dört yönde de algılanması, hayati, gizli ve önemli yerlerin korunması için ek bir güvence sağlar. Yani herhangi biri, yasak bir mekana giderse, sistem hareketli nesneleri başarılı bir şekilde bulabilir ve alanı güvende tutabilir.

Gözetleme sistemleri için en önemli değerlendirmelerden biri düşük ışık performansıdır. Sistem, düşük ışıkta veya minimum aydınlatma ile insan hareketini algılama ve uyarıları etkinleştirme yeteneğine sahiptir. Düşük ışık veya minimum aydınlatma alanlarında gözlemcileri insan hareketine karşı uyarmak, sistemi daha verimli hale getirir ve hırsızlardan ve vandallardan korunması gereken yerler için daha fazla güvence sağlar.

Değerlendirme sonuçları, sistemin insan hareketini belirlemedeki doğruluğunun %95 olduğunu göstererek, sistemin kritik ve gizli yerleri koruma ve alanları izleme yeteneğini göstermektedir. Yetkisiz hareketleri tespit etme ve insan faaliyetini gözlemciye mümkün olan en kısa sürede bildirme yeteneği, gözetim sisteminin en önemli avantajlarından biridir. Sistemin insan hareketini algılamasının ve uyarıları etkinleştirmesinin ne kadar sürdüğünü belirlemek için örnek olarak 10 insan hareketi kullandık. Sonuç, sistemin hareket algılama süresi ile izinsiz giriş algılama ve uyarı etkinleştirme süreleri arasında 1,635 saniyeden daha kısa süre olduğunu göstermiştir. Sistem, olayların kolayca kontrol edilebilmesi için gözlemcileri yetkisiz faaliyetler konusunda mümkün olan en kısa sürede uyarabilir. Gözlemciler aynı anda kameralar sayesinde birçok farklı lokasyonu izleyebilirler.

Gelecekteki çalışmalar arasında, olayların en kısa sürede kontrol altına alınmasına yardımcı olacak gözlemcilere mobil arama gibi uyarıların eklenmesi ve gözlemcilerin cep telefonlarından alanları izleyebilecekleri bir uygulamanın sisteme eklenmesi olabilir. Ayrıca güvenlik kameralarının kurulduğu alanlarda yangın ve duman algılaması yapılabilecektir. Gözetleme ve güvenlik uyarı sistemlerinde insan algılama ve diğer hareket algılama yöntemleri için diğer Yolo modellerini kullanmak.

# 1. INTRODUCTION

Effective and accurate intrusion detection with an alert system is necessary because burglaries frequently and widely occur. Attacks on buildings such as houses, offices, industries, and banks are rising. The security system must account for anyone trying to trespass or cause damage. Security is the level of defense against risk, loss, and criminal activity. Humans have always worked to safeguard their lives, possessions, and lines of work. The need for security and protection systems has grown rapidly, especially for high-risk areas such as companies, banks, and government institutions [1]. With the use of modern technology, homeowners can safeguard their homes from criminals even if they are located in separate places. Today, security can be viewed as a very important issue in our life [2]. Criminal activities are becoming dexterous conduct nowadays due to the sophisticated tactics crooks maneuver to succeed in their actions. Safety is one of the most crucial things everybody wants. Globally speaking, the rise in criminal activity is quite concerning and has sparked a need for the government to act quickly to reduce the problem. A security system is a mix of hardware and software that guards against infiltration to safeguard people and property. The development of the security system has an interesting history because there has long been a need for protection and security. Security systems have evolved into high-tech devices from basic control panels and locks [3]. In this thesis, we have created a system for human movement detection in important and secret places based on motion detection. In video surveillance systems, motion detection is crucial, particularly for video compression, human detection, and behavior analysis. For a real-time video surveillance system, we require motion detection that can give reliable detection. Various methods have been employed to detect motion in a continuous video stream. Since it offers sophisticated security measures and can be employed in a monitoring system, motion detection is typically crucial in a security system. Think about a protected location, such as a bank safe or money vault, where we do not want unauthorized individuals to enter or approach that secured region. In this situation, motion detection can identify if somebody is entering or leaving the secured area and, if necessary, sound an alert. It can deliver high accuracy with a straightforward and affordable implementation. Security is not at all compromised by motion detection [4].

In this study, the system was developed in such a way that it could detect human movements to protect the areas to be protected. Cameras are used to monitor areas and detect human movement. The system has several features that can provide additional security assurance, including a video recording of movement detected by the system, as well as alarms such as sound alarms, LED alarms, and observer alerts via email. It can also store the time, location, and movement picture in the database. The system can also be used indoors and outdoors to detect human movement. The system can also detect human movement in all four directions. In low or minimal lighting, the system can detect human movement. Evaluation results show that the system's accuracy in determining human movement is 95%, demonstrating the system's ability to protect critical and secret locations and surveil areas. The system's goal is to protect important and confidential items that need protection from thieves, such as banks with large amounts of money or museums that own many pieces of history that must be protected from theft, or confidential state data that should not be accessed by anyone.

### 1.1. Problem Statement

Security worries have significantly increased as the public safety sector faces more modern challenges. Traditional security measures can no longer effectively combat the sharply rising number of crimes and terrorist threats. The use of labor-intensive security is declining, and its replacement with automatic monitoring has been proposed. We have many places that the state and state institutions try to protect and do not want to be harmed, including banks, museums, rare historical books, the center for carrying secret documents of the state, etc. Due to the increase in theft and vandalism in important places, these are unwanted incidents and should be prevented, so there must be a system to control these situations. Many previous systems used for surveillance purposes had no alerts in the event of an accident or movement so that observers could be aware of and control the situation. In addition, many previous surveillance systems do not work on human movement detection, so solving these problems will be important and necessary to protect important and confidential sites. Therefore, we have proposed the system so that the observers can control these situations and be aware of the events.

### 1.2. Literature Review

At this point, we present a literature review of the previous related works of security alert systems as the following:

In the study [5], the authors wrote that the use of motion detection as a security precaution is emphasized by this security system. As the video source, a webcam is employed. The video recorder is started once the threshold of the frames determines whether there is motion. The video is compressed to save memory and recorded in bits so that the time can be easily distinguished. The system can warn carers of an incursion in the area being monitored by activating an alarm system. The webcam is built-in, but it may also be used to transmit video from a separate webcam, and extension cords can be used to hide the camera from prying eyes. The system was developed utilizing the prototype development methodology and MATLAB. The system is created to ensure that all requirements are satisfied and everything operates exactly as it should.

In the study [6], the authors wrote that a typical video surveillance system's time-consuming reviewing process led to the development of motion detection surveillance technology. Over the past few years, it has attracted much interest. We propose a motion detection surveillance system, comprising its Graphic User Interface and its mechanism for motion detection, through the research and evaluation of currently available goods and methodologies. The suggested technique works well and is practical for both homes and offices.

In the study [7], the authors wrote that one of the biggest problems in the world now is security. According to the Metropolitan Police Department, there were a total of 33,471 robberies (90% personal, the rest commercial) and a total of 92,135 burglaries, of which 70% were residential and the rest non-residential. Unquestionably, we need a system that can serve as a surveillance system for our homes and offices, is user-friendly, can run on a PC, and can be accessible by various channels like mobile phones, email, or PDAs. The best form of monitoring has always been thought to be the human eye. This research aims to develop a computer-based surveillance system to replace the human eye. SMS and email communication technologies allow machine vision to be deployed to identify intruders and alert people to unexpected motions. Because it is a distributed application, the system can communicate with users anywhere in the world. A viable option was selected for the project after discussing various motion detection techniques. The more reliable the system is required to be, the more efficient algorithms are available.

In the study [1], the authors wrote, because of the frequent and widespread incidents of burglary, the need for effective and accurate intrusion detection with an alarm system has become an absolute necessity. Attacks on buildings such as houses, offices, industries, and banks are rising. By monitoring the change in speed or vector of an item in the range of view, motion can now be detected through technology. Electronic techniques that quantify and surveil environmental changes can accomplish this, as can mechanical techniques that interact directly with the field. The motion detector is used in some additional applications, including home automation systems, energy efficiency systems, and so forth, in addition to intruder alerts. An embedded microcontroller system is used in this project to build an alarm or motion detector system by sensing an intruder's motion in a limited area. However, a passive infrared sensor uses the person's body heat to identify the movements of the person. The movement detector in this project, a passive infrared sensor, is linked to a microcontroller, which activates the alert system and any other related output devices to alert the home's owner. The design performed as planned after going through its initial testing.

In the study [2], the authors wrote that people can keep intruders out of their homes even if they are in different places. This study describes a remote protection security system combining an Arduino and a smartphone. An infrared sensor in the suggested system detects motion and delivers a signal to the microcontroller. Following signal processing, the mobile device snaps a photo and sends alerts to the property owner's saved phone numbers. This can lower the possibility of a burglary threat. The advantages of the suggested design include minimal cost and adjustable security.

In the study [3], the authors wrote that creating a microcontroller-based security system for indoor geo-location utilizing motion detectors was the main topic of this research. Intruder detection was used by the system to support surveillance technology and provide vital security with related control and alarm functions. Integrating cameras and motion detectors into online applications is the key to security. A smart surveillance system called the Raspberry Pi uses the motion detector as input to operate (actuate) the Pi camera for remote sensing and surveillance. The video is sent to a web server, where it can be accessed by a user or homeowner through a web application. When there is an intrusion, the system buzzes the nearby alarm and sends an SMS to the owner. The developed security system features an effective video camera for remote sensing and monitoring, streaming live video and recording for later playback, and provides a practical, cost-effective, and simple surveillance solution.

In the study [8], the authors wrote that according to figures on the video surveillance market, there would be an 11% increase between 2019 and 2021. Video surveillance has shown symptoms becoming more and more common in today's society. Intelligent video applications are replacing traditional security purposes for video surveillance. There is a spike in the usage of this technology with high-quality standards, from airports, cities, casinos, retail establishments, and workplaces all over the world to the surveillance of pets and older people in homes. Coming into the mainstream are 4K cameras, which offer a degree of detail comparable to a big-screen movie presentation. Security teams can avoid or warn of potential threats by being able to distinguish minor visual features at a distance in order to protect lives and property. With this in mind, it is designed to save storage space by only recording when motion is detected and saving frames with faces for easy retrieval.

The study [9] proposes an efficient and fully autonomous monitoring and control system for bank money rooms. The security system is designed to identify unauthorized entrances, which frequently occur during robberies, in the bank's money room regions. With the existing manually supervised security systems, the main worry is that, in the event of a robbery, the banks won't be able to identify the attackers owing to a lack of evidence. The technology keeps bank cash rooms safe by detecting and restricting illegal movements. Whenever motion is detected, the proposed security system will record the images, which can later be used for investigation. The system will continuously transmit image data to remote location control rooms via web-based monitoring and a local area network (LAN), and it can also send text-based alerts to the operator via short message service (SMS) over GSM technology.

In the study [10], the authors wrote that monitoring and surveillance are crucial for security reasons. High-end, expensive surveillance systems are needed in residential areas, businesses, government buildings, commercial spaces, schools, hospitals, factories, banks, and other difficult indoor and outdoor conditions. The motion detection and tracking system for surveillance is suggested in this research. To detect moving many objects in the surveillance zone, the proposed system uses a Raspberry Pi and computer vision software called SimpleCV. It then turns on the lights to take pictures and streams the camera feed online using MPJG Streamer so that anyone with access to the feed can watch it wherever they are.

In the study [11], the author wrote that the options on the market for surveillance technologies now appear to be inflexible alert systems and few features. Real-time alarm systems must be implemented, in addition to users becoming more aware of effective home monitoring systems. Using a GSM modem for SMS notice and email notification for off-site data recording to FTP storage allows for real-time deployment. Microsoft Visual Studio 2005 TM is used to run the system's algorithms for SMS and e-mail notification as well as for informing visual devices when motion is detected. With OpenCV TM converted to MATLAB TM for output display, the visual device's tracking and recognition capabilities were built. The system's results were demonstrated in this study in a sequential manner, showing that real-time components were emulated by sending alerts concurrently with the motion event.

**Table 1.1.** Comparison of the related works.

| Ref. | Motion Detector | Alerts | Record Video | Save Image | Record Event |
|---|---|---|---|---|---|
| [5] | Camera | True | True | False | False |
| [6] | Camera | True | False | True | True |
| [7] | Camera | True | False | True | False |
| [1] | PIR | True | False | False | False |
| [2] | PIR | True | False | True | False |
| [3] | PIR | True | True | False | False |
| [8] | Camera | False | True | True | False |
| [9] | Camera | True | False | True | False |
| [10] | Camera | True | False | True | False |
| [11] | Camera | True | False | True | False |

Table 1.1 evaluates all previous work on the surveillance systems mentioned in this study. Ten studies have been evaluated. Only seven studies used cameras for motion detection; three used PIR devices. Nine studies also have alerts that are activated after detecting motion. Alerts are such as alarms, LEDs, emails, SMS, etc. Not a single study listed any alerts. One of the most important features of the surveillance system is video recording after motion detection. Only three studies mentioned in this study used it, and seven others did not have this important feature. Another feature is the storage of an image of the event after detecting motion, which seven of the studies had and three studies did not. This important feature helps identify the things that caused the alerts to activate. Incident data recording is another important feature of the surveillance system. Only one study included this feature but collected little information about the incident. However, none of the studies had all the characteristics together.

The observers need a system that has some special features for surveillance. In this study, we decided to develop a system that combines the most features to provide the best surveillance system using motion detection. The system uses three different types of alerts to notify carers in real-time, such as LED, sound, and email. Observers will receive the time, date, rate, and location of the movement by email, which will help caregivers go directly to the appropriate location to control the condition. The system also has limited motion detection, with only alerts activated to detect human movement by using YOLO; this is one of the important features of this system that distinguishes it from previous studies. Also, recording information about events that the system identifies, such as date, time, location, the name of the observer, and a picture of the movement. Another feature of the system is to record video after detecting human movement, which will help to identify the people who caused the accident. Providing a user-friendly interface and an important and easy system for observers is another feature. The system allows observers to surveil the areas in real-time from the locations where the cameras are installed and also shows the motion rate of the areas directly. Observers can track several different places at the same time. All these features make it necessary to have this system to control theft and damage to vital and secret places.

### 1.3. Motivation

The main motivation for conducting this research is to serve society and humanity so that we can be part of those who want people to live comfortably and have more security by protecting their lives. We should also make an impact on reducing theft and eradicating this ugly phenomenon. Another motivation for this study is to protect places that need a security and surveillance system, such as banks, which store people's and state money and need to be protected from thieves. On the other hand, museums have many historical pieces that are humanity's property and must be protected from those who want to steal them from museums and trade them illegally. On the other hand, libraries contain many rare ancient history books, some unique worldwide. Therefore, we felt responsible and decided to develop a surveillance system that can protect those places that need a surveillance system that does not allow human movement. The observers also want to be notified about human motion.

