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A New Surveillance and Security Alert System Based on Real-Time Motion Detection

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ABSTRACT

Due to the frequent and widespread instances of burglary, effective and accurate intrusion detection with an alarm system is now necessary. In this study, the proposed system is used for secret and vital places that need a good monitoring system based on human motion detection. The system can protect museums that contain critical historical objects and libraries with old historical books. The security alert system is also essential to the protection of banks. The system uses a two-frame difference algorithm and a simple background modeling algorithm for motion detection with the help of AForge.NET. Whenever the system detects motion, it interprets the frames of motion to determine humans by using YOLO. The security alert system activates the alerts whenever it detects human motion, like sending an email to an authorized person, triggering the LED alert and sound alert, recording a video of that place, taking a motion picture, and saving it within the databases. The system has the advantages of low cost, a user-friendly interface, and high security. The system was thoroughly tested to detect human movement in unauthorized areas. The system successfully detected human activity indoors and outdoors and activated the alarms. Also, the system could detect human movement in all four directions and alert observers directly at the time of the incident. In low light or minimum illumination, the system can determine human motion. The evaluation results showed that the system's accuracy in detecting human movement was 95%, which shows that the system is able to protect vital and secret places and can successfully monitor areas.

Keywords: Human motion detection, security alert system, YOLO, camera assisted security, Surveillance system

1 Introduction

Over the years, video surveillance has seen substantial development and is now an essential tool for many organizations regarding safety and security needs [1]. The globe has progressed in various socio-economic sectors over the past twenty years. Life has gotten more complicated in many ways, including personal safety and security. It is now essential to be secure and under observation. Therefore, installing

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surveillance cameras in public and private spaces is a good idea to ensure safety [2]. The yearning for safety and security extends back thousands of years, making the history of the security system interesting. Due to the intelligent and new tactics thieves use to succeed in their actions, criminal activity has become a very dexterous act in recent years. Life safety is one of the most powerful requests in the world. Globally, the rising trend of criminal activities is concerning, and there has been widespread public outcry that the government should work to reduce and prevent theft in banks as well as protect private places such as museums and old libraries, on which the country's civilization is built [3]. This study considered designing a security alert system based on human motion detection. Computer vision researchers are interested in motion detection because it has numerous potential uses, including video surveillance, traffic monitoring, and sign language recognition [4]. Motion detection is generally necessary for a security system since it provides superior security. Consider a security vault, a money vault in a bank or museum, or old books in a library, where we don't want unauthorized persons to access or come close to that secured area. Human motion detection can be implemented in this case. In this study, we developed a system to detect any motion in front of a webcam in secret and vital places by using a two-frame difference algorithm and a simple background modeling algorithm for motion detection with the help of AForge.NET. The system interprets frames of the motion; if a human is detected in the frames by using the Tiny YOLOv2. The Tiny YOLOv2 model can detect objects in real-time on a variety of devices more quickly, more effectively, and with a reasonable level of accuracy [5]. The system will activate an LED alert, activate a sound alert, send an email to the observer, and record a video of that place. Recording videos and storing them on the computer makes it easier for observers to review events. It can produce accurate results with a simple and low-cost implementation. The main goal of developing such a system is to protect and reduce threats in secret places. So, these areas are always protected and away from intruders and thieves. Supervisors and security guards must also be aware of movement in confidential and critical areas through email, LED, and sound alerts. This will further ensure the protection of such a place. Another objective is to make it easier for guards to monitor critical areas by providing an easy-to-use system and a user-friendly interface. Several tests were conducted on the system to determine its ability to detect human motion. In the first test, the system could detect human motion indoors and outdoors, activate timely alarms, and alert observers to the presence of movement. In the second test, the system could detect human movement in all four directions (back, forward, right, and left), ensuring that the system could fully control vital and secret areas. The third test showed that detecting motion for nearly 1,191 to 1,635 seconds can detect a person within the movement and activate alarms. In another test, in low light or minimum illumination, the proposed security alert system can detect human motion. The accuracy of the system for detecting human movement and activating alarms was 95% as a result of 40 tests conducted, which shows that the system can protect vital and secret places and can successfully monitor areas.

1.1 Previous Work

There is some previous work on motion detection [6-9].

In the study [6], motion detection is used as a security measure, which is a security system. The camera is used as the video source, and if motion is detected, a threshold of the frames confirms it before activating the video recorder. Additionally, the system sets out an alarm system to notify users of any intrusions in the area that is being monitored. The system was created using the prototype development technique, and the programming language MATLAB was employed.

