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SMART HOME SECURITY SYSTEM FOR INTRUDER DETECTION USING YOLO V3 ALGORITHM

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Abstract. *Empirical studies suggest that environment is the main factor influencing crime patterns so that closed circuit television (CCTV) becomes the choice to reduce the risk of crime. However, CCTV is less effective because it requires high bandwidth & storage and cannot provide notifications. Therefore, a technology called the Internet of Things (IoT) appears so that CCTV or webcam can work together with sensors to detect the presence of intruders and provide notifications. This study proposes a system that detects intruders and sends notifications to homeowner regardless of time and place. This system is usually referred to as a smart home security system. The authors proposed the smart home security system for intruder detection using YOLO V3 algorithm. This research is implemented using magnetic door sensor and alarm or buzzer and a webcam connected to Raspberry Pi 3B+. This proposed system will send notifications using telegram. We have implemented the proposed system and found the result that most accurate intruder detector is the YOLO V3 algorithm with an accuracy of 98.58%.*
Keywords: Internet of Things (IoT), Raspberry Pi, Smart home security system, YOLO V3

1. **Introduction.** Based on empirical studies, it is stated that environmental factors have a significant influence on crime patterns [1]. CCTV can be used to prevent crime, but it is less effective because it does not provide a warning or initial reaction when capturing a suspicious object [2,3]. In addition, CCTV also requires high bandwidth and storage [4]. However, currently there is a concept called Internet of Things (IoT). IoT can provide an integrated system or application by connecting various things using the Internet [5]. The implementation of IoT can be in the form of smart home, smart security, intelligent transportation, and others [6-8]. Smart home consists of smart home system [9] and smart home security system [10,29]. In the case of home security, IoT technology can be adopted to make home security system smarter, safer, and automated [11].

Research on the application of IoT has been carried out, one of which is the monitoring system. Monitoring system in the form of a home security system that uses the human detection method has been implemented to detect intruders to prevent crime. However, the human detection method by implementing the histogram of gradient (HoG) algorithm and support vector machine (SVM) only obtains an average accuracy of around 90% [12,13]. The authors consider that accuracy is an important factor in this system so that it can detect the presence of intruders and prevent crime. In addition, early notification

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through an application on a smartphone is also needed to increase the sense of security and comfort to homeowner.

Therefore, the authors try to develop a system using YOLO V3 algorithm that can detect the presence of intruders more accurately so that it can better prevent crime. In addition, the authors also added a notification feature via telegram regarding the intruder attendance information so that users can monitor home security through their smartphone anytime, anywhere. This system will certainly also be able to increase the sense of security and comfort to homeowner. In addition, this system is also relatively economical and inexpensive because it only consists of Raspberry Pi 3B+ [14], webcam [15], magnetic door sensor [16], buzzer [17], standard Internet connection and general smartphone that is used by homeowner to receive notifications about intruder presence information. The proposed method performs intruder detection with high accuracy, but low detection time. This system can detect intruder presence with highest accuracy level around 98.58% by implementing YOLO V3 algorithm in its detection process.

This paper consists of 5 sections. Section 1 begins with an introduction to the problems and shortcomings of several methods used by homeowner to prevent crime. In Section 2 the authors discuss the research related to methods that can be used to support smart home security systems that are more effective and efficient. Furthermore, the authors explain the ideas about the proposed system in Section 3. Then the results and discussion regarding the implementation of the proposed system are analyzed in Section 4. Meanwhile, the conclusions are summarized in Section 5.

2. **Related Works.** Several studies about monitoring system had been done. One of the studies is human detection method by using video surveillance system. This system can detect human by using extraction feature of histogram of gradient (HoG) and classification by using SVM algorithm. This method only acquires accuracy approximately about 89%-90% [12]. Besides that, HoG and SVM method had been implemented on a home security system that possesses capability of human detection by using Raspberry Pi 3B+, Arduino Uno, webcam, PIR sensor and buzzer. Result of the system and method can detect presence of intruder by average accuracy of 90% [13].

In [18], user location discovery (ULD) and the role of smart homes in the future were studied. The system designed in this paper has a context for user privacy or security services, tag-free, fault tolerance, and accuracy. This can be realized along with the development of new technologies such as the IoT, embedded systems, intelligent devices, and machine-to-machine communication with more sensors available or can be used in our homes. Furthermore in [19], it discusses an alert system for a home security system using or based on IoT. The alert system works by sending images captured by webcams when an incoming intruder is detected with PIR sensors. This paper contributes by providing an explanation of the design of an alert system for a home security system. In addition, this paper provides a working reference and information on the proposed alert system.