## 1.4. Thesis Goal

The main goal of the thesis is to provide more security and safety for people. The demand for security has increased due to theft and vandalism in important and secret places. Therefore, we are trying to provide and develop an important security system to protect important areas. Provide a security system capable of detecting human movement in areas where such movement should not be permitted. It also provides an easy-to-use security system with a friendly user interface that allows observers to easily control the locations and can use it easily. Another objective of the study is to alert observers of the incidents directly at the time of the incident via email alert, sound alert, LED alert, and record video of the events so that the situation can be easily controlled and the areas are protected from vandals and thieves. Another objective of the study is to provide a low-cost security system available to users. Another goal of the research is to detect human motion indoors, outdoors, and in low-light areas, as well as to detect human motion in all directions as soon as possible.

## 1.5. Method

In this study, based on human motion detection, plans were made to create a system to protect vital and secret places from thieves and criminals. Also, plans were made to build an easy-to-use, efficient, and suitable system for real-time security alert systems. Figure 1.1 displays the overview of the study. Initially, we need cameras to monitor the areas and detect motion in vital and secret places. Then if there is any movement in the areas, the system detects it by AForge.NET. A set of classes that implement various motion detection and motion processing methods are offered by the AForge.NET framework. Only continuous video frames are targeted by motion detection algorithms, which also output the amount of motion that has been identified. A detected frame is then interpreted using YOLO to detect human motion. Security systems can use YOLO to impose security on a location; it is assumed that access to a particular region has been restricted for security reasons. The YOLO algorithm will identify anyone who enters the restricted area. After detecting human motion, the system activates LED, sound, and email alerts and starts recording videos of motions in the area. As a result, the system can contribute to reducing the level of risk where it is used, and observers can control incidents with the assistance of the system.

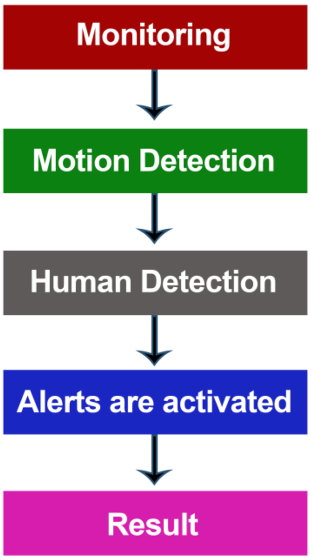


**Figure 1.1.** Overview of the study.

### 1.6. Contributions

Due to the increase in theft crimes in some countries, efforts are being made to develop surveillance and security systems. There are continuous efforts in this regard by researchers. We present some important contributions from the system developed in this study.

1. In this study, a surveillance system has been developed that can contribute to reducing and preventing theft and crime.

2. The system detects human movement, providing greater security for areas.

3. The system alerts observers to the presence of human movement directly, which will be an important contribution to event control.

4. The study provides a simple and easy-to-use surveillance and security alert system that can be easily used by observers.

5. The system is designed to help observers identify offenders. The system works in such a way that when it detects human movement, it stores an image of the movement and records a video of the movement, which will contribute directly to reviewing the incidents and identifying the people involved in the incident.

6. Since security and surveillance systems are expensive, this system is cheap and low-cost. The system activates alerts in real-time at the lowest cost.

## 1.7. Thesis Plan

In chapter one, firstly, the introduction of this research is written, and the introduction is covered with a short description. The problem statement has been explained, as well as goals and motivations of the research are clarified. Also, in the literature review, some previous works have been discussed, contributions, methods, and finally explained the research outline.

In chapter two, the background material for this project is presented. The need for the project has been discussed in the background information. There is an additional discussion of the project's tools.

In chapter three, the design and implementation of the project are explained. The design of this project includes the design of the whole system, as well as databases and diagrams. The implementation of the whole system has been discussed. The implementation is explained with different types of figures.

Chapter four describes the tests and experiments of the system, as well as the performance of the surveillance and security alert system and the ability to directly notify observers of events.

In chapter five, the conclusion and future work is illustrated. The main conclusion that we got from this project has been discussed.

## 2. BACKGROUND

### 2.1. Computer Vision

Computer vision focuses on gathering details about a situation from photographs of scenes. It has numerous uses in robotic guiding, radiography, microscopy, remote sensing, document processing, and industrial inspection [12]. The study of image analysis, modification, and deep comprehension is known as computer vision, a topic that is expanding quickly. Computer vision aims to determine what is happening in front of the cameras or webcams and use that data to control a computer or robotic system or to give humans new views that are more enlightening or aesthetically pleasing than the original camera photos. Video surveillance, biometrics, automotive, photography, movie production, web search, medicine, augmented reality gaming, innovative user interfaces, and many other fields are among the application areas for computer vision technologies [13]. Computer vision studies automated systems interpreting image data by drawing out broad information. Image data can be in various formats and modalities. This can be a single natural image or a multispectral satellite image series collected over an extended period. Similarly, the high-level information captured can range from physical characteristics such as surface normal for each image pixel to object-level attributes such as common object classes (such as 'car,' 'pedestrian,' etc.). , varies [14].

### 2.2. Motion Detection

Motion detection is necessary for every surveillance system, occupancy detection program, and moving object system. It is also extensively utilized in real-time image-processing applications in toys, medical equipment, wireless security systems, occupancy detection systems, and other devices [15]. Finding a change in an object's position in relation to its environment or a change in the environment in relation to an object is the process of motion detection. A motion detection system's job is to find an "area of motion" in the environment that is being watched. The region of motion in this context refers to the area of the environment that is active due to the movements of moving objects [16]. In the area of security, the surveillance system is crucial. Video surveillance systems have traditionally employed moving object detection extensively. In addition to motion estimation, other components of surveillance video processing, like video filtering and frame compression, are crucial [17]. Simply, "motion detection" is the process of detecting physical movement in a certain area [18]. Motion detection surveillance technology was created due to the complex reviewing process required by conventional video surveillance systems [6]. Computer vision research is currently focused on motion detection. Finding moving objects in a series of images is referred to as motion detection. It is vital to ensure accurate detection because the obtained result has a significant impact on the vision system's subsequent tasks [19]. One of the primary elements of the system is motion detection, which measures changes in an object's rate or vector. For motion detection in this study, the AForge.NET framework was used. The AForge.NET library provides a variety of classes that implement various motion detection and motion processing techniques. Only continuous video frames are targeted by motion detection algorithms, which also output the amount of motion that has been identified, as well as a binary motion frame image that displays all motion-detected regions. Algorithms for motion processing are designed to post-process motion that has been identified, such as emphasizing motion regions, counting moving objects, tracking them, etc. Various motion detection techniques may be used by various motion detection classes. However, they are all comparable in terms of how they gather video frames for analysis and report detected motion levels. These classes all offer a motion level property, which represents the amount of motion between [0, 1]. For instance, if the property is 0.05, the motion detection class has detected a 5% motion level, according to that definition. When the detected motion level exceeds the amount deemed safe, the alarm might be raised by analyzing this attribute and comparing it to a specified threshold [20].

### 2.2.1. Two frames difference motion detector

The two-frame difference motion detection approach is frequently used to identify moving objects from a series of frames taken by a static camera. Based on the difference between the current and reference frames, this method attempts to detect moving objects. A popular technique for the detection of motion is the frame difference method. In this procedure, the moving item is identified using the pixel-by-pixel difference [21]. Because it has a high detection speed, is simple to implement on hardware, and has been widely used, the frame difference method is the most straightforward method for detecting moving objects in surveillance video captured by an immobile camera [22]. This type of motion detector is the simplest and fastest. The idea of this detector is based on finding the magnitude of the difference between her two consecutive frames of the video stream. The greater the difference, the greater the surface of motion. Highly recommended for tasks that only require motion detection [20]. It is excellent positioning for tasks that merely require motion detection, as shown in Figure 2.1.

In picture sequences, $I_k$ is worked to display the value of the $k^{th}$ frame. An image sequence's $(k+1)^{th}$ frame has a value of $I_{k+1}$ [23].

This is an equation of the absolute differential picture:

$$I_{d(k,k+1)} = |I_{k+1} - I_k| \tag{2.1}$$

**Figure 2.1.** Two frames difference motion detection [20].

### 2.2.2. Simple background modeling motion detector

The main elements of motion detection and analysis with a stationary camera are background modeling and subtraction [24]. A crucial part of many computer vision systems, background modeling is frequently used before foreground detection, object segmentation, tracking, and video surveillance tasks [25]. An illustration of the backdrop modeling algorithm-based motion detector is shown in Figure 2.2. The process of extracting moving objects from video frames is known as background modeling. This method can be applied to video frame compression and monitoring applications in machine vision. To model the background in video frames, first, a scene background model is built. After that, the current frame is subtracted from the model. In the end, the moving items are determined by the difference [26]. Object detection can be achieved by creating a representation of the scene called the background model and finding the deviation from the model for each received frame. Significant changes in the image area from the background model indicate moving objects. Pixels that make up the changing area are marked for further processing [27]. This motion detector compares the current video frame to a frame representing the background and looks for differences. This motion detector makes an effort to use basic modeling techniques to model the background of a scene and to update that model over time to account for scene changes. This motion detector can highlight motion regions based on its background modeling function [20]. A background-modelling algorithm-based motion detector is based on finding the difference between an existing square frame in the video and the background. Because it highlights motion zones, it is more sensitive than the two frames' differences. It is formed by the background pattern augmenting the pixel value of the next incoming frame by the $\zeta$ coefficient and renewing it. This will update the existing background of the model. A refreshed background is recognized by the $H_t$ pixel value. So you can see changes such as light changes and background differentiation [28].

$$H_t = (1 - \zeta)H_{t-1} + \zeta I_t \tag{2.2}$$

$H_t$ = t background pixel value at a time

$H_{t-1}$ = t-1 background pixel value at a time

$I_t$ = t pixel value of the image at a time

$\zeta$ = The renewal coefficient values between [0.005 – 0.1] are used.

**Figure 2.2.** Simple background modeling motion detection [20].

$H_{t-1}$ is the background pattern of the next incoming frame. $H_t$ can be changed in $I_t$ by choosing $\zeta$ more or less in the structure of the renewed model. If $\zeta$ is selected less, it will cause some parts of the moving object to be added to the background. If $\zeta$ is chosen too much, it increases the efficiency of the model, and even a sudden change in light causes it to be perceived as motion.

## 2.3. Used Technologies

### 2.3.1. C# programming language

Programming languages that are object-oriented and general-purpose include C#. It was created and developed by Microsoft company in tandem with the .NET framework. The C# and the .Net platform construct many software, including desktop applications, web applications, office applications, websites, games, and mobile applications [29]. A high-level language, C# is comparable to C++, Java, Embarcadero, Delphi, C, and VB.NET. All C# programs follow an object-oriented design philosophy. They involve a collection of definitions in classes that also have methods, and the logic of the program is contained in the methods. One of the most widely used programming languages is C#. Around the world, many developers use C#. The Common Language Runtime (CLR) is a unique environment for execution and distribution along with the C# programming language. This environment is a component of the .NET Framework platform, which also contains other development tools like compilers and debuggers as well as the CLR, a collection of standard libraries that provide basic functionality [30].

### 2.3.2. .Net framework

Microsoft introduced the .NET effort in July 2000, a collection of programming languages, such as C# and VB.NET, a collection of development tools, such as Visual Studio.NET, a sizable class library for creating web services, web, and Windows applications, and the Common Language Runtime to run objects created within this framework. The Microsoft .NET Framework has numerous design objectives built in that are both realistic and exceedingly ambitious. The Microsoft .NET Framework's primary design objectives are improved component support, language integration, application interoperability across the internet, ease of development and deployment, improved reliability, and increased security [31]. The C# programming language is a component of the Microsoft .NET Framework platform, not a separate product sold separately (pronounced "Microsoft dot net framework"). Programs created in C# or another .NET compatible language (such as VB.NET, Managed C++, J#, or F#) can be developed and run on the .NET Framework [30].

It is made up of the following components:

- C#, VB.NET, and other .NET programming languages;
- A managed code execution environment (CLR) that runs C# applications in a regulated fashion.
- A group of development tools that translate C# programs into intermediate code (referred to as MSIL) that the CLR can read, such as the CSC compiler.
- A group of industry-standard libraries, including ADO.NET, that enable access to databases (such as MS SQL Server or MySQL), as well as WCF, which links applications using industry-standard frameworks and protocols like HTTP, REST, JSON, SOAP, and TCP connections.

### 2.3.3. SQL server

Microsoft created the relational database management system (RDMS) known as SQL Server [32]. Microsoft SQL Server uses MS-SQL and Transact-SQL as its main structured programming languages. They rely on relational algebra, which is primarily utilized for data access control as well as data entry, modification, deletion, and retrieval [33]. Databases are used to alter data as well as to gather and store it. Database management systems (DBMS) are required for the effective management of databases and the efficient use of data. The system known as SQL Server, which was developed by Microsoft Corporation, defines the procedures for managing databases. In corporate IT environments, it manages relational databases and provides a variety of business intelligence, transaction processing, and analytics tools. SQL Server Management Studio is the main management tool for the server and database. Both the programs used today in academia and at the industry level are SQL Server-based. Some variations include Enterprise, Standard, Web, Developer, and Express [34]. Its major function is to organize and store various data types. A wide range of services, including searches, queries, reports, data integrity, and analysis, are also available through the RDMBS for interacting with stored records. Transactional replication, snapshot replication, and merge replication are the three types of replication offered by Microsoft SQL Server [35].

### 2.3.4. Aforge.net

AForge.NET is a C# framework that is open-source and free. The AForge.NET library provides ways to solve problems involving artificial intelligence. The library uses various technologies, including image processing, genetic algorithms, fuzzy logic, machine learning, robotics, and more [36]. The AForge.Net Framework offers the essential and necessary libraries for the operation to be successful in real-time [37].