In the study [7], through research and analysis of available products and techniques, they suggest a motion detection surveillance system that consists of a Graphic User Interface (GUI) and a mechanism for motion detection. The proposed solutions are effective and practical for use in offices and at home.

In the study [8], a Raspberry Pi and a camera module will be used in the suggested project to create a straightforward application that detects motion and notifies the smartphone. The user's phone or web application will inform you if there is movement in the field of the camera setup. Users may see the text, still photos, and video in the notice directly on IOS or Android. It uses open-source applications and services, including Pi Camera, FFmpeg, and Pushbullet.

The study [9] focuses on creating a computer-based surveillance system to take the role of the human eye. To find intruders, machine vision is used. The system uses email and SMS communication technologies to alert people about unexpected motions. After discussing various motion detection techniques, a decision that was appropriate for the purpose was made.

Table 1: *Evaluate previous work*

Ref.	Motion Detector	Alerts	Record Video	Save Image	Record Event
[6]	Camera	True	True	False	False
[7]	Camera	True	False	True	True
[8]	Camera	True	True	True	False
[9]	Camera	True	False	True	False

We evaluated previous studies that provide protection systems. As explained in Table 1 Study Characteristics, none of the earlier studies contain all the essential features that a protection system should have, including motion alerts, video recording, movement image storage, and data recording. Previous studies activate alerts when there is any movement. Still, in this study, we have created a system that interprets movements and activates alarms only for human activity, which is an essential feature of the system. It also alerts observers to move in three ways: sound, LED, and email. It also emails the location of movements to observers so that the source of the movement can be controlled as soon as possible. Observers can also directly monitor several areas simultaneously through cameras installed in different locations.

2 Background

2.1 Motion Detection

Motion detection is the process of identifying a shift in an object's position compared to its environment or a change in the environment comparing an object [10]. The first phase of video surveillance, motion detection, seeks to identify areas that correlate to moving objects [11]. Many computer vision applications, especially those that analyse data from video surveillance systems, depend heavily on motion detection. Its goal is to extract moving items one at a time from a video clip [12]. For this purpose, the system detects motion using a two-frame difference motion detection algorithm or a simple background modeling motion detection algorithm with the help of AForge.NET libraries. A set of classes that implement various motion detection and motion processing methods are offered by the AForge.NET framework. Only continuous video frames with movement can be recognized using motion detection techniques, providing a binary image that displays all motion-detected regions. Different motion detection classes may employ various motion detection techniques. However, they are all comparable regarding how they gather video frames for analysis and report observed degrees of motion [13].

2.1.1 Frame Difference Approach

The frame difference approach is the simplest way to find moving objects in surveillance footage shot by an immovable camera since it has a fast detection rate, is simple to implement on hardware, and is extensively utilized [13,14]. The quickest and easiest motion detector is this kind. This detector's concept is based on calculating the difference between two subsequent video stream frames. The level of motion increases with the size of the difference. Figure 1 demonstrates how well it positioned itself for activities requiring motion detection. The moving item is located using this method, which uses pixel-based distinctions. In picture sequences, I_k is designed to represent the value of the k^{th} frame. The $(k+1)^{th}$ frame in an image sequence has a value of I_{k+1} [15].

This is a definition of the complete differential picture:

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

Figure 1: Two frames difference motion detection [13]

2.1.2 Simple Background Modeling Motion Detector

A method for extracting moving objects from video frames is background modeling. Applications for machine vision that employ this method include monitoring and compressing video frames. To model the background in video frames, a model of the scene background is first built, and the background is then subtracted from the current frame. The moving objects are ultimately determined by the difference [16, 17]. Figure 2 shows an example of the background modeling algorithm-based motion detector. This motion detector's background modeling capability allows it to highlight motion areas. It is more sensitive than the difference between the two frames because it emphasizes motion zones. Tiny objects are challenging to detect. It is formed by the background pattern multiplying the pixel value of the next incoming frame by the ɀ coefficient and updating it. This refreshes the model's existing background. The H_t pixel value detects the refreshed background. Therefore, changes such as light change and background differentiation can be seen [18].

$$H_t = (1 - ɀ)H_{t-1} + ɀI_t \quad (2)$$

$H_t = {}_t$ 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
ꝣ = The renewal coefficient values between [0.005 – 0.1] are used.