In addition, there is a method or algorithm called as you only look once (YOLO) which can generally be used to detect pedestrian and tracking system. YOLO algorithm already exists up to YOLO V3 which is more accurate and faster compared to previous versions. In several experiments, YOLO V3 can detect, trace pedestrian, human in basketball game or other several objects successfully on each video frame. YOLO V3 is more accurate and faster compared to previous versions. YOLO V3 can detect various objects such as human, car and other objects with accuracy level more than 90% [20-23,27]. Moreover, YOLO can also detect disturbances such as road surface damage and landslides [26,28]. In [24], a training process was conducted for a new network classifier that is better than before so that the YOLO V3 algorithm can improve the accuracy of object detection performance by an average of 95%. YOLO V3 can also be combined with other deep learning algorithm

to achieve better accuracy [30]. This is proven because YOLO V3 can run faster than other detection methods using the same GPU [25].

Therefore, the design and implementation of a security system that can send warning or notification messages based on the output produced by the system is considered important on a home security system. This is also needed as a trigger so the system can determine whether to activate the alarm or not. Therefore, an alarm or alert system for the home security system is needed when an intruder is detected [7,17]. High accuracy, security warnings with notifications and lower power consumption are the main benefits of the main smart home security system which will certainly be able to provide convenience, safety, and comfort [10].

3. **Proposed System.** The authors propose a system design that is divided into three process areas. The initial process begins with the arrival of intruders (arrival of intruders), the path of human detection & intruder detection (human detection & recognition flow), and receipt of notifications by homeowners (acceptance of notification). The proposed system is shown in Figure 1.

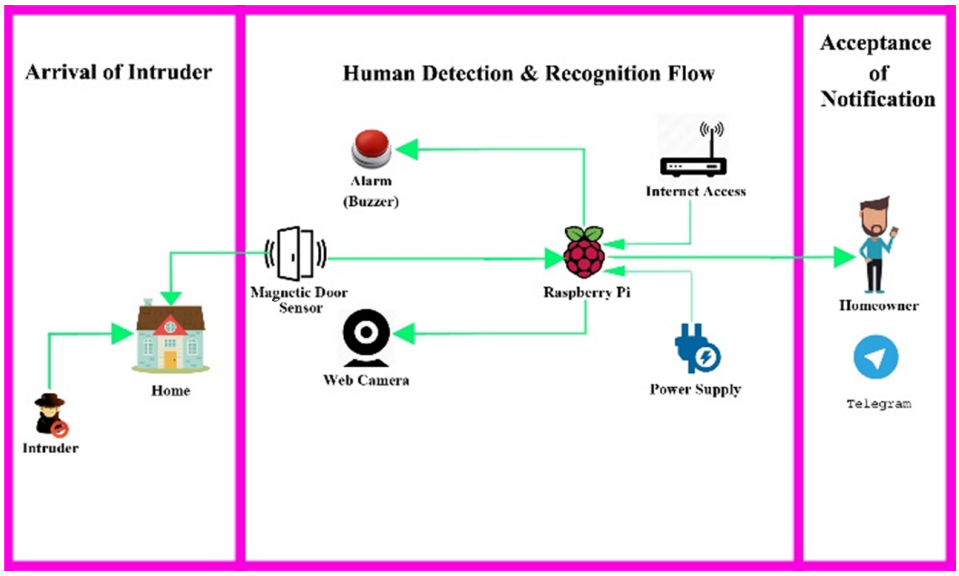

FIGURE 1. System architecture

In the area of arrival of intruders, the authors assume the intruder will enter from the front door. The next process occurs in human detection & recognition flow. Magnetic door sensors will always be ready to monitor or control the status of the door whether it remains closed or open after the system is activated by the homeowner. The magnetic door sensor will continuously monitor the door status as long as the door status is closed. However, when the door is open, the system will use a web camera to capture images in the detection area. The next system will process images that have been captured by the web camera using the HoG + SVM and YOLO V3 methods for human detection. If the captured image is not detected as human, the system will only send notifications to the homeowner via telegram with the description "Not Human". However, if the captured image is detected as human, the system will send a notification to the homeowner via telegram with the description "Human" and will also activate an alarm. The workflow of the system is illustrated using the use case diagram in Figure 2.