Following is a list of the key elements of the AForge.NET library:

- AForge.Imaging: a library made specifically to work with filters and photos;
- AForge.Vision: a library that employs computer vision techniques;
- AForge.Video: a package of libraries for handling tasks involving video data;
- AForge.Neuro: a program library that takes advantage of neural networks;
- AForge.Genetic: a library created to use genetic algorithms to tackle various issues;
- AForge.Fuzzy: a library that employs fuzzy logic;
- AForge.Robotics: a library that supports robotics-related techniques;

### 2.3.5. Arduino

Arduino is a maker of open-source computer hardware and software. Microcontroller-based development boards are created and used by the project and user community known as the Arduino Community. These development boards, or prototyping platforms, are open-source Arduino modules. The streamlined microcontroller board is available in a variety of development board packages. The most well-liked programming environment is the Arduino IDE, which employs the C programming language. You now have access to a sizable Arduino library that is continually expanding as a result of the open-source community [38]. The open-source Arduino platform is used to build and program electronics. Most gadgets can receive and communicate information from it and even send commands to particular electronic equipment via the internet. The Arduino Uno circuit board is the hardware component, while software (simplified C++ or C) is used to program the device. Because it has user-friendly or simple-to-use settings, Arduino is now frequently used in microcontroller programming, among other things. The Arduino is a circuit board with a chip that, like any other microcontroller, can be programmed to carry out many tasks. Information is sent from the computer software to the Arduino microcontroller and then to the specific circuit or machine with many circuits in order to carry out the given command. An Arduino can send data to output devices like LEDs, speakers, LCD panels, DC motors, and other devices as well as read data from input devices like sensors, antennas, trimmers (potentiometers), and so on [39]. The open-source platform Arduino offers a solid foundation for both hardware and software. Some researchers at the Interaction Design Institute in Ivrea, Italy, launched the Arduino Project in 2005. Arduino was created with the intention of providing a platform for hobbyists, experts in embedded systems, and open-source hardware developers to create devices and projects using a variety of sensors and actuators [40].

### 2.3.6. Yolo

Yolo is among the most well-liked object detection techniques in computer vision. The candidate box extraction, feature extraction, and object categorization methods are all incorporated into the YOLO neural network. Using the YOLO neural network, candidate boxes are directly extracted from photos, and objects are found using all of the image's attributes [41]. A one-step procedure comprising detection and classification was designed with You Only Look Once (YOLO). After evaluating the input image once, the bounding box and class predictions are created. On a computer with a GPU, Tiny YOLOv2 can run up to 244 frames per second, while the fastest architecture of YOLO can reach 45 frames per second [42]. YOLO takes a different approach to predicting numerous bounding boxes and class probabilities for those boxes by applying a single neural network to the entire image. The architecture of Tiny YOLOv2 is shown in Figure 2.3, which consists of 9 convolutional layers, each with a batch normalization operation and a leaky rectified linear unit (ReLU)-based activation function, spaced out between 6 max-pooling layers, and a region layer. With an input image size of 416 × 416, Tiny YOLOv2 has 20 output classes in VOC datasets and 80 output classes in COCO datasets [43].

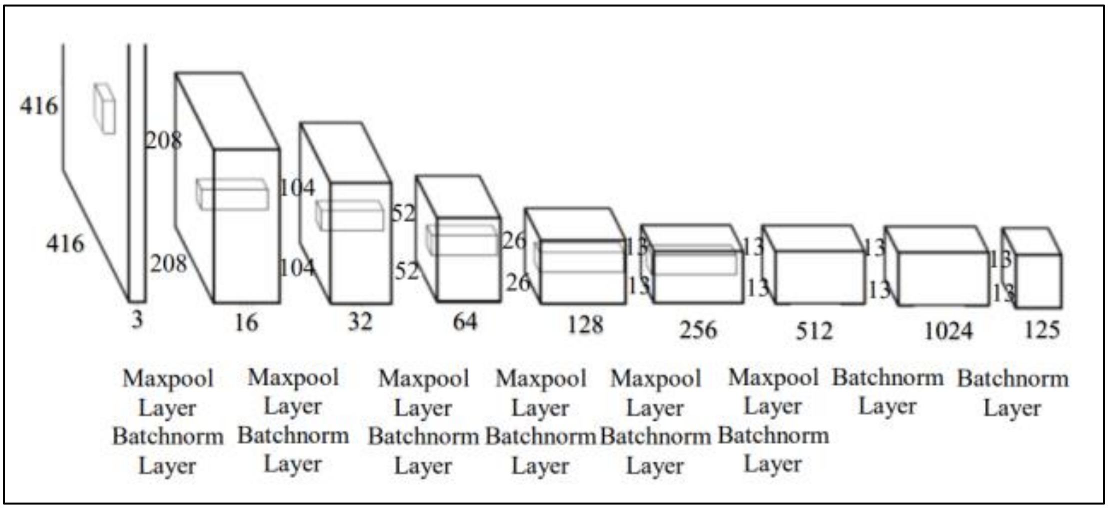


**Figure 2.3.** Tiny YOLOv2 Architecture [43].

Target detection is used by the YOLO network model as a regression issue for a spatially distinct target box and its category confidence. The category of the entire image and the confidence of the target box can both be accurately predicted by a single neural network. Figure 2.4 depicts the YOLO network model's pedestrian detection procedure.

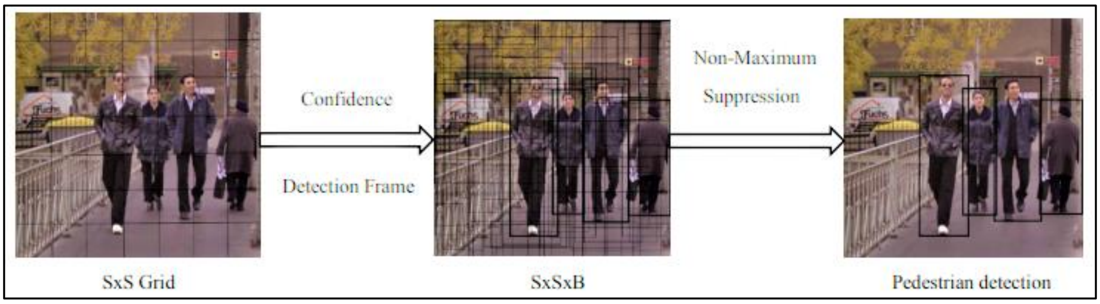


**Figure 2.4.** Pedestrian detection by YOLO.

1. First, create an S*S grid on the image. The grid is in charge of spotting the pedestrian if it is inside a grid. Each grid forecasts B detection boxes and their confidence, and each image's total number of detection frames is S*S*B.
2. There are five anticipated values for each detection box (X, Y, W, H, and Conf). Where W and H are the projected box width ratios to the full image, Conf is the detection box's confidence, and X and Y are the offsets of the prediction box's center in relation to the cell boundary.
3. Every grid forecasts the conditional probability Pr(class|object) of the pedestrian whenever there are pedestrians in the known grid.
4. To determine the confidence score for each detection box walkers category, the conditional probability is multiplied by the predictive value of various detection box confidences at the time of detection. The likelihood that walkers will emerge in the detection frame and the verification of the correspondence between the box and the walker's goal is also included in these pedestrian types.

The confidence score formula as in (2.3):

$$Conf(class) = \Pr(class) * IOU_{Pred}^{Truth} \tag{2.3}$$

Pr(class) represents the probability that a pedestrian appears in the grid, and *IOU* represents the overlap region between the prediction box and the base true box. *Pred* gives the area of the predicted box and *Truth* gives the area of the ground truth box. The larger the *IOU*, the more accurate the pedestrian detection. The final output vector for each image on the network is S*S*B*[X, Y, W, H, Conf, Conf (class)] [44].

# 3. DESIGN AND IMPLEMENTATION OF SECURITY ALERT SYSTEM

Our system consists of two main parts, software and hardware, and has several important features. This section describes the design, security alert system requirements, flow chart, and Relational Database Management System (RDBMS) for every component of designing a security alert system, including hardware and software components.

## 3.1. System Design

The system design includes the design of interactions, experiences, encounters, and procedures. The system is designed to define a system's components, like its architecture, components, GUI, and information systems, depending on the predefined requirements. System components include cameras, applications, databases, and alerts. The system is designed in such a way that it can successfully surveil secrets and vital places. The system monitors the locations in real-time via a camera. The system can control four different areas simultaneously. The system is designed to detect human motion in the areas it is assigned to protect. Whenever the system detects motion using a two-frame difference motion detection algorithm or a simple background modeling motion detection algorithm, with the assistance of AForge.NET, the system processes the motion using the Tiny YOLOv2 model. If the motion is human, it immediately activates alerts. There are three different types of alerts in the system: sound, LED, and email. Also, the system starts recording video of the zone where human movement is detected so that the least amount of storage is required and records incident information in the database using an SQL Server. The system is designed to notify the observer whenever it detects human movement. If there is movement other than human movement, it does not notify the observer, for example, the movement of several pieces of a cardboard box for any reason. Figure 3.1 depicts the basic scheme of the system, with the first section containing two types of motion: human and falling boxes. The second section is that the system is connected to a multi-camera for monitoring in several locations. And the third section is the system's start of video frame processing to determine human motion. In the final section, the system will activate the alerts if the motion is human.

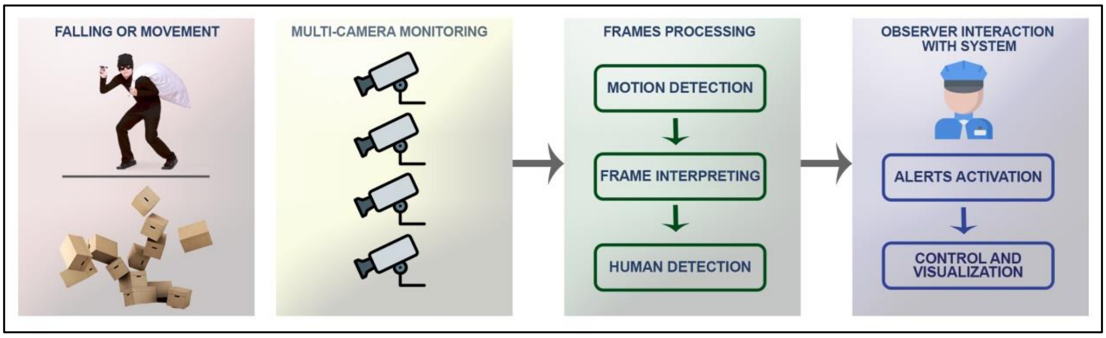


**Figure 3.1.** The basic scheme of the proposed security alert system.

Figure 3.2 shows the architecture of the surveillance system and how all of the components of the system work to detect human movement and notify the carers.

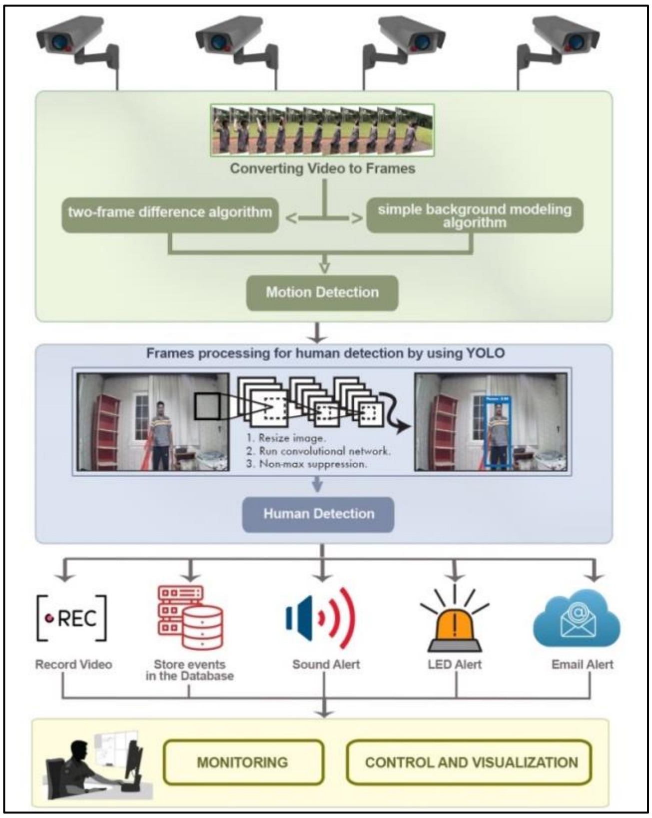


**Figure 3.2.** The architecture of the surveillance system.

The system is designed in such a way that it does not allow any human movement in vital and secret locations, which provides more security and does not allow thieves and vandals to easily access the places where this system is located, making those places safe. A flowchart illustrating the system's operation is shown in Figure 3.3.

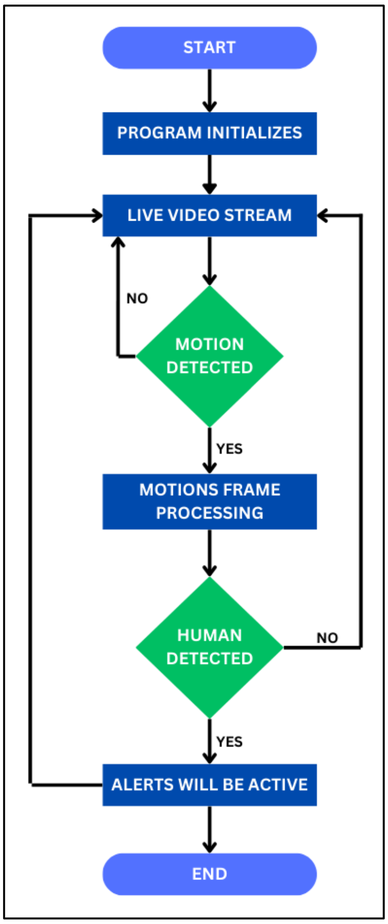


**Figure 3.3.** Flowchart of the proposed system.

### 3.2. Requirements Analysis

To verify the existing system, there are many requirements, such as:

A- User Requirements

In order to completely engage system users and avoid the issue of change management, user requirements are essential. The stakeholder who will use the proposed system expects the following from the proposed system:

1- A system that is easy to use and learn.

2- A system that improves the efficiency of information storage and retrieval.

3- A system that is faster, more flexible, and more convenient.

4- A system that is best to monitor and protect the areas.

5- A system capable of detecting and recognizing human movement.

6- A system that directly alerts observers when it detects human movement.

B- Functional Requirements

The operations and activities that the system must be able to perform are referred to as functional requirements.

1- Recording the information of observers who play a role in the system's operation.
2- Detection of human movement in areas where human movement is prohibited.
3- The system notifies monitors directly when it detects human movement.
4- The system records information about any event or human movement it detects.

C- Non-Functional Requirement

Non-functional requirements specify criteria that can be used to assess the system's performance instead of specific behaviors.

In the security alert system, the non-functional requirements that need to be investigated include:

1. Accuracy and Precision: Requirements for precision and accuracy.
2. Modifiability: Requirements for the software change effort.
3. Reliability: The causes of the software's failure.
4. Security: Requirements about the protection of your system and data. This measurement is expressed in various ways to break into the system.
5. Usability: The ease with which the system or process can be operated or learned.

### 3.3. Database Design of the Security Alert System

The database is one of the most important parts of the surveillance and security alert system design. All the data related to the motion detected is stored in database tables. The database was implemented by using the SQL Server database, and it can be accessed by using the C# programming language. The database includes five tables. Figure 3.4 shows the tables and the relationships between them.