Figure 2: Simple background modeling motion detection [13]

2.2 You Only Look Once (YOLO)

The YOLO algorithm is built on a convolutional network, a straightforward network architecture that implements the whole image during training and testing. The prediction of several probability classes and bounding boxes for these objects by a neural network maximizes detection. The main steps of this approach are to resize the input image and run a single convolutional network operation. The confidence model limits the detection results of this algorithm. The region convolutional neural network's predictions differ from those of the synthetic neural network (R-CNN). The system needs thousands of predictions to process an image, which makes YOLO considerably quicker than R-CNN [19]. Using all of the image's attributes, the YOLO neural network immediately extracts candidate boxes from images to identify items [20]. Tiny YOLOv2 is relied upon to detect humans in the images the system records after motion detection. The highest pooling layer is placed after the first six Conv layers in Tiny YOLOv2, with nine overall Conv layers and six maximum pooling levels [21]. The architecture of Tiny YOLOv2 is depicted in Figure 3.

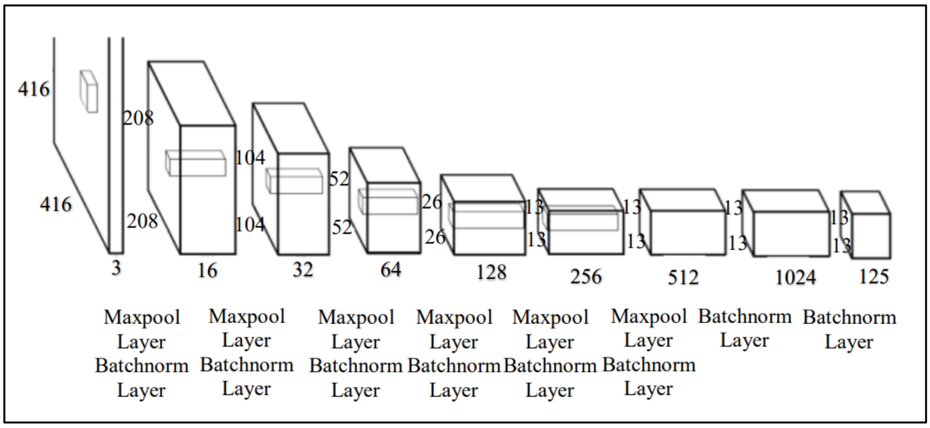

Figure 3: Tiny YOLOv2 Architecture [22]

2.3 AForge.NET

AForge.NET is a free and open-source C# framework. The AForge.NET framework provides classes that implement different motion detection and motion processing algorithms. The AForge.NET library offers opportunities for dealing with issues related to artificial intelligence. The library employs various technologies, including image processing, genetic algorithms, fuzzy logic, machine learning, robotics, and more [23]. There are a few computer vision frameworks that work with .NET, such as OpenCV, ML.NET, AForge.NET, etc. We chose to use AForge.NET because it offers a collection of tools and algorithms for developing and deploying AI models in .NET applications. The AForge.Net Framework provides libraries that are required and suitable to make the operation's performance successful in real time. A list of the critical elements of the AForge.NET library:

- A library called AForge.Imaging that is made to deal with filters and images.
- A computer vision-based library called AForge.Vision.
- AForge.Video is a collection of libraries for handling video data.
- AForge.Neuro is a library that takes advantage of neural network technology.
- AForge.Genetic is a library that uses genetic algorithms to handle various issues.
- A fuzzy logic-based library called AForge.Fuzzy.
- AForge.Robotics is a library that provides robotics-related techniques.

3 Design and Implementation of a Human Motion Detection System

The system we have proposed consists of two main parts: application and Arduino hardware, each of which has several features, and we will discuss them in detail. Figure 4 shows a flow chart describing the system's mode of operation.