In accuracy testing of human detection, it will be taken 106 attempts which consist of standing human object, facing backward, facing sideways, or other conditions. In addition, authors also will try to do non-human object detection such as animals or other objects in the amount of 106 attempts as complement. In this research, performed evaluation to

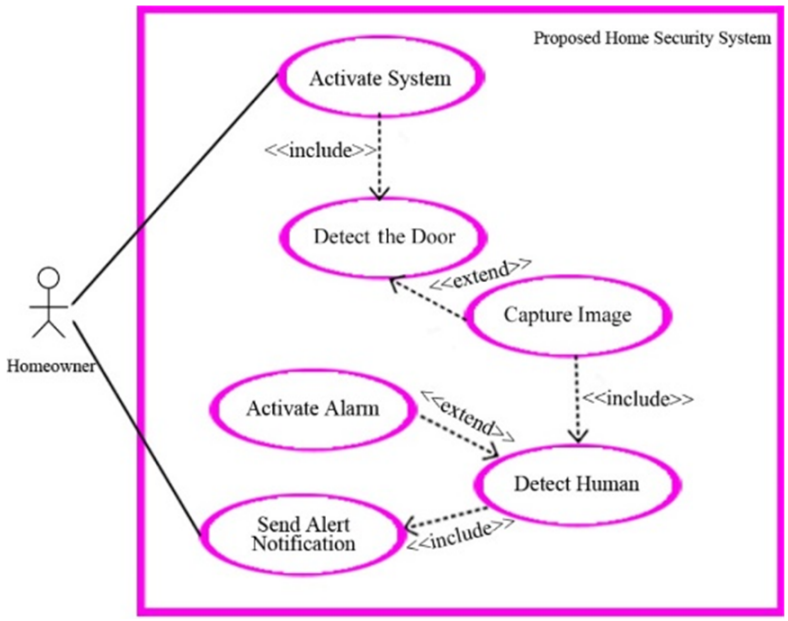

FIGURE 2. Use case diagram of system workflow

measure accuracy percentage is by using accuracy paradox equation. Therefore, it will be obtained accuracy percentage equation as follows:

$$A = \frac{(TP + TN)}{(TP + TN + FP + FN)} \times 100\% \tag{1}$$

The explanations of the symbols in the equation are

- Accuracy (A) = accuracy percentage.
- True positives (TP) = quantity of true detection on tested human object.
- False positives (FP) = quantity of false detection on tested human object.
- True negatives (TN) = quantity of true detection on tested non-human object.
- False negatives (FN) = quantity of false detection of tested non-human object.

4. **Result and Discussion.** This research is implemented by using Raspberry Pi 3B+ which is connected with webcam Logitech C525, magnetic door sensor and alarm or buzzer. Function of Raspberry Pi 3B+ is to perform all computational process. Raspberry Pi 3B+ is connected with webcam by USB port. In addition, Raspberry is connected with magnetic door sensor also buzzer by jumper cable which is connected to pins in the Raspberry Pi 3B+ board. Computational process which is performed by Raspberry Pi 3B+ starts from receiving signal from magnetic door sensor, doing command to capture image to the webcam, detecting the image as human or non-human by 2 algorithms and sending notification to the house owner by telegram. Installation and implementation of the system model can be found in Figure 3.

Based on the results of the algorithm testing that has been carried out, there are two main data that are of concern. In this study, the main data of concern are accuracy data (A) and processing time (DT) from the detection results of the three algorithms that have been tested. The detection process is carried out by taking two parameters. The first parameter is the start time which is the initial time taken before starting the detection process and the second parameter is the end time taken after the detection is complete. The process of taking parameters is used to calculate the detection process time. From 106 times of testing, on each human and non-human object as well as on the three algorithms, the confusion matrix can be seen in Table 1.