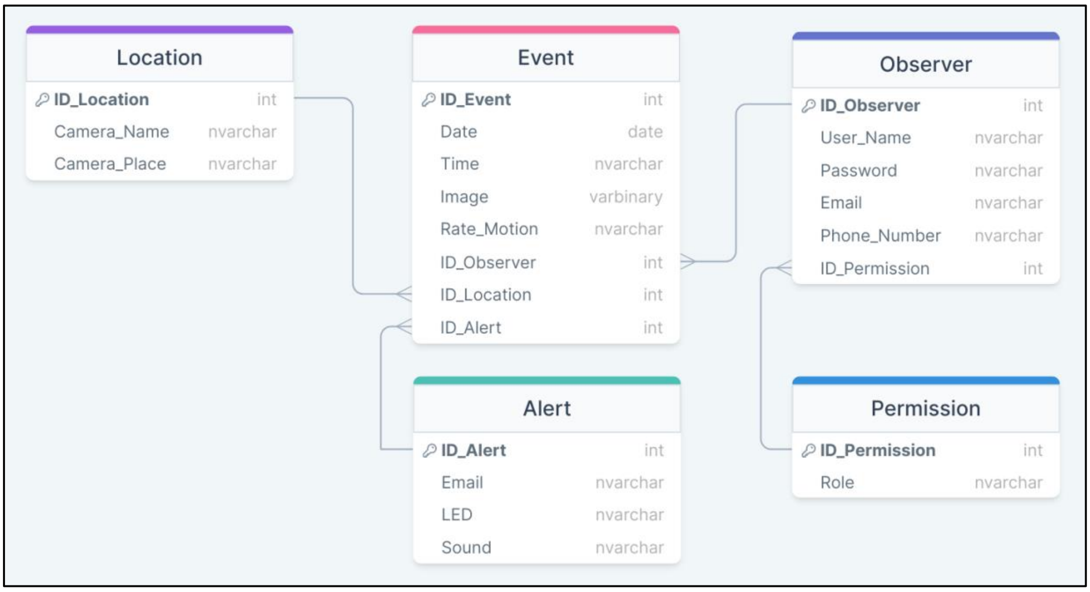


**Figure 3.4.** SQL Server ERD diagram of the security alert system.

A relational database divides information among tables. The relationship between tables is established by employing the primary and unique keys. It can then use relation tables to bring the information together as needed. Table 3.1 shows the database table name and description.

**Table 3.1.** The description of the database tables.

| NO | Tables | Descriptions |
|---|---|---|
| 1 | Event | Whenever the system detects a human motion, it records information in this table about the event. |
| 2 | Location | The user records the names of the locations in this table where the cameras are installed. |
| 3 | Alerts | This table provides information about the alerts that were activated during the incidents. |
| 4 | Observer | This table provides information about the observers who use the system. |
| 5 | Permission | This table determines the permission of the observers for the use of the system. |

The system has five special tables for collecting information and improving the system, which plays an important role in recording events. Then the observers can easily review the system's detected movements.

Following are the tables of the system:

1- Event Table

This table records information about the human motions detected by the system, such as date, time, images of the motion, etc., so that observers can easily review the events later. Table 3.2 contains more information.

**Table 3.2.** Description of the event table.

| NO | Attribute | Data Type | Descriptions |
|---|---|---|---|
| 1 | Id_event | int | A unique serial number is given to the event |
| 2 | Date | date | Recording the date of the human motion found. |
| 3 | Time | nvarchar | Recording the time of the human motion found. |
| 4 | Image | varbinary | Recording the image of the human motion found. |
| 5 | Rate_Motion | nvarchar | Recording the ratio of the human motion found. |
| 6 | ID_Observer | int | Record the observer's unique number to identify the event observer. |
| 7 | ID_Location | int | Record the location's unique number to identify the event location. |
| 8 | ID_Alert | int | Record the alert's unique number to see how many alerts worked. |

2- Location Table

The location table lists the names of the places where the cameras are installed. This table helps users because, during motion detection, it locates the motion so that observers can properly control events. Table 3.3 contains more information.

**Table 3.3.** Description of the location table.

| NO | Attribute | Data Type | Descriptions |
|---|---|---|---|
| 1 | ID_Location | int | A unique serial number is given to the location |
| 2 | Camera_Name | nvarchar | Recording the camera name of the locations. |
| 3 | Camera_Place | nvarchar | Recording the name of the locations. |

3- Alert Table

The system has three different alert types. The table lists the alerts the observers have activated to be active when human motion is detected. Table 3.4 contains more information.

**Table 3.4.** Description of the alert table.

| NO | Attribute | Data Type | Descriptions |
|---|---|---|---|
| 1 | ID_Alert | int | A unique serial number is given to the alert |
| 2 | Email | nvarchar | Recording on or off of this type of alert |
| 3 | LED | nvarchar | Recording on or off of this type of alert |
| 4 | Sound | nvarchar | Recording on or off of this type of alert |

4- Observer Table

The observer table contains the specific information of the observers allowed to use the system. Table 3.5 contains more information.

**Table 3.5.** Description of the observer table.

| NO | Attribute | Data Type | Descriptions |
|---|---|---|---|
| 1 | ID_Observer | int | A unique serial number is given to the observer |
| 2 | User_Name | nvarchar | Recording the name of the observers. |
| 3 | Password | nvarchar | Recording the password of the observers. |
| 4 | Email | nvarchar | Recording the email of the observers. |
| 5 | Phone_Number | nvarchar | Recording the phone number of the observers. |
| 6 | ID_Permission | int | Record the permission unique number to identify the observer's permission. |

5- Permission Table

In the permissions table, the permissions of the observers are specified to use the system. Table 3.6 contains more information.

**Table 3.6.** Description of the permission table.

| NO | Attribute | Data Type | Descriptions |
|---|---|---|---|
| 1 | ID_Permission | int | A unique serial number is given to the permission |
| 2 | Role | nvarchar | Recording the type (user, manager) of the permission. |

### 3.4. Software Application

This part provides information about the application of the security alert system. The application was built with popular and modern tools to help users manage their work effectively, using C#, SQL server, and the .NET libraries. The application plays an effective role in surveilling vital and secret places and keeping track of all events.

With the aid of AForge.NET, the system uses a two-frame difference algorithm and a simple background modeling algorithm to determine movement in real-time in the locations where the cameras are set up. After the system determines motion, a frame of motion is processed, and alerts are activated if a human participated in the event. The tiny YOLOv2 model in the system determines humans in motion frames. The system is made to be user-friendly and simple to use so that users can effectively manage it.

### 3.4.1. Surveillance form of the security alert system

The surveillance form is one of the main forms of the system. Using this form, observers can surveil the places where the cameras are installed in real-time. In Figure 3.5, we explain the system surveillance form.

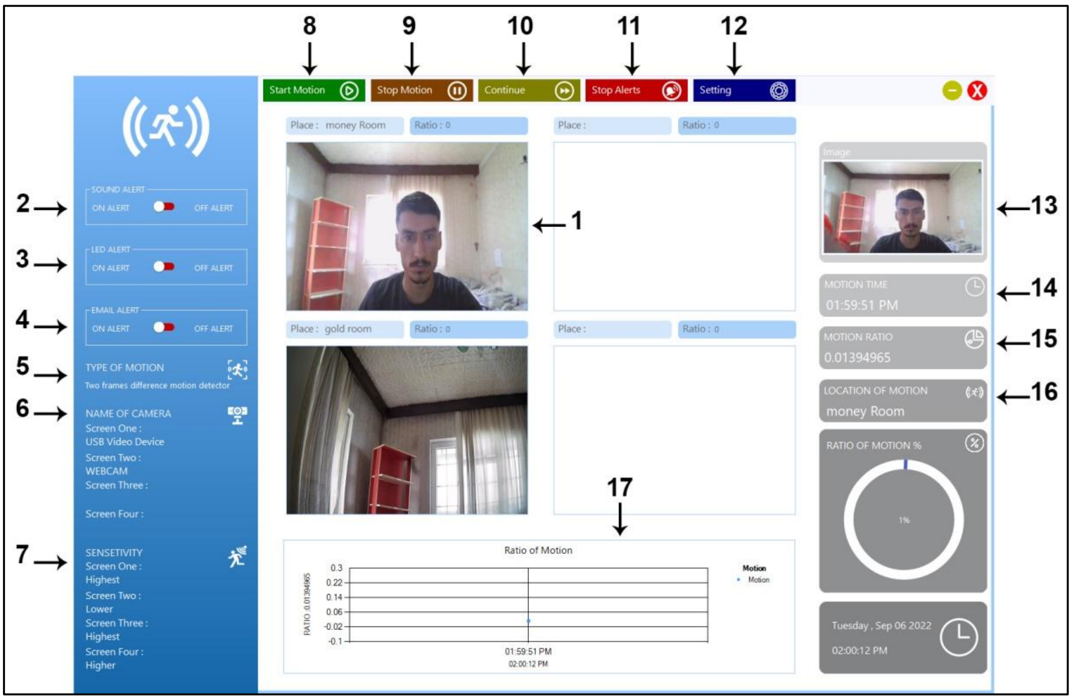


**Figure 3.5.** Surveillance form of the desktop application.

1. The system's four main screens for surveillance places also show the locations' names and how much movement there is in each.
2. The observer can activate or deactivate the system sound alert.
3. The observer can activate or deactivate the system LED alert.
4. The observer can activate or deactivate the system email alert.
5. The system has two types of motion detection; the selected type is shown here.

6. The system has four screens for cameras; here, it displays the names of the cameras.
7. It displays the sensitivity ratio for each of the four screens. The system features a sensitivity ratio for detecting motion.
8. This button starts motion detection on the system.
9. This button stops motion detection on the system.
10. This button is continuous with motion detection on the system.
11. This button stops alerts on the system.
12. This button is the settings, and you can make changes.
13. It displays a picture of the last motion that the system picked up.
14. It displays the time of the last detected motion detected by the system.
15. It displays the ratio of the last motion detected by the system.
16. It displays the place of the last motion detected by the system.
17. It displays all the human motion detected and recorded by the system after activation.

### 3.4.2. Settings form of the security alert system

The system contains several sections that users can change when they visit the Settings section. Parts consist of motion, camera selection, email, a user profile, sounds, sensitivity, and video.

Following are the parts of the setting:

1- Form of motion types

The system offers the user and observer a choice between two motion-detecting types.

The varieties are:

- Two frames difference motion detector
- Simple background modeling motion detector

Figure 3.6 demonstrates how the user may choose the motion types by visiting the settings form in the motion type section.

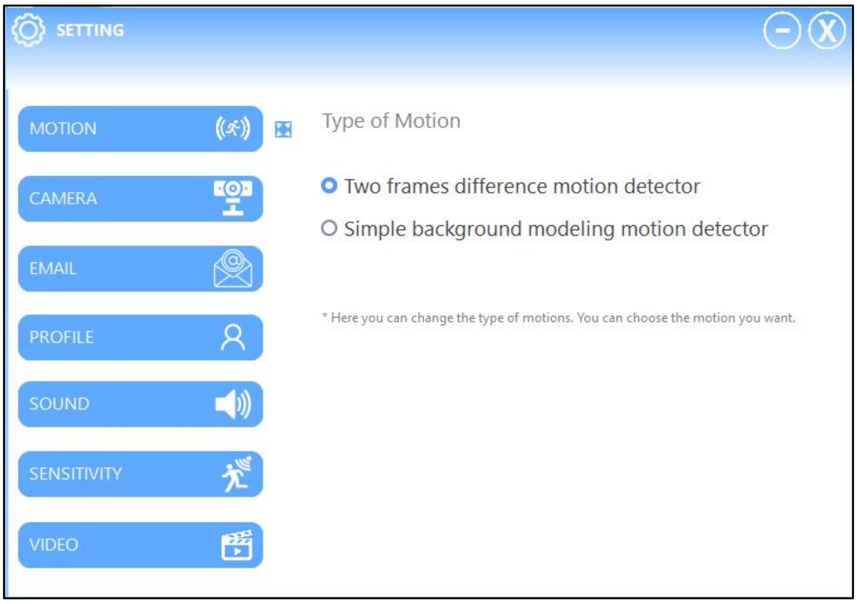


**Figure 3.6.** Form of motion types.

2- Form of cameras selection

The system includes four main screens to show the zones where the cameras are installed. The user can select the cameras they want to monitor the locations for within the Camera Settings section. Figure 3.7 demonstrates how users may choose the cameras by visiting the settings form in the Camera Settings section.

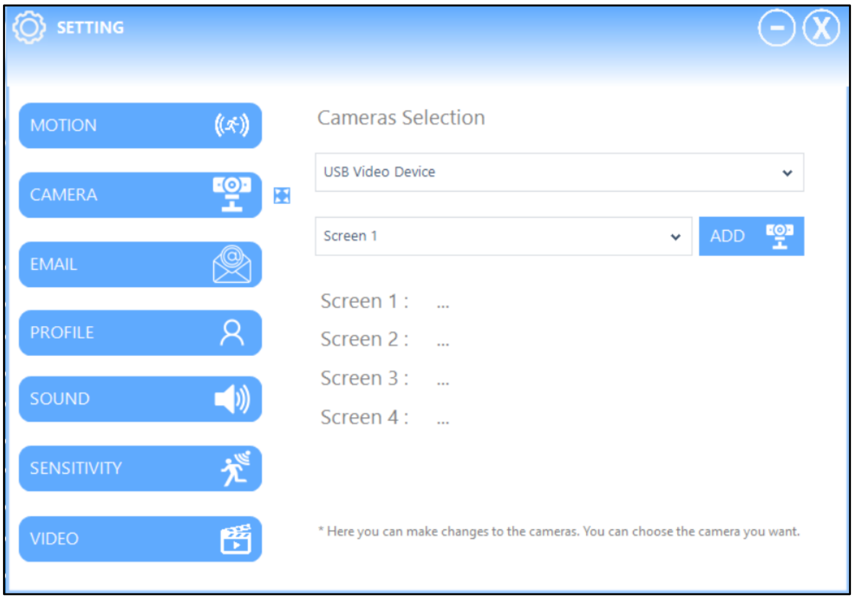


**Figure 3.7.** Form of camera selection.

3- Form of email alert

The system features a part for emailing the observers when there is human motion via an SMTP server. The SMTP (Simple Mail Transfer Protocol) transport mechanism is used to transfer email messages across the Internet. To transfer emails alert from one server to another server is used SMTP. Email clients and email servers both send messages using SMTP [45]. Today, one of the most used network services is electronic mail or email. Most email systems use the Simple Mail Transfer Protocol to send emails online. From one server to another, messages are sent using SMTP. Then, using an email client and Post Office Protocol (POP) or Internet Message Access Protocol (IMAP), the messages can be obtained. To deliver the mail, an SMTP client will communicate with the destination host's SMTP server directly. It will delay the transmission of the mail item until the recipient's SMTP has successfully received it [46].