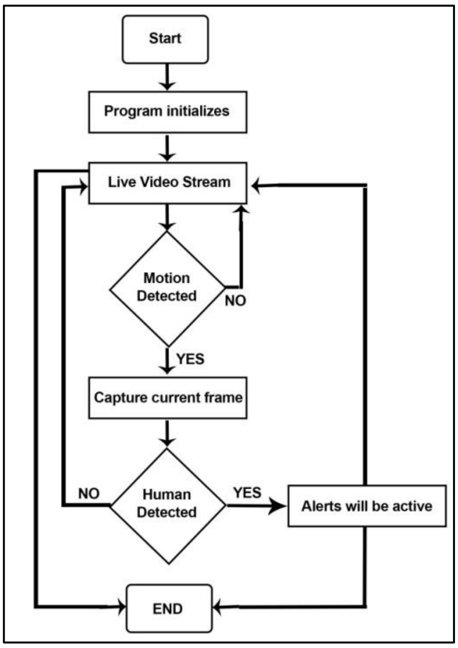

Figure 4: Flow chart of the proposed system

System parts include WEBCAM, applications, databases, and alerts. In the application, we can monitor the secret and essential location that our webcam has set up. We can connect WEBCAM via USB to our computer or use our computer's WEBCAM. Then, if there is any motion in front of the webcam, it must be detected by the system depending on the two-frame difference algorithm and simple background modeling algorithm with the help of AForge.NET. Following motion detection, the system interprets a frame of motion using Tiny YOLOv2. If there is a human in the frames, it will activate the alarms. The system is designed to alert observers to human movement in areas but does not activate alarms when the type of movement is not human movement. The system can monitor four different places simultaneously. The system offers alerts in three different formats: sound, LED, and email. Additionally, the system begins videoing the area where human motion is detected so that the least amount of storage is needed, and it records event information using a SQL Server to store it in the database. Figure 5 shows the system architecture and how all of the components of the system work together to detect human motion and alert the observers.

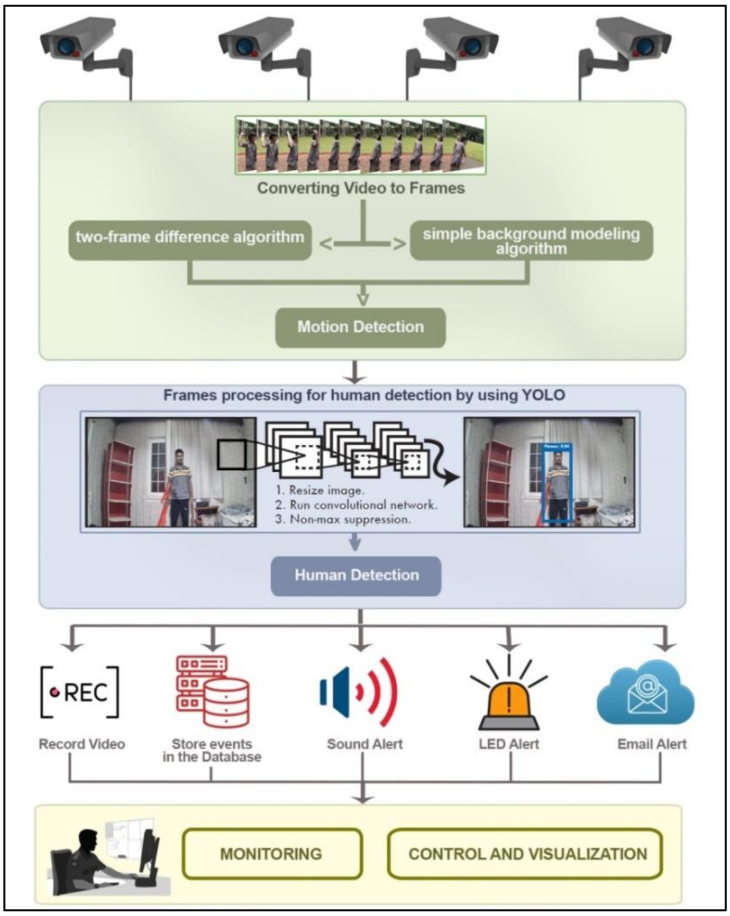

Figure 5: Architecture of the security alert system

In order to increase security and prevent thieves and vandals from having easy access to the areas where this system is located, the system is designed in a way that it does not permit any human motion in crucial and secret areas. This makes those areas safe.

3.1 Software Application

The application was created in a strong and modern way using C#, GUNA UI, SQLSERVER, and .NET Framework so that we can manage the work in the best way possible. This application plays a good role in monitoring important areas and keeping track of all incidents. We used a two-frame difference algorithm and a simple background modeling algorithm with the help of AForge.NET to detect motion in real time in the areas where the cameras were installed. After the system detects a movement, a frame of motion is interpreted. If there is a person involved in the incident, alerts are activated. Tiny Yolov2 is used to detect humans in the frames. The system is designed to be easy to use and have a user-friendly interface. So that the observers can manage the system properly. The proposed system only works on computers and can only be used by observers and authorized persons. Unauthorized persons cannot use the system to monitor the areas intended. In Figure 6, we explain all the parts of the system monitoring form.