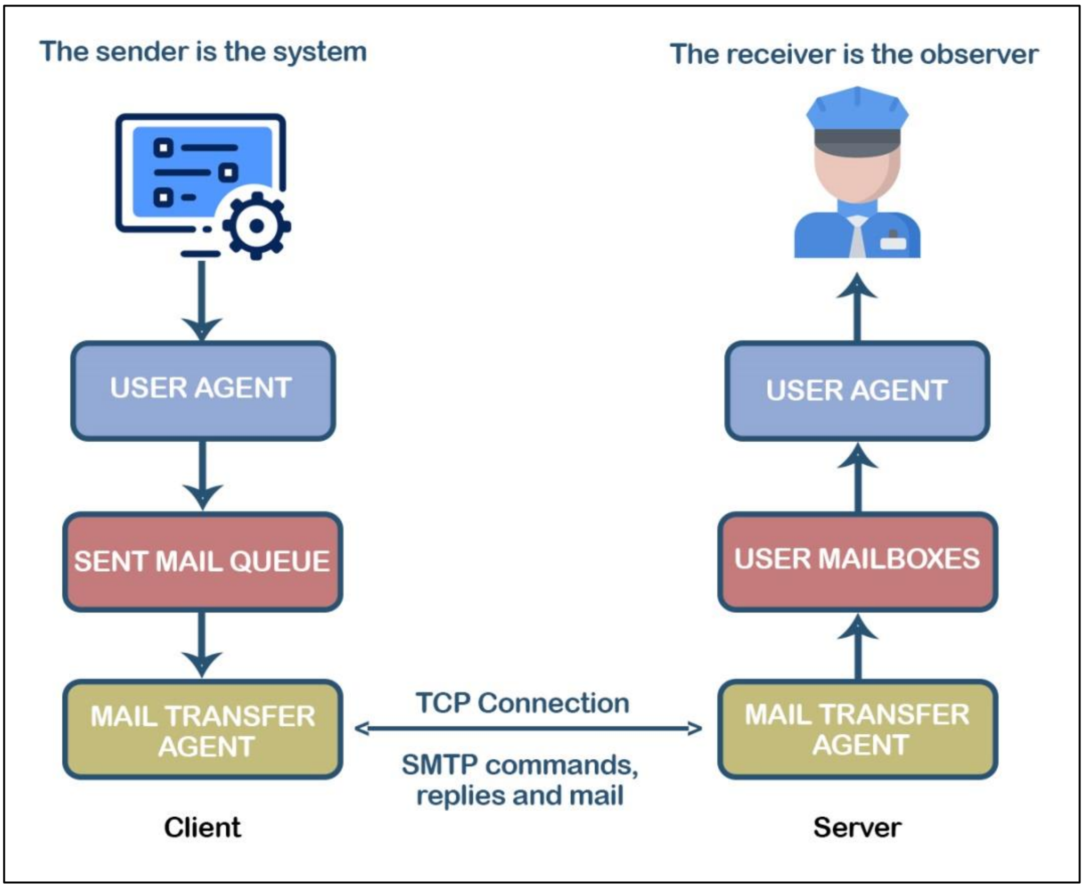


**Figure 3.8.** Simple Mail Transfer Protocol (SMTP) model.

The user will register an email address for the system in this form, and in Figure 3.9, the system will have its email address. The email setting form also shows the sender's and recipient's email addresses.

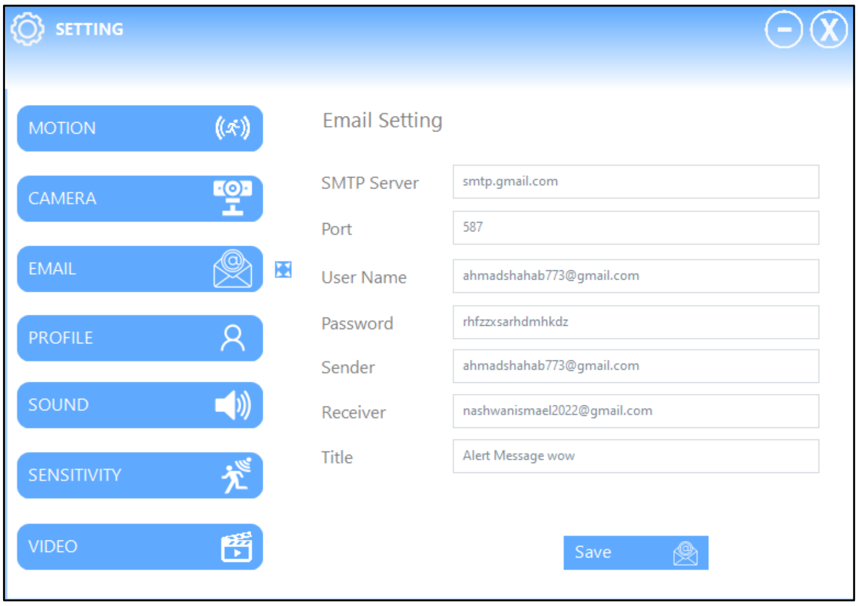


**Figure 3.9.** Form of Email alert.

Figure 3.10 shows a form the user can use to change the email's subject and content. The user can add event information to the email, such as (the date and time of the event, event location, and motion ratio).

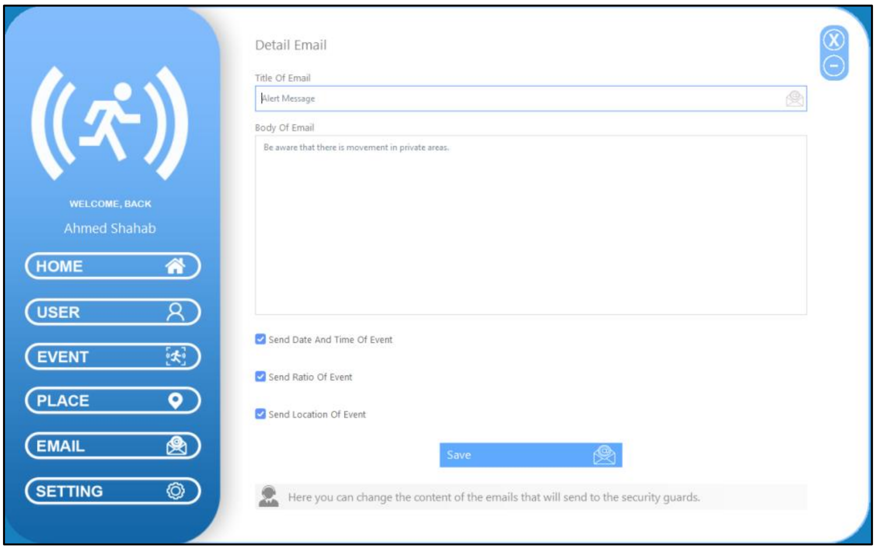


**Figure 3.10.** Form of Email detail.

4- Form of user profile

Users can only make changes to their account password. Figure 3.11 demonstrates how the user may change the password by visiting the settings form in the Profile Setting section.

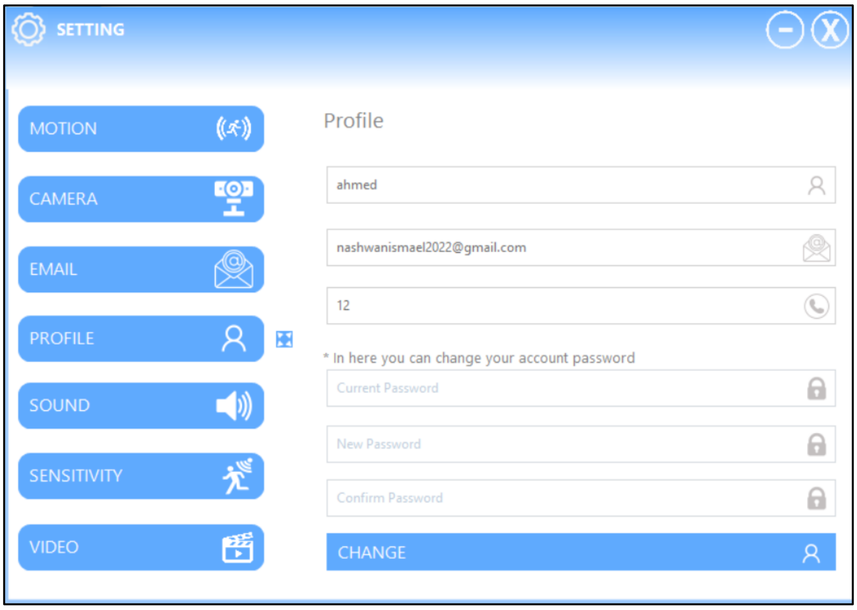


**Figure 3.11.** Form of the user profile.

5- Form of sound alert

Users can change the sounds that are activated when detecting human motion. Figure 3.12 shows the sound-changing form.

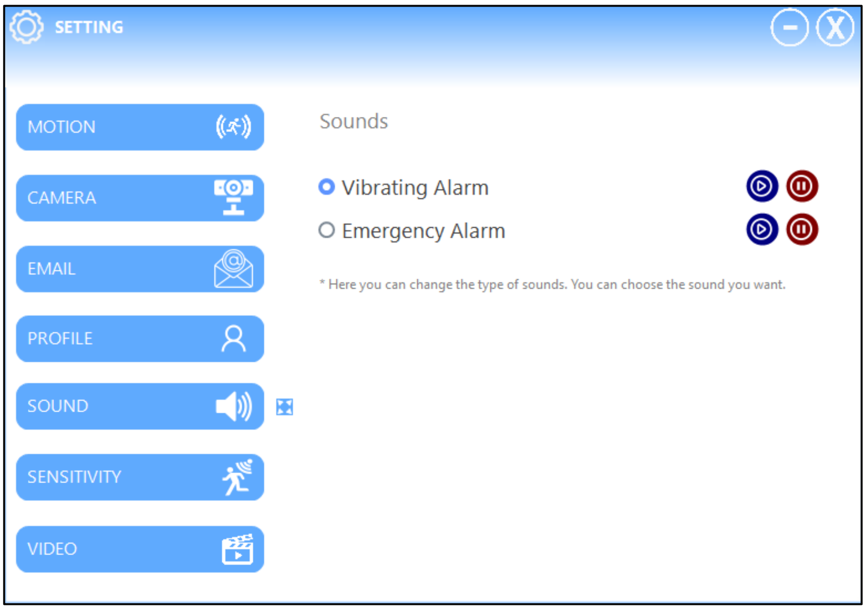


**Figure 3.12.** Form of sound alert.

6- Form of motion sensitivity

Each of the system's four screens has a different level of motion-detecting sensitivity. The form for choosing the sensitivity is shown in Figure 3.13. The user can select one of six different sensitivity ratios for each screen. They are highest, higher, high, middle, lower, and lowest for the sensitivity coefficients.


**Figure 3.13.** Form of motion sensitivity.

7- Form of recording video

Video recording is another aspect of the system. When the system notices human motions, it begins to record a video of the area of motion.

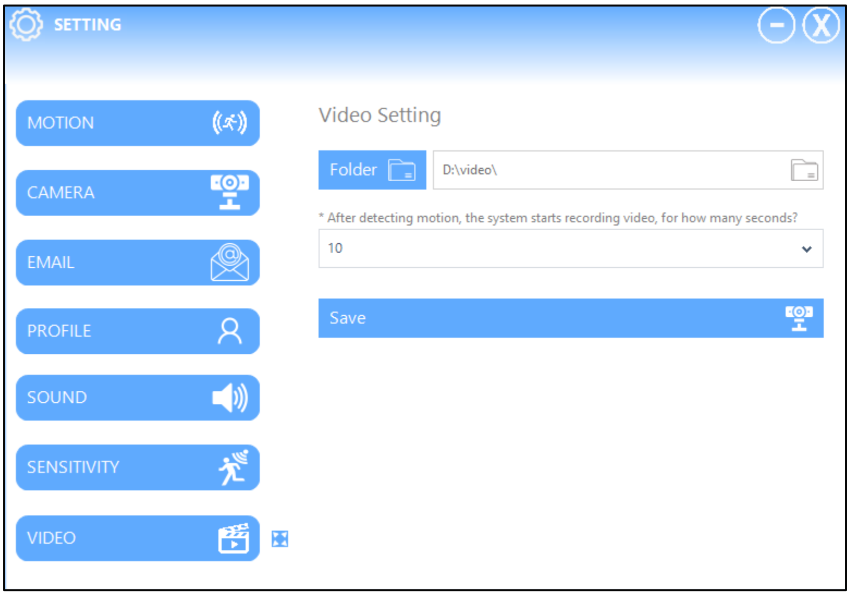


**Figure 3.14.** Form of recording video.

Figure 3.14 demonstrates how the user may choose the path of the video by visiting the settings form in the video settings section. The consumer can also set the length of the motion videos between 10 and 60 seconds. For example, after detecting motion, the machine will record a video of the region for 10 seconds.

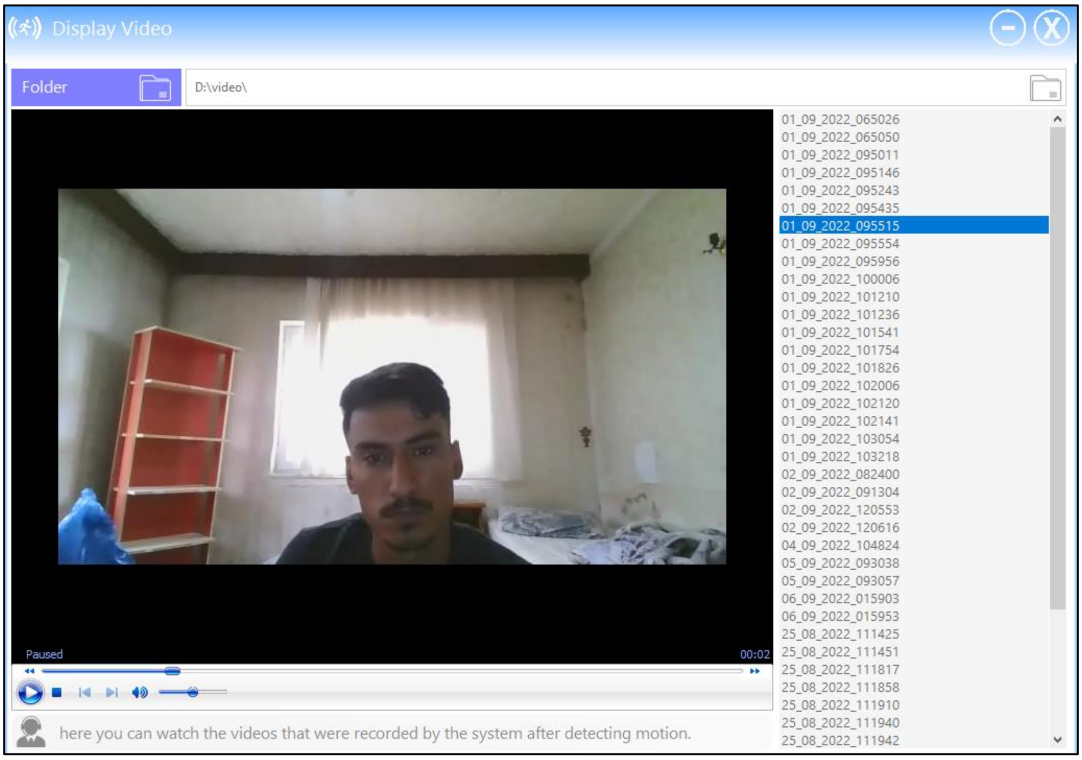


**Figure 3.15.** The form for displaying recorded videos.

The arrangement for playing back recorded videos is shown in Figure 3.15. Viewers can see the videos that the system has captured in this format. Verify the locations' safety by watching the videos.

8- Form of determining camera position

Observers or users should record information about the locations where the cameras are installed because whenever the system detects human movement, it will immediately notify the observers and locate the movement. This feature allows observers to go directly to the destination during human movement in areas to control incidents as soon as possible. In this form, users enter the name of the location where the cameras are installed and the name of the camera connected to the system. Observers or users can also easily select and change the names of locations and camera types.

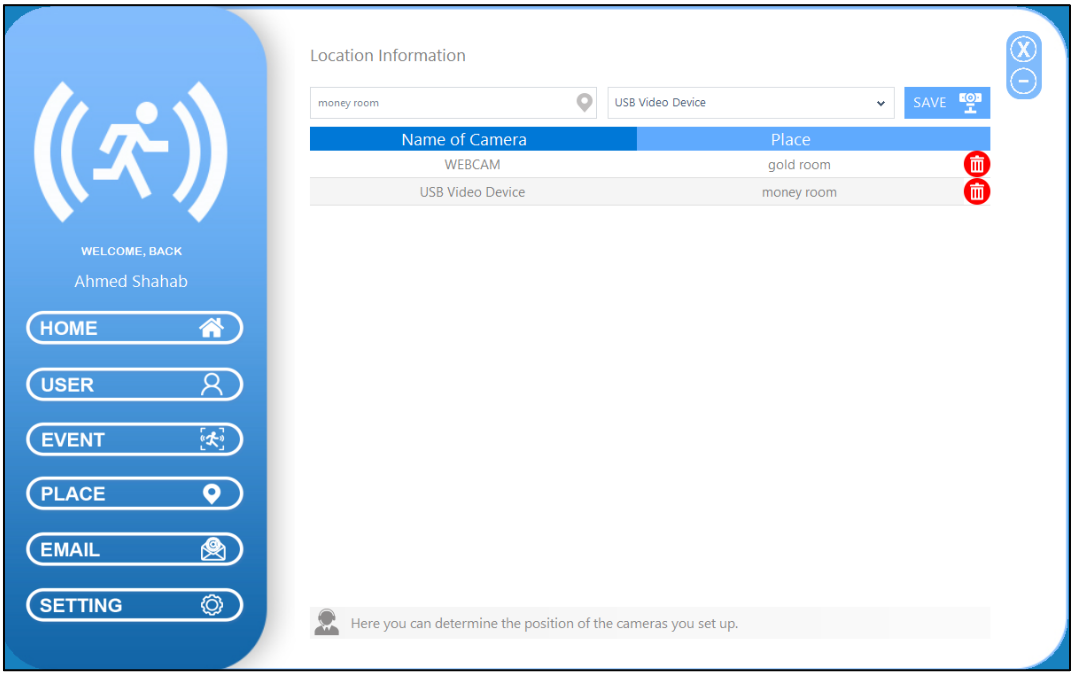


**Figure 3.16.** The form of determining camera position.

### 3.4.3. Observers' roles in the security alert system

The system has two types of observers with different authorities for using it. There are two types: users and managers. Figure 3.17 explains all the observer's permissions to use the system. The manager has full authority over the system and can control it completely. However, the user can only use the system for monitoring purposes; their permission is limited. This feature makes the system more powerful. Because only managers can review events and change information, users have less access to events recorded in the system. A manager can change all user information, but users can only change their account password.

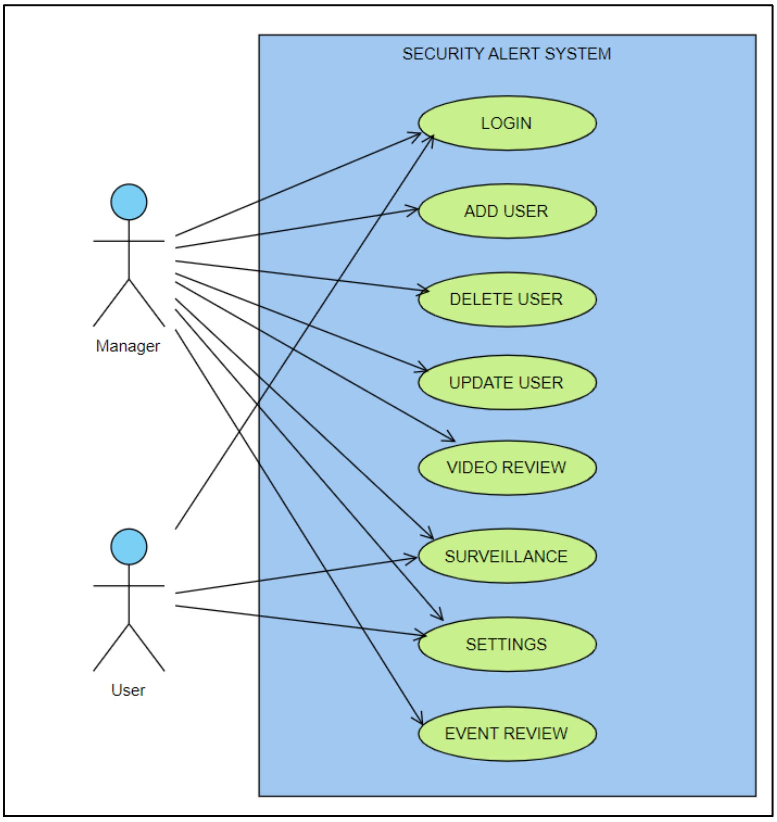


**Figure 3.17.** A use-case of observer's permission.

Both types of observers can access the system by using the same login form shown in Figure 3.18.

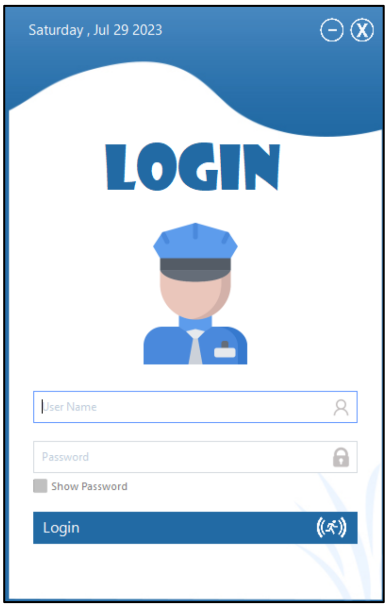


**Figure 3.18.** Form of login in the system.

After entering their password and user name, a special form will be opened according to the type of permission assigned to the observers. The main dashboard opens for the observer if the observer is a manager permission type; Figure 3.19 shows the dashboard form.

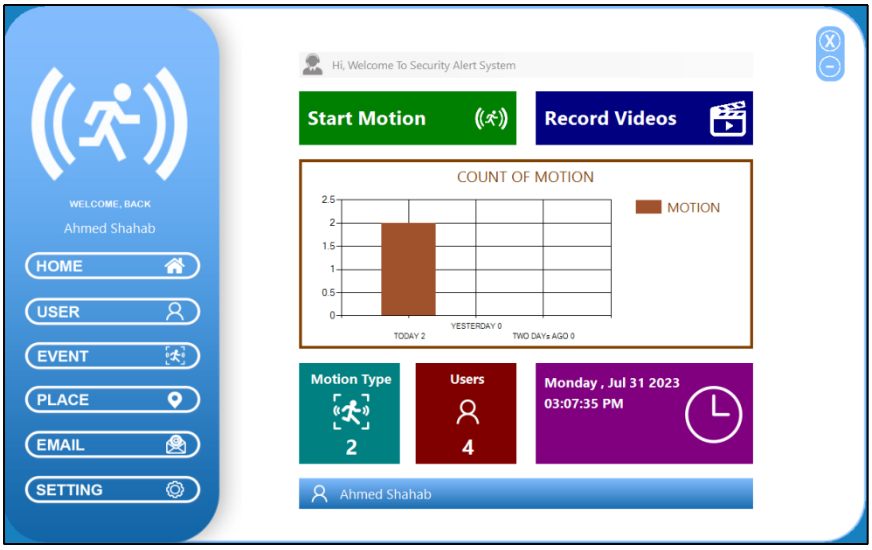


**Figure 3.19.** Dashboard form of the security alert system.

But the surveillance form opens for the observer if the observer type is a normal user. The system manager can also increase the number of observers or change their information. Figure 3.20 shows the form of the observers.

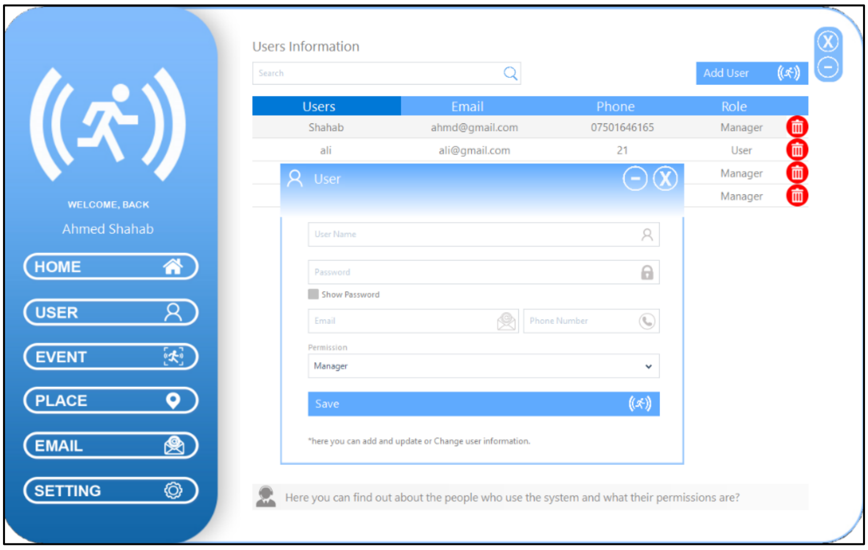


**Figure 3.20.** Form of observer's information.

### 3.4.4. Form of events in the security alert system

The system starts recording information such as location, time, date, rate, photos, and so on whenever it detects human motion. This will help observers follow up on incidents and make it easier to identify perpetrators. This is one of the features of the system that makes it necessary to use it for vital and secret places. Figure 3.21 shows the form of events recorded by the system. In this form, observers can view the latest information and search for events by date.


**Figure 3.21.** Form of events.

Observers can learn more about the events by clicking on each recorded one. Figure 3.22 shows the form of the event for which the observer wants to know all the information. The information includes the location, time, date, rate, and name of the observer who reactivated the system at the time, as well as how many alarms for the event were activated.

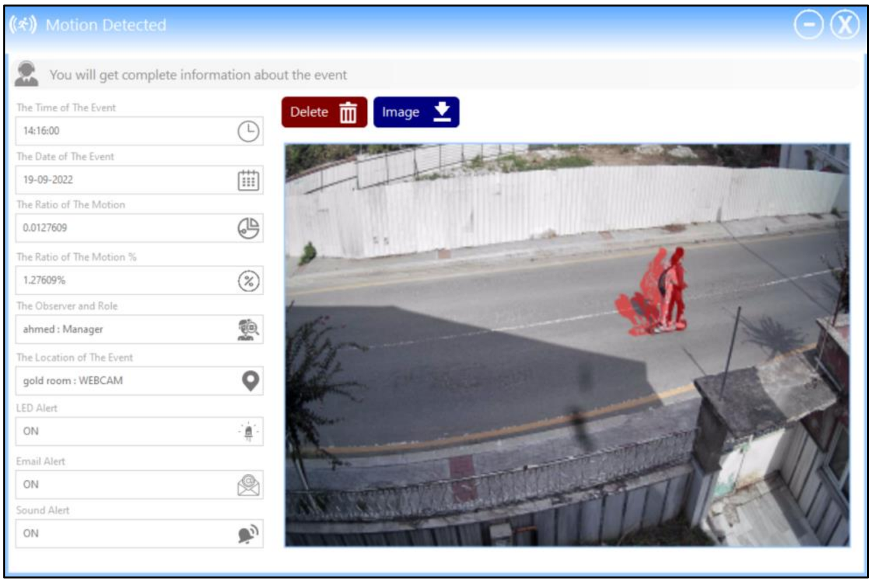


**Figure 3.22.** Form of event detail.

### 3.5. LED Alert Using Arduino

An Arduino will be connected to a computer and communicate with it using a C# Windows application. It may be quite beneficial to connect devices to a PC so you can send orders and track their progress. Arduino is a brand of open-source microcontrollers. It takes little time to program, delete, and reprogram [47]. This section is one of the main parts of the system. In this section, one of the alerts produced is the LED alert, which will play an effective role in alerting observers to the presence of human motion in vital and secret places. LED alerts can be placed in the observer room, or anywhere else that is easily visible. In this section, the Arduino is used in collaboration with several other components. Figure 3.23 demonstrates the interaction of all the parts in the Arduino part.

The parts of creating an LED alert contain:

1- LED
2- Arduino UNO
3- Jumper wire
4- Breadboard
5- Resistors (1k Ohm)

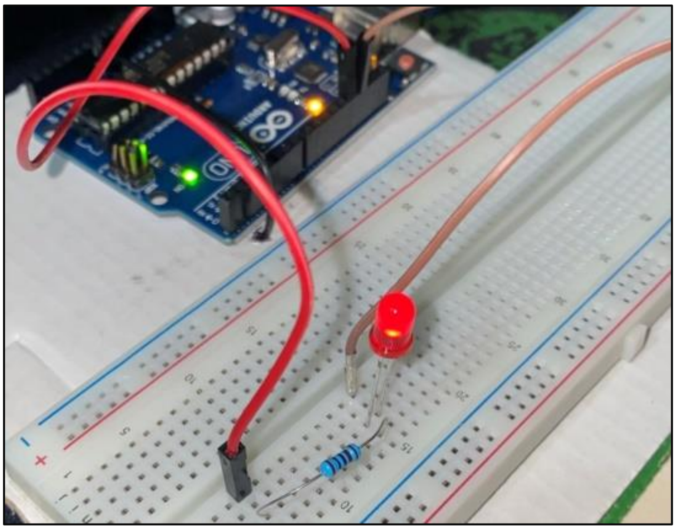

**Figure 3.23.** Components of LED alert.

## 4. TESTS AND EXPERIMENTS

In this part, we examine the system and present its capability for monitoring the locations where it is responsible for doing so. The multi-camera is used as the video source. The tests were duration of human motion detection and alert activation, four directions of human motion, evaluations of the system indoors and outdoors, evaluation of the system in low light, and evaluation of the accuracy of the system. The results were presented.