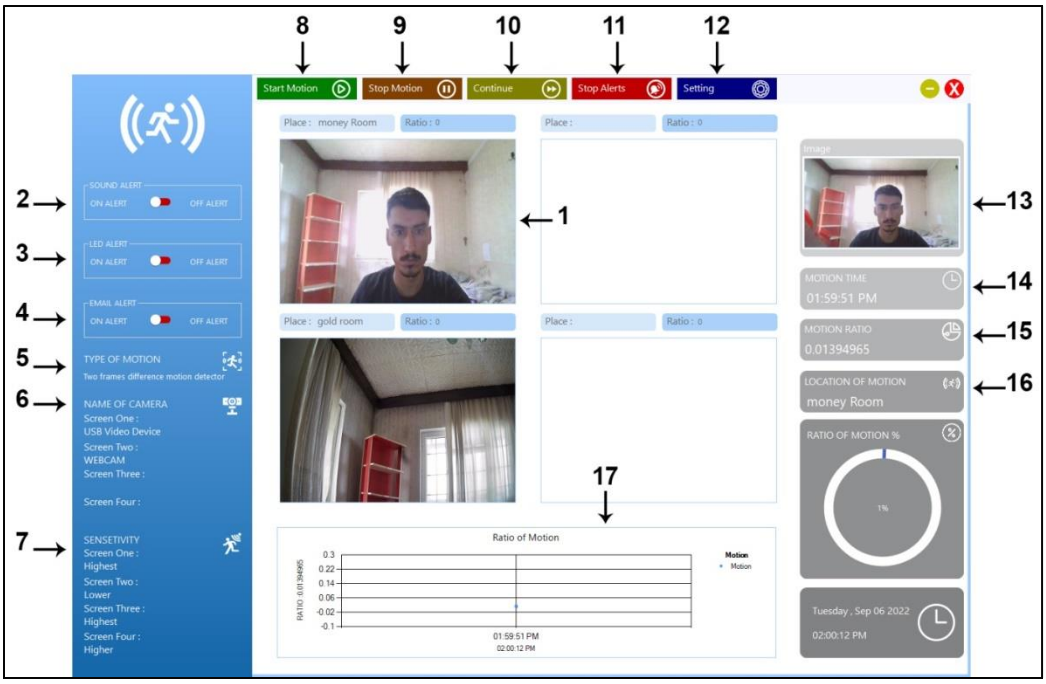

Figure 6: Surveillance form of the desktop application

1- The system has four main screens for monitoring areas and displays the names of places and the amount of motion in those areas.
2- The system has a sound alert; the user can activate or deactivate it.
3- The system has an LED alert; the user can activate or deactivate it.
4- The system has an email alert; the user can activate or deactivate it.
5- The system has several types of motion, showing the selected type here.
6- The system has a four-screen to display Webcams; here, it shows the names of the active Webcams.
7- The system has a sensitivity ratio for detecting motion on the screens; here, it shows the sensitivity ratio of all four screens.
8- By clicking this button, the system starts motion detection.
9- By clicking this button, the system stops motion detection.
10- By clicking this button, the system is continuous with motion detection.
11- Clicking this button will prevent the alarms.
12- Clicking this button will open the settings form, and you can make your desired changes.
13- Here, it shows an image of the detected motion, which was detected by the system.
14- Here, it shows the time of the previously detected motion detected by the system.
15- Here, it shows the ratio of the previous detected motion detected by the system.

16- Here, it shows the location of the last detected motion detected by the system.
17- Here, it shows all the events detected and recorded by the system after the system is activated.

The system also has several essential features that we will discuss in detail: One of the system's features is the sound alert, essential for alerting observers when detecting people in secret and vital places. The system has a section dedicated to notifying the observers of human movement via email using an SMTP server. Email messages are transferred over the Internet using the SMTP (simple mail transfer protocol) transport mechanism. All email servers use SMTP to send emails from one server to another [24]. The system sends emails to the observer who is responsible for the care at the time. Email is efficient. It can be sent by simply pressing a button. Email is almost instantly sent, received, and read. Anywhere you have an internet connection, you can access email. You can access your inbox and browse your messages from anywhere. Email is a free tool. Once you are connected to the internet, sending and receiving messages don't require any additional expenditure. The system has another feature: video recording. After the system detects human movement, it starts recording a video of the area where the motion is detected. This will help observers get the necessary information about the incident.

3.2 LED Alert using Arduino

A C# Windows application will link an Arduino to a computer and communicate with it. Connecting hardware to a PC might be highly advantageous because you can transmit orders and check their status. An open-source microcontroller is called Arduino. The Arduino can be quickly programmed, erased, and reprogrammed [25]. It's one of the essential parts of the system that we have here in the Hardware section, and in this section, we have some components working together to get their work done. The alert LED will be activated when the system feels movement in front of the webcam. Figure 7 shows how all the components of the Arduino section work together. Numerous people have used the Arduino board to build things for their science, electronics, robotics, or engineering projects [26]. Due to its user-friendly or simple-to-use settings, Arduino is widely used today, among other things, in microcontroller programming. An Arduino is a circuit board with a chip that can be programmed to perform a variety of tasks, like any microcontroller. To carry out the specified command, information is sent from the computer program to the Arduino microcontroller and then to the particular circuit or machine with multiple circuits. An Arduino can help you send information to output devices like LEDs, speakers, LCD screens, DC motors, etc., as well as read information from input devices like sensors, antennas, trimmers (potentiometers), etc [27]. Arduino contributes well to this study by alerting observers to the presence of movement in places where there should be no human movement directly through LED alerts to alert observers to the presence of movement, which makes observers aware of incidents and try to control them as soon as possible.