### 4.1. Duration of Human Movement Detection and Alert Activation

The ability to detect motion and notify the security guard of human activity as quickly as possible is one of the surveillance system's key advantages. In order to determine how long it takes for the system to detect human motion and activate the alerts, we used ten human motion detections as an example. We have the data in Table 4.1.

**Table 4.1.** Duration of human movement detection and alert activation.

| Hours: Minute: Seconds. Millisecond | | | |
|---|---|---|---|
| Testing | Motion Detected | Human Detected | Receive Email |
| 1 | 05:05:57.205 | 05:05:58.840 | 05:06:03.000 |
| 2 | 05:11:41.681 | 05:11:42.915 | 05:11:44.000 |
| 3 | 05:15:11.938 | 05:15:13.230 | 05:15:15.000 |
| 4 | 05:19:24.757 | 05:19:25.948 | 05:19:27.000 |
| 5 | 05:21:22.142 | 05:21:23.344 | 05:21:25.000 |
| 6 | 05:22:51.038 | 05:22:52.243 | 05:22:54.000 |

**Table 4.1. (Continued)** Duration of human movement detection and alert activation.

| Hours: Minute: Seconds. Millisecond | | | |
|---|---|---|---|
| Testing | Motion Detected | Human Detected | Receive Email |
| 7 | 05:25:16.098 | 05:25:17.327 | 05:25:20.000 |
| 8 | 05:28:02.720 | 05:28:03.973 | 05:28:06.000 |
| 9 | 05:32:51.833 | 05:32:53.133 | 05:32:55.000 |
| 10 | 05:34:07.117 | 05:34:08.376 | 05:34:09.000 |

We only include data from ten occurrences in Table 4.1 when the system recorded the time when movement was detected using a camera. The motion's image was processed, and the moment humans were discovered was noted. For instance, in the first test, the motion detection time was 05:05:57.205, and it took only 1.635 seconds for the alerts to be activated once the person was discovered in that movement (05:05:58.840). At 05:06:03.000, the carer received the email. Figure 4.1 shows the period of the received email for all tests. This chart shows that the system can notify carers by email as soon as possible, compared to other previous studies.

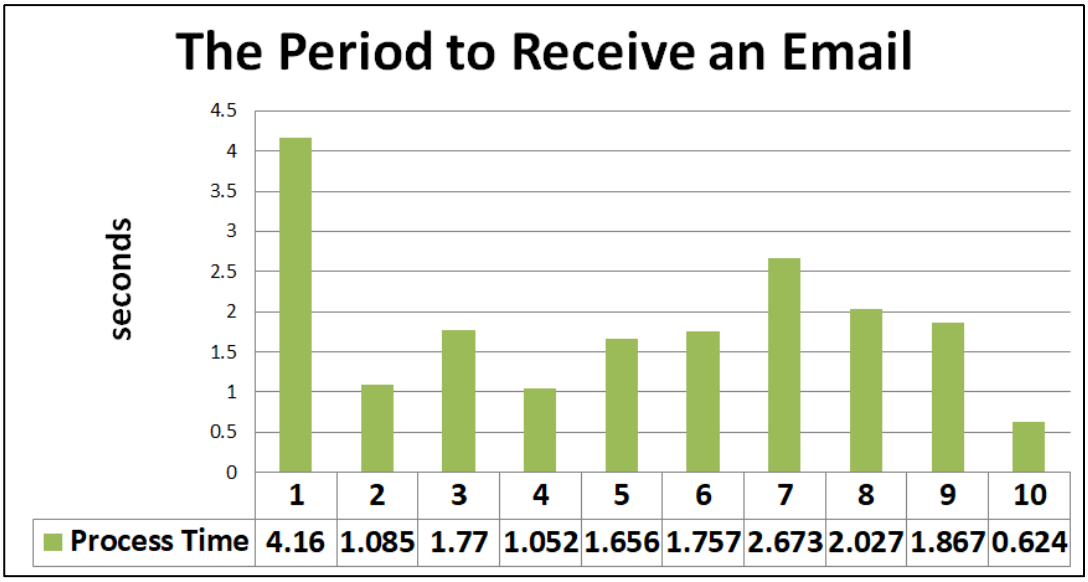


**Figure 4.1.** The period to receive an Email.

To demonstrate the ability and speed of the system to send emails alert to carers, we compared the system with a previous system [48]. Figure 4.2 shows how much faster our system sends email notifications than the study [48]. Five initial tests of systems are sampled to show the time taken to send emails.

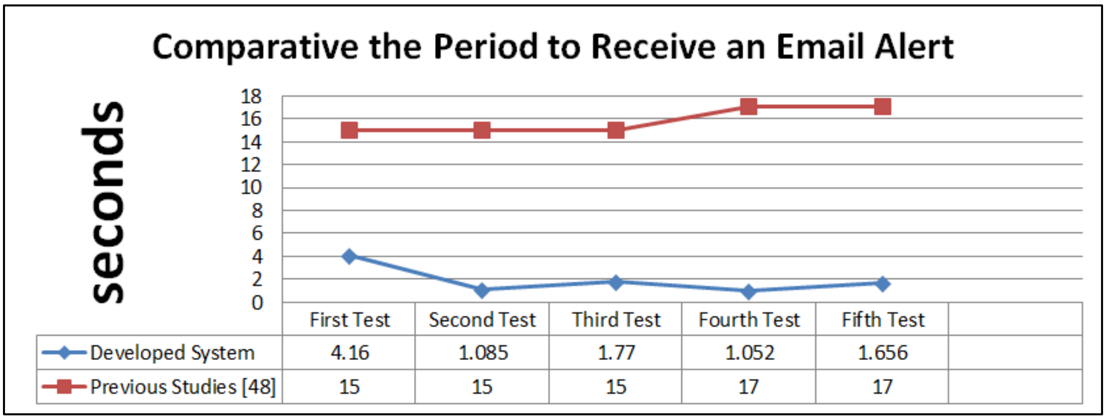


**Figure 4.2.** The comparison of the period to receive an Email alert.

This outcome demonstrates that our system is more capable of monitoring and safeguarding locations than this system [48]. An email sent using this system [48] takes 15 to 17 seconds to reach the carers. We also compared the system to several similar previous systems in order to determine the elapsed average time in sending message alerts. Our system is faster than the previous systems, and the results of the studies are shown in Table 4.2.

**Table 4.2.** The comparison of the average time elapsed in message alerts between studies.

| Previous Studies | Average of Seconds | Type of Message Alert |
|---|---|---|
| [48] | 15.8 / Seconds | Email Alert |
| [49] | 12 / Seconds | Email Alert |
| [50] | 2 / Seconds | Email Alert |
| [51] | 3.9 / Seconds | Telegrambot Alert |
| [52] | 27.5 / Seconds | SMS Alert |
| [Developed System] | 1.8 / Seconds | Email Alert |

Figure 4.3 depicts the time between motion detection and alert activation to notify observers in each test.

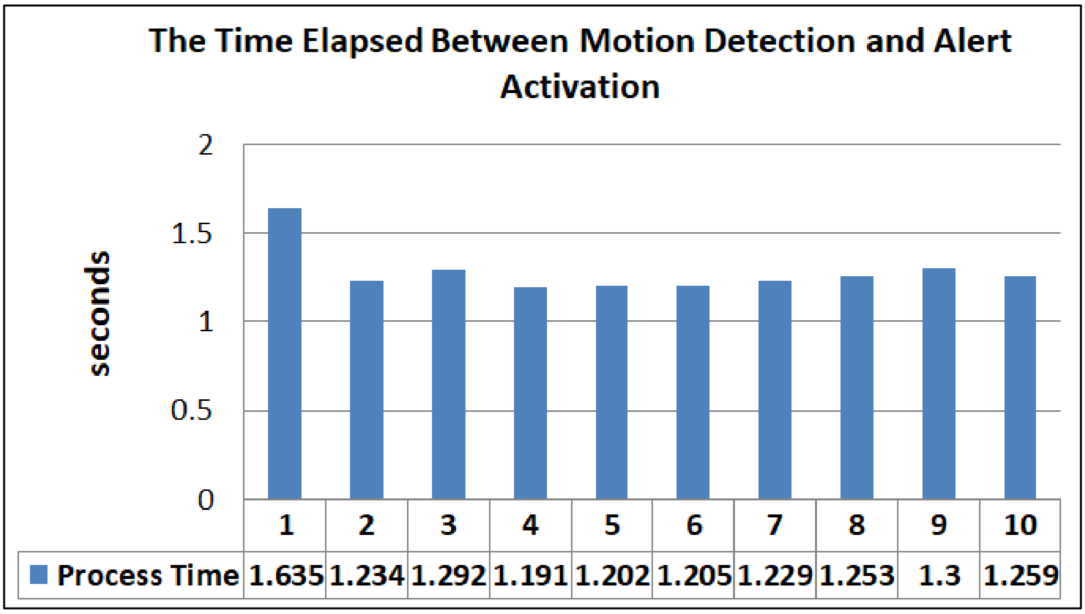


**Figure 4.3.** The time elapsed between motion detection and alert activation.

Figure 4.3 illustrates the time it took for the alerts to be activated following motion detection. This conclusion was reached by contrasting the motion detection time with the human detection time during ten tests, shown in Table 4.1. As a result, for the first test, 1.635 seconds elapsed between the time of motion detection and determining human motion and alert activation, less time than this security system's [53] result of 2.007 seconds.

### 4.2. Evaluation of the Surveillance System for Four Human Motion Directions

Another important feature of the system is its ability to detect human movement in all directions. In this part, we examined the ability of the system to detect human motion and activate alerts in four different directions: forward, backward, right, and left. Figure 4.4 includes more images taken by the system that depict people moving in all four directions. Determining human motion in directions provides more capability for the system to protect vital and secret locations. So if anyone goes to places where humans are not allowed to enter and this system is in the place, then by moving the human in any direction, the system can successfully find them and keep the area secure.

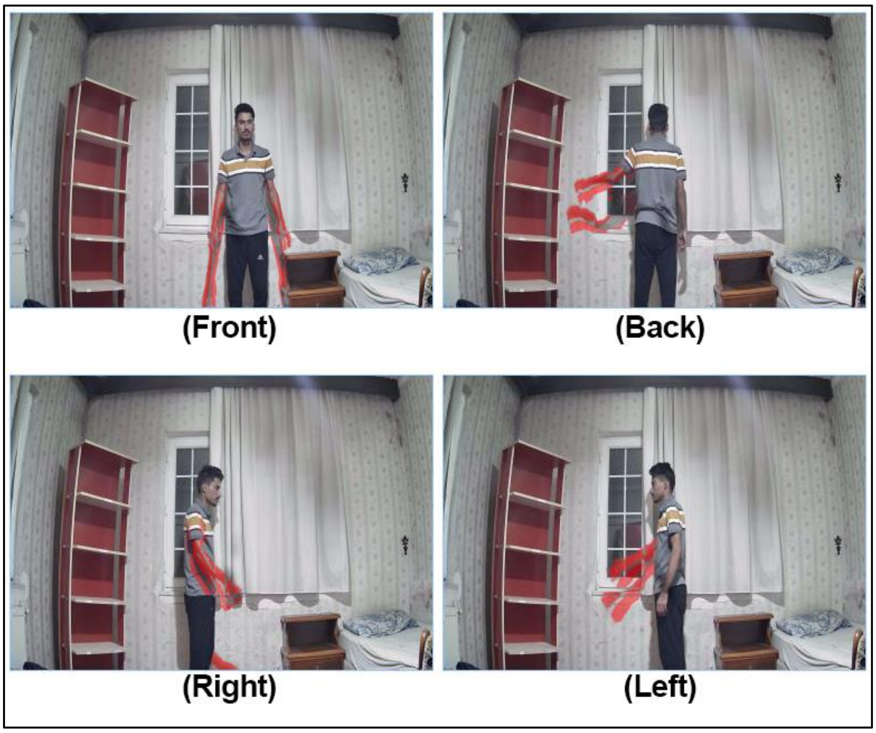


**Figure 4.4.** Four different directions of human movement.

### 4.3. Evaluation of the Surveillance System in the Indoor and Outdoor

The system has the ability to determine human movement both outdoors and indoors. The system can detect human motion in front of outdoor or indoor cameras. As shown in Figure 4.5, the system correctly found human motion indoors and outdoors. It activated alerts that human motion existed so that observers could take control of the situation as soon as possible.

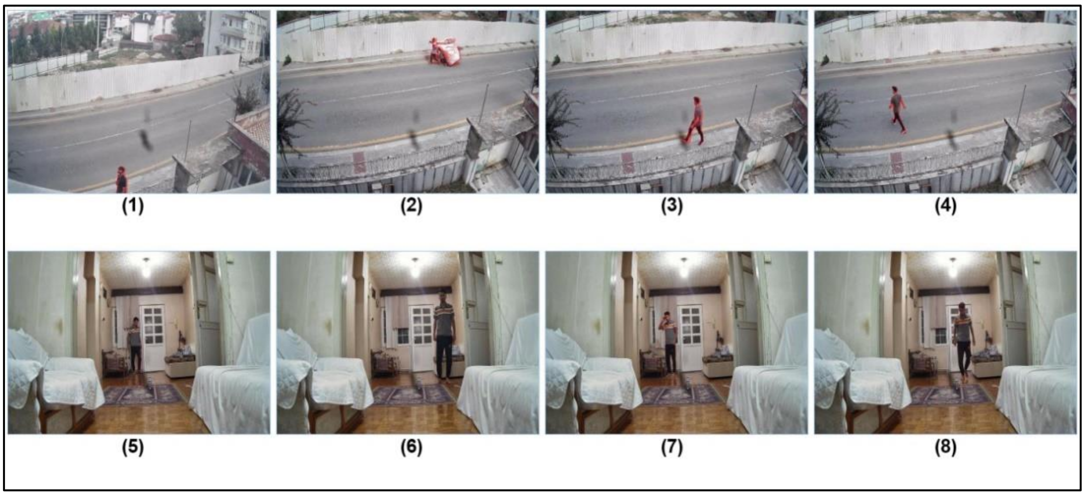


**Figure 4.5.** Evaluation of the surveillance system indoors and outdoors.

Figure 4.5 shows images that are examples of outdoor and indoor human motion detection that the system could detect. Some places do not allow motion indoors, such as cash rooms in banks, where there should be no human motion to be safe. Also, some places do not allow human motion outdoors; people should not approach them. The use of this system will have an important impact in both cases.