The components of creating a LED alert include:

1- LED
2- Arduino UNO
3- Jumper wire
4- Breadboard
5- Resistors 1k ohm

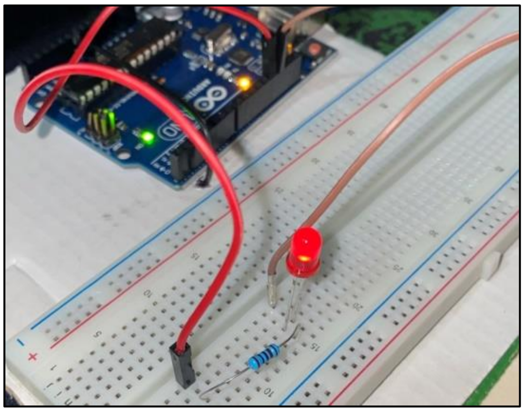

Figure 7: Component of LED alert

4 Experiments

In this section, we will evaluate the system and present its effectiveness in protecting the places where it is responsible for protecting it. We conducted tests on the system and presented the system's test results:

4.1 Duration Of Human Motion Detection And Activation Of Alerts

One of the essential features of the surveillance system is to detect unauthorized movement and alert the observer to human activity as soon as possible. So, we took ten human movement detections as an example to see how long it takes for the system to detect human movement and activate the alarms. In Table 2, we have put the data.

Table 2: *Duration of human motion detection and activation of alerts*

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
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

In Table 2, we present data from only ten instances in which the system recorded the time when motion was detected with the help of a camera. An image of the motion was interpreted, and the time when humans were detected was recorded. For example, in the first test, the movement detection time was (05:05:57.205), and then (05:05:58.840), the person was detected in that movement, and the alarms were activated, which took only (1.635) seconds. The email reached the observer at (05:06:03.000). This result shows that our system is better able to monitor and protect places than this system [28]. This system takes (15 to 17) seconds for an email to reach the observer. Figure 8 shows the delay in notifying observers of all tests.

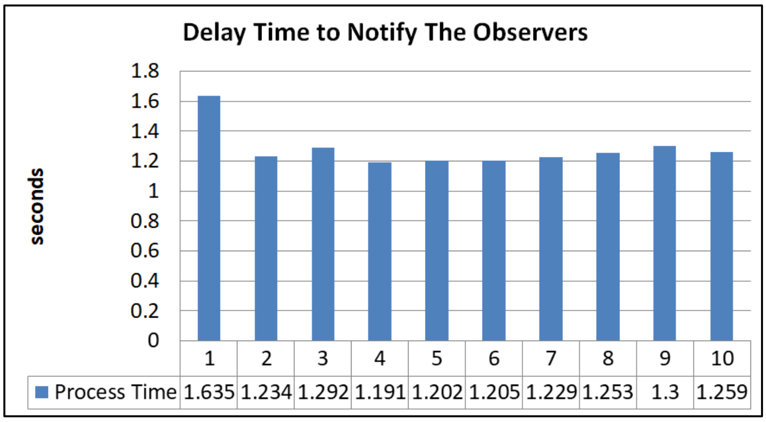

Figure 8: Delay in notifying the observers

Figure 8: Shows how long it took for the alarms to activate after motion detection. We obtained this result by comparing both (motion detection time and human detection time) available in Table 2 for ten tests. As a result, 1.635 seconds passed between the time of movement detection and the time of intruder image detection and activating the alerts for the 1st test, which is better than the result of this security system [29], where the result is equal to 2.007 seconds.

4.2 Four Directions Of Human Motion

In this section, we tested human movement detection in four different directions: forward, back, right, and left, and the system was successful in detecting human movement and activating alerts. Figure 9 also shows images recorded by the system showing human motion in four directions.