### 4.4. Evaluation of the Surveillance System in Low Light/Minimum Illumination

One of the most important examinations for surveillance and security alert systems is minimum illumination performance. In this part, we examined the ability of the surveillance and security alert system to detect human motion and activate alerts in low light or with minimal illumination. Figure 4.6 shows a set of person movement frames detected by the surveillance system in dimly lit areas. The surveillance and security alert systems are more effective and offer greater assurance when carers are alerted to human movement in dimly lit regions. This increases the likelihood that essential and sensitive facilities will be safe from thieves.

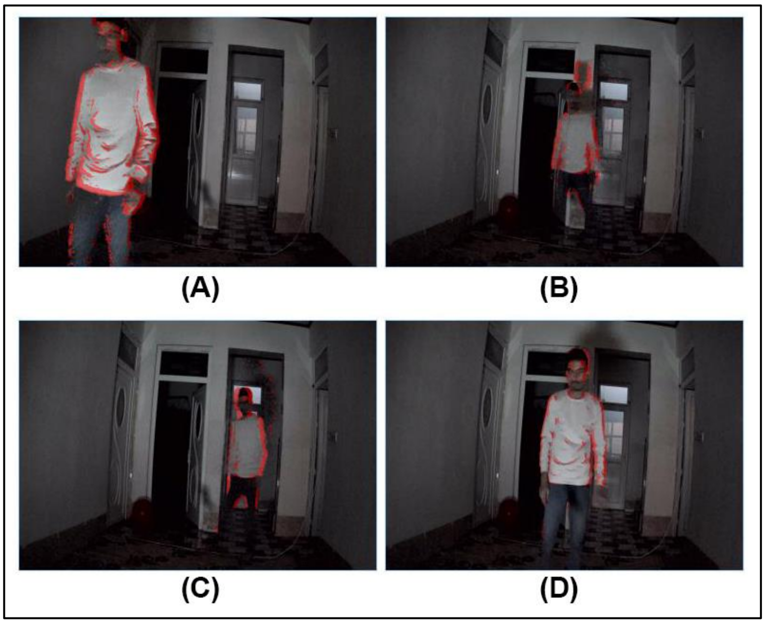


**Figure 4.6.** Evaluation of the surveillance system in minimum illumination.

The system was successful in detecting people in low-light or minimal-illumination areas. There were human movements from different angles in low-light or minimal-illumination areas. Still, the system could perfectly detect human movements and directly alert carers to protect the area.

### 4.5. Evaluation of the Accuracy of the Surveillance System

The goal of the assessment is to decide and determine the accuracy of the system in human movement detection by using the Two Frames Difference Algorithm, Simple Background Modelling Algorithm, and Tiny YOLOv2 model. For both types of motion detection, we conducted 60 tests to decide the system's accuracy. We utilized two distinct rooms with various lighting conditions for human motion detection. The system was tested using humans and non-humans, such as a ball, a bird, and a dog. Some different objects were used to determine the system's capability to detect the motion of different objects. The system is worked to notify the security guard whenever the system detects human motion. First, we performed 30 tests by using the two-frame difference algorithm and Tiny YOLOv2 to detect human motion and non-human. The system should detect every type of motion but only activate alerts for human motion. Table 4.3 presents results from 30 experiments where a two-frame difference algorithm and Tiny YOLOv2 were used.

**Table 4.3.** The system experiment to detect motion by using a TFDA and Tiny YOLOv2.

| Two Frames Difference Motion Detection Algorithm | | | | |
|---|---|---|---|---|
| Testing | Motions Type | Motion Detected | Human Detected | Alert Activation |
| 1 | Human | Yes | Yes | Yes |
| 2 | Human | Yes | Yes | Yes |
| 3 | Human | Yes | Yes | Yes |
| 4 | Ball | Yes | No | No |
| 5 | Ball | No | No | No |
| 6 | Ball | Yes | No | No |
| 7 | Ball | Yes | No | No |
| 8 | Ball | No | No | No |
| 9 | Human | Yes | Yes | Yes |
| 10 | Human | Yes | Yes | Yes |

**Table 4.3. (Continued)** The system experiment to detect motion by using a TFDA and Tiny YOLOv2.

| Two Frames Difference Motion Detection Algorithm | | | | |
|---|---|---|---|---|
| Testing | Motions Type | Motion Detected | Human Detected | Alert Activation |
| 11 | Human | Yes | Yes | Yes |
| 12 | Human | Yes | Yes | Yes |
| 13 | Human | Yes | Yes | Yes |
| 14 | Human | Yes | Yes | Yes |
| 15 | Human | Yes | Yes | Yes |
| 16 | Bird | Yes | No | No |
| 17 | Bird | Yes | No | No |
| 18 | Bird | No | No | No |
| 19 | Bird | Yes | No | No |
| 20 | Bird | Yes | No | No |
| 21 | Human | Yes | Yes | Yes |
| 22 | Human | Yes | Yes | Yes |
| 23 | Human | Yes | Yes | Yes |
| 24 | Human | Yes | Yes | Yes |
| 25 | Human | Yes | Yes | Yes |
| 26 | Dog | Yes | No | No |
| 27 | Dog | Yes | No | No |
| 28 | Dog | Yes | No | No |
| 29 | Dog | Yes | No | No |
| 30 | Dog | Yes | No | No |

As you can see from Table 4.3, the system correctly detected human movements and other objects and activated alarms only for human motion. In the 30 tests, there were 15 human movements. The system could detect all movements, identify the person, and activate the alarms. Fifteen other objects' motion detection tests were conducted to determine the system's ability to detect the motion of objects other than humans. The system should detect all types of objects' movements in front of cameras but only activate alerts for human motion. The system was able to successfully detect the movements of the ball, dog, and bird in 12 attempts and did not activate any warnings. Still, it could not detect the movements for only two ball attempts and one bird attempt and was unsuccessful. Figure 4.7 shows the motions detected by the system using the Two-Frame Difference Algorithm and Tiny YOLOv2. The system was used in different locations to further demonstrate its capability.


**Figure 4.7.** An example of motions determined by the system using TFDA and Tiny YOLOv2.

Second, we performed 30 tests by using a simple background modeling algorithm and Tiny YOLOv2 to detect human motion and non-human. The system should detect every type of motion but only activate alerts for human motion. Table 4.4 presents results from 30 experiments where a simple background modeling algorithm and Tiny YOLOv2 were used.

**Table 4.4.** The system experiment to detect motion by using a SBMA and Tiny YOLOv2.

| Simple Background Modeling Motion Detection Algorithm | | | | |
|---|---|---|---|---|
| Testing | Motions Type | Motion Detected | Human Detected | Alert Activation |
| 1 | Human | Yes | Yes | Yes |
| 2 | Human | Yes | Yes | Yes |
| 3 | Human | Yes | Yes | Yes |
| 4 | Human | Yes | Yes | Yes |
| 5 | Human | Yes | Yes | Yes |
| 6 | Human | Yes | Yes | Yes |
| 7 | Human | Yes | Yes | Yes |
| 8 | Human | Yes | Yes | Yes |
| 9 | Human | Yes | Yes | Yes |
| 10 | Human | Yes | Yes | Yes |
| 11 | Human | Yes | Yes | Yes |
| 12 | Human | Yes | Yes | Yes |
| 13 | Human | Yes | Yes | Yes |
| 14 | Human | Yes | Yes | Yes |
| 15 | Human | Yes | Yes | Yes |
| 16 | Ball | Yes | No | No |
| 17 | Ball | Yes | No | No |
| 18 | Ball | Yes | No | No |
| 19 | Ball | Yes | No | No |
| 20 | Ball | Yes | No | No |
| 21 | Dog | Yes | No | No |

**Table 4.4. (Continued)** The system experiment to detect motion by using a SBMA and Tiny YOLOv2.

| Simple Background Modeling Motion Detection Algorithm | | | | |
|---|---|---|---|---|
| Testing | Motions Type | Motion Detected | Human Detected | Alert Activation |
| 22 | Dog | Yes | No | No |
| 23 | Dog | Yes | No | No |
| 24 | Dog | Yes | No | No |
| 25 | Dog | Yes | No | No |
| 26 | Bird | Yes | No | No |
| 27 | Bird | Yes | No | No |
| 28 | Bird | Yes | No | No |
| 29 | Bird | Yes | No | No |
| 30 | Bird | Yes | No | No |

As shown in Table 4.4, the system correctly detected human movements and other objects and activated alarms only for human motion. In the 30 tests, there were 15 human motions. The system could detect all motions, identify humans, and activate the alarms. The system successfully detected the movements of non-humans like birds, dogs, and balls in 15 attempts and did not activate any warnings.

The system completed 30 tests in this second experiment and passed all attempts. This result gives users more confidence to rely on the system to protect vital and secret areas.

Figure 4.8 shows the motions detected by the system using the simple background modeling algorithm and Tiny YOLOv2. The system was used in different locations to further demonstrate the capability of the system to detect human motion.


**Figure 4.8.** An example of motions determined by the system using SBMA and Tiny YOLOv2.

To determine the accuracy of the system for detecting human movement in secret and vital areas with the help of a confusion matrix based on the data and information from the tests we have conducted. The surveillance system accuracy can be obtained from the confusion matrix as follows [54, 55]:

$$Accuracy = TN+TP \,/\, TP+FN+TN+FP \quad (2.3)$$

TP: is the total number of correct positive predictions in tests.

TN: is the total number of correct negative predictions in tests.

FP: is the total number of incorrect positive predictions in tests.

FN: is the total number of incorrect negative predictions in tests.

A confusion matrix table that counts how many predictions in tests were both correct and incorrect. The computation of performance measures like accuracy can be utilized to analyze the impact of a surveillance system using a confusion matrix. Figure 4.9 displays the confusion matrix table design for the surveillance system.

| | | Predicted | |
|---|---|---|---|
| | | Negative (N) - | Positive (P) + |
| Actual | Negative - | True Negative (TN) | False Positive (FP) Type I Error |
| | Positive + | False Negative (FN) Type II Error | True Positive(TP) |

**Figure 4.9.** Confusion matrix of the surveillance system.

The accuracy of the surveillance and security alert system in detecting human motion and activating alerts was 0.95, equal to 95 percent, using a confusion matrix based on surveillance system tests. According to the results of this experiment, the system has a very good ability and accuracy in detecting human motion in places that should be completely protected, so using the proposed security alert system makes these places protected from humans who want to enter unauthorized areas. Figure 4.10 displays the result of the surveillance system's accuracy for humans and non-humans through a confusion matrix.

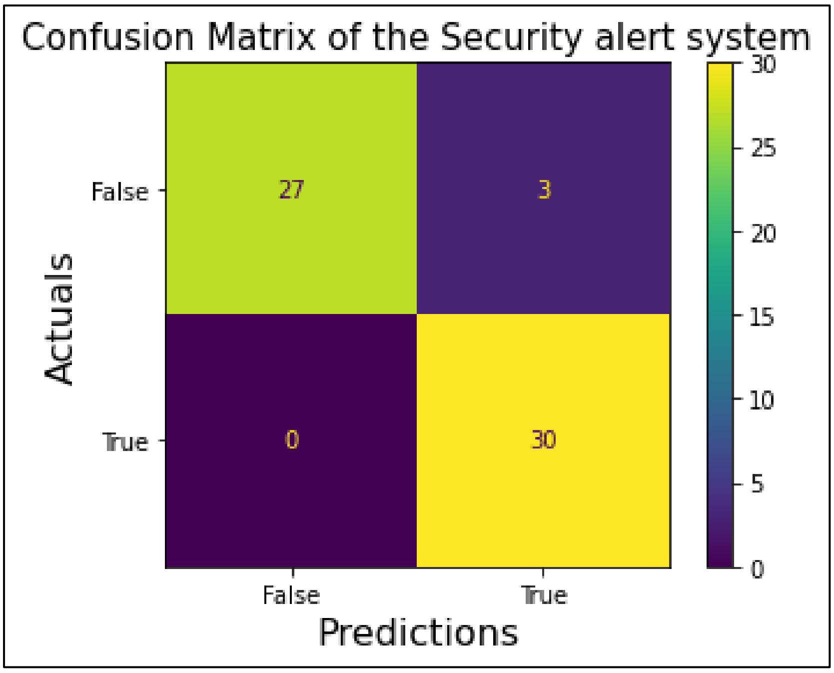


**Figure 4.10.** The confusion matrix result of surveillance system predictions.

The system is more accurate than previous surveillance systems that notify observers of an incident. Table 4.5 shows the comparison of some surveillance systems' accuracy.

**Table 4.5.** The accuracy comparison of the surveillance systems.

| Previous Studies | Accuracy |
|---|---|
| [50] | 90 % |
| [56] | 80 % |
| [57] | 85 % |
| [58] | 90 % |
| [59] | 83.56 % |
| [Developed System] | 95 % |

## 5. CONCLUSIONS AND FUTURE WORKS

In this research, we created a real-time surveillance and security alert system using motion detection algorithms like a two-frame differencing algorithm and a simple background modeling algorithm, and we used YOLO to determine humans in motion. The system is a real-time surveillance and security alert system to protect vital and secret places. The system was designed to detect human movement in the areas it is responsible for protecting, and it performed successfully. The system notifies observers directly whenever it detects human movement through notifications such as sound, LED, and email. After detecting human movement, the system recorded video of areas where there was movement, which helped observers identify the perpetrators and facilitate investigations. Several tests were conducted to evaluate the performance of the system, such as detecting human movement in different directions, where the system was able to recognize the human movement in all directions (forward, backward, right, and left) and notify observers of the movement. Another test was detecting human movement indoors and outdoors, where the system successfully detected human movements and activated alerts to allow observers to control the incident. Another test was how long it took to detect movement and detect humans in the movement. It recognizes human movement and alerts observers of unauthorized human movement in the shortest possible time. By alerting observers to human movement in dimly lit or low-light areas, the system provides greater assurance in protecting crucial and secret areas that must be protected from thieves and vandals. The accuracy of the system for detecting human motion and activating an alert is 0.95, which is equal to 95%; the system has very good abilities and accuracy for human motion detection. It can also alert observers of unauthorized activity as soon as possible so that incidents can be easily controlled. Observers can also surveil four different locations through the cameras at the same time. The system was designed to have a user-friendly interface that could be easily used by observers to surveil areas. As a result, this system plays an effective role in protecting banks, museums, and libraries from those who want to harm them. The system can protect important and confidential locations from thieves and vandals.

Future work will involve sending SMS and phone calls to carers via the system to alert them of impending danger. This will help handle crises as early as possible. Additionally, it will have a mobile application allowing observers to remotely watch the areas using their smartphones. Also, it will be possible to detect fire and smoke in areas where surveillance cameras are installed. And it uses other Yolo models for human detection and other motion detection methods in the surveillance and security alert systems.

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