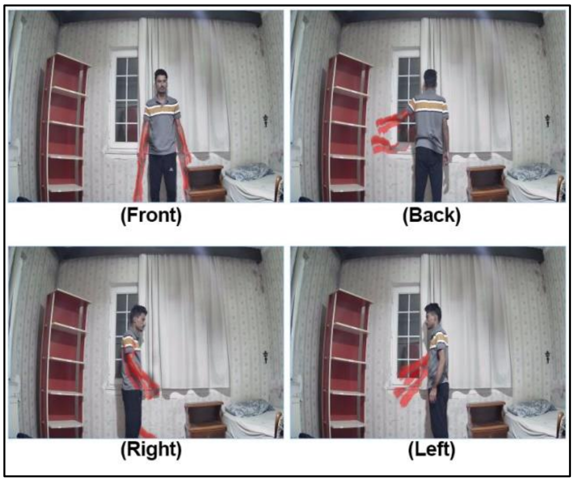

Figure 9: Four directions of human motion

Detection of human movement in all four directions provides additional assurance to protect private, confidential, and essential places.

4.3 Indoor And Outdoor Surveillance Evaluation

The system can be used indoors and outdoors for human motion detection. It can protect areas and detect human movement in appropriate conditions, provided that the cameras can detect human movement. As shown in Figure 10, the system successfully saw human activity indoors and outdoors and activated the alarms.

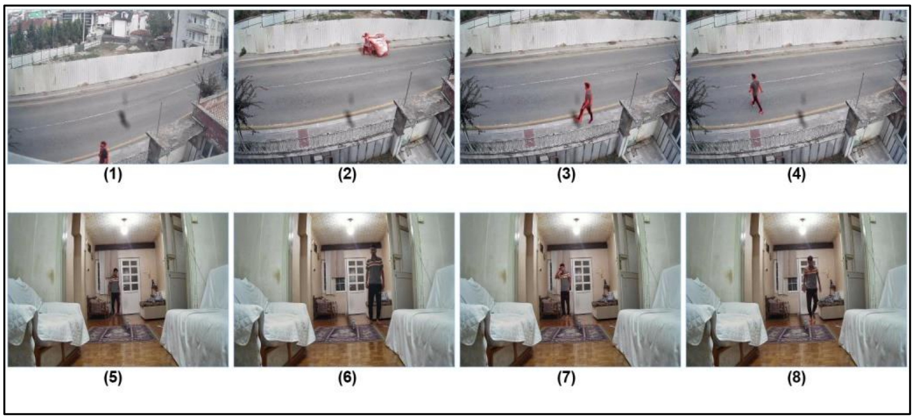

Figure 10: Indoor and outdoor surveillance evaluation

Figure 10: Images 1 to 4 are examples of outdoor human motion detection, and images 5 to 8 are examples of indoor human motion detection that the system could detect.

4.4 Evaluation Of The Surveillance System in Low-Light/Minimum illumination

Low-light performance testing is one of the most crucial aspects of surveillance system evaluation. In this section, we looked at the system's capability to determine human motion and activate alerts in low-light or minimal illumination environments. Figure 11 displays a collection of human motion images that the system determined in low-light or low-illuminated areas. The system is more effective and offers more assurance to protect vital and secret areas that must be protected from thieves and vandals by alerting observers to human movement in low-light or minimal illumination areas.

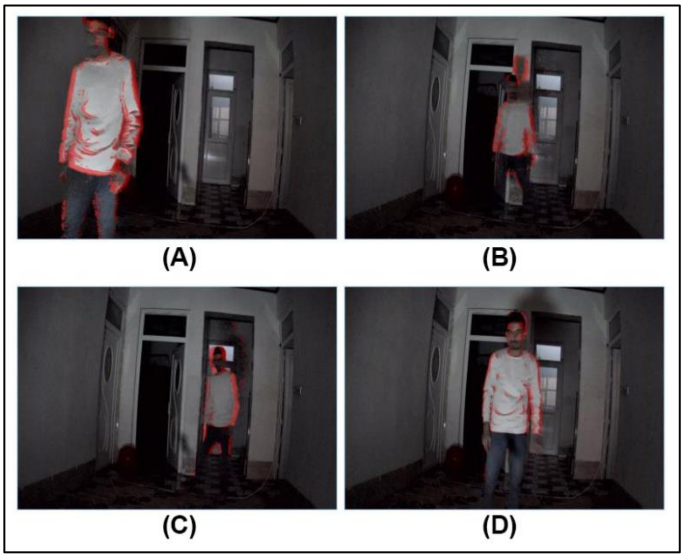

Figure 11: System Evaluation in Low-Light or Minimum Illumination

4.5 Evaluate The Accuracy Of The Security Alert System

The purpose of this evaluation is to determine the accuracy level of human motion detection using a two-frame differencing algorithm, a simple background modeling algorithm, and Tiny YOLOv2. For both types of motion detection, we ran 40 experiments to determine the accuracy of the system. Two different rooms with different lighting were used for each type of motion detection. The system is designed to alert the monitor when human movement is detected. First, using a two-frame differencing algorithm and Tiny YOLOv2, the system ran 20 trials to determine the movement of the humans. We then ran 20 trials using a simple background modeling algorithm and Tiny YOLOv2 to determine the motion of the human. The system should detect all movements, but only enable human movement alerts.

The accuracy of the system can be determined from the confusion matrix as follows [30, 31]:

$$Accuracy = \frac{TN+TP}{TP+TN+FP+FN} \tag{3}$$

TP: is the number of correct positive predictions.
TN: is the number of correct negative predictions.
FP: is the number of incorrect positive predictions.
FN: is the number of incorrect negative predictions.
A confusion matrix is a table that counts the number of predictions that were both correct and incorrect in a system test. It can be used to evaluate the performance of security alert systems by calculating performance metrics such as accuracy. Figure 12 shows the design of the confusion matrix table for the security alert 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 12: Design of the confusion matrix table of the security alert system

The accuracy of the system to detects human movement and triggers an alarm is 0.95, which is 95% using a confusion matrix based on testing security alert systems. The results of this experiment show that the system has very good capabilities and accuracy in detecting human movement in areas that should be fully protected. These areas can be completely protected from those who want to enter vital and secret areas. Figure 13 shows the security alert system accuracy results using the confusion matrix.

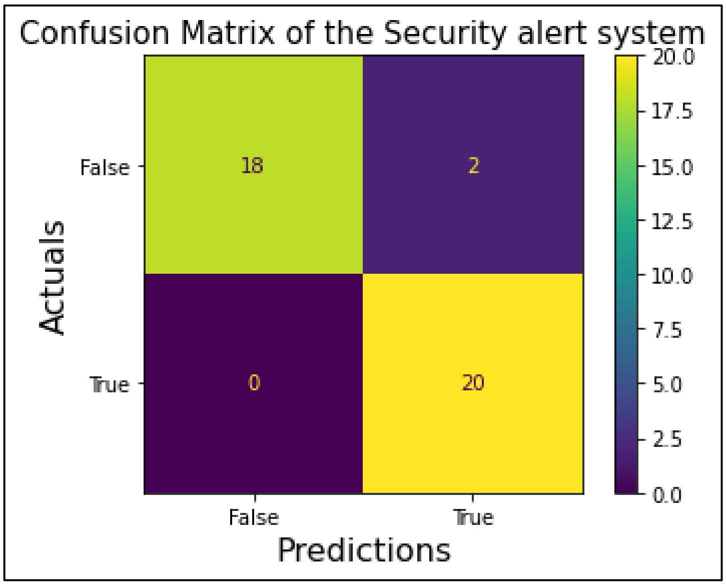

Figure 13: The result of security alert system predictions by confusion matrix

5 Conclusion

In this study, we have developed a real-time surveillance system by using the C# programming language, Tiny YOLOV2 for human motion detection, and AForge.NET libraries. This system is a real-time surveillance system that will alert the user by sound, email, and LED alerts when it detects human motion in essential places. It is also a system that records videos of areas where human motion has been detected. This will help protect necessary and secret places such as banks, museums, and libraries, as well as military and security affairs. The system design has the advantages of low cost and high security. We completed this system by combining inexpensive, widely available devices, interfaces, and software with an easy-to-use and user-friendly interface. The system can be used outdoors and indoors to detect human movement, activate alarms, and detect human movement in all four directions (forward, back, right, and left). The system offers more assurance to protect vital and secret areas that must be protected from thieves and vandals by alerting observers to human movement in low-light or minimally illuminated areas. The result of tests showed that detecting motion for nearly 1,191 to 1,635 seconds can detect a person within the movement and activate alarms, and the accuracy of the system to detect human movement and trigger an alarm is 0.95, which is 95%; the system has very good capabilities and accuracy in detecting human movement. These results show this system is better than the previous study. This study has created a monitoring system that can aid in decreasing and preventing theft and crime as well as directly and as soon as possible alert observers to the presence of human movement, which will be an important contribution to incident control.

Future work will include mobile calls and SMS warnings to observers via the system, which will help handle situations as quickly as possible. The system will be possible to develop in the future to add both web applications and mobile applications where observers may monitor the areas via their mobile phones, enabling them to do so from anywhere.

6 Declarations

6.1 Competing Interests

There is no conflict of interest in this study.

6.2 Authors’ Contributions

Corresponding Author Ahmed AL-SLEMANI: Design and implementation of the research, analysis of the results, and writing of the manuscript.

2. Ahmet ZENGIN: Design and implementation of the research, analysis of the results, and writing of the manuscript.

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