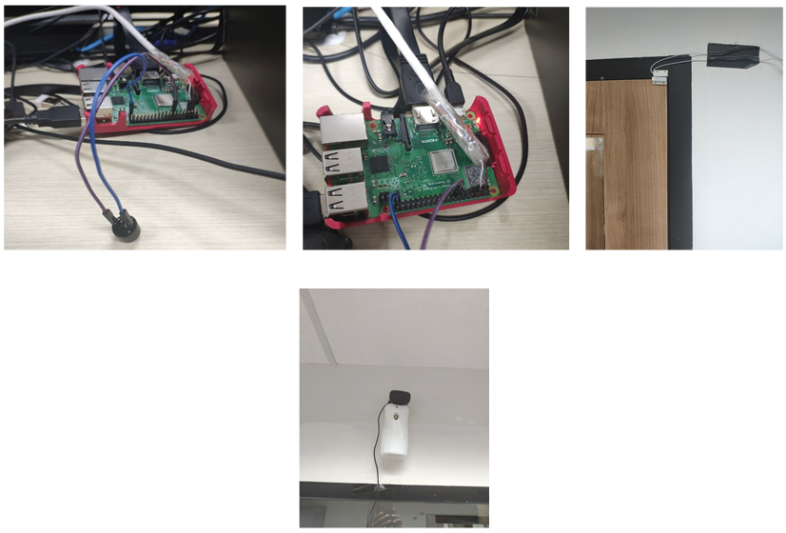

FIGURE 3. Raspberry Pi connected to magnetic door sensor, webcam & buzzer

TABLE 1. Confusion matrix

		Prediction : HoG + SVM	
Total sample = 212		Negative	Positive
Actual	Negative	TN = 96	FP = 11
	Positive	FN = 10	TP = 95
		Prediction : Haar Cascade	
Total sample = 212		Negative	Positive
Actual	Negative	TN = 93	FP = 29
	Positive	FN = 13	TP = 77
		Prediction : YOLO V3	
Total sample = 212		Negative	Positive
Actual	Negative	TN = 106	FP = 3
	Positive	FN = 0	TP = 103

Based on Table 1, the HoG + SVM algorithm produces an average accuracy of 90.09% and the detection process time is around 1.952 seconds. Then the Haar Cascade algorithm produces an average accuracy of 80.19% and the detection process time is around 0.406 seconds. Furthermore, the YOLO V3 algorithm produces an average accuracy of 98.58% and the detection process time is around 49.673 seconds. There are factors that affect the level of accuracy in each algorithm so that it produces different detections in the same image, and these factors are

- The dataset used in each algorithm is different because it is already provided in the OpenCV library and other sources in the literature.
- The YOLO V3 algorithm uses CNNs, while HoG + SVM and Haar Cascade classifier do not use it so that the accuracy of YOLO V3 is better because it consumes a higher GPU so that the detection process is slower if run on devices that have low GPU specifications.
- Height does not affect the detection results because in the results of the detection algorithms there are human objects with different heights and also squatting or hunched positions whose results are the same as humans. This is also because the method of detecting the algorithms does not focus on height alone, but also on other body parts such as hands, feet, head, and other parts which will have their own threshold value to determine whether the object is as a human or non-human. This

threshold value affects the detection results in each image because it has different values, categories, and other configurations so that the level of similarity between the detected objects and the dataset is different.

The results in Table 2 show that the fastest detection process time is the Haar Cascade algorithm with an average detection process time of 0.152 seconds. Then for HoG + SVM and YOLO V3 it was slightly different, namely 1.401 seconds for HoG + SVM and 1.405 seconds for YOLO V3. An interesting thing happened in the detection using YOLO V3 using a laptop. There was a very significant difference in processing time from the previous average detection process time of around 49.673 seconds using the Raspberry Pi 3B+ to an average of about 1.405 seconds.

Table 2. Comparison of detection accuracy and detection process time

No	Works	Methods	Accuracy	Detection times (in Raspberry Pi)	Detection times (in Laptop)	Total sample
1	[13]	HoG + SVM	90.09%	1.952 s	1.401 s	212
2	Our work	Haar Cascade	80.19%	0.406 s	0.152 s	212
3	Our work	YOLO V3	98.58%	49.673 s	1.405 s	212

This can happen because YOLO V3 is very complex in detecting objects, resulting in high object detection accuracy, which is an average of 98.58%. Under these conditions, the YOLO V3 algorithm requires better specifications, especially on the graphics processing unit (GPU) which is getting higher if you want to get a faster detection process time. This is corroborated by the results of research from [24] that the dataset that has been trained using the Darknet-53 model will achieve the largest floating-point measurement per second. This means that the network structure makes better use of the GPU making it more efficient to evaluate and thus producing faster results.

In addition, [25] states that object detection algorithms such as YOLO, SSD, and R-CNN will produce better and more efficient performance by using GPUs that have better performance as well. With better GPU quality, our proposed YOLO V3 algorithm in our work can have better accuracy and faster detection times.

5. **Conclusions.** Based on the results of implementation and testing that has been done, this smart home security system can be utilized to detect presence of intruder and send notifications to the house owner by telegram. That can be accessed anytime and anywhere on house owner's smartphone so it can increase comfort in monitoring the house's security. Besides that, installed buzzer in the system will be active when there is detected object as human or intruder so at least it can increase security because it can draw attention of neighbors or people around the house and make the intruder out of the house or at least be panic. This smart home security system for intruder detection is considered simple and low cost due to the fact that it only consists of Raspberry Pi 3B+, webcam, magnetic door sensor and buzzer. This system can detect intruder presence with highest accuracy level around 98.58% by implementing YOLO V3 algorithm in its detection process.

However, this system must be further developed to make homeowners more secure and comfortable. This system will be better in the future if we add a feature to be able to see videos in real time or live streaming via webcam which aims to ensure the condition of the house further when the door is open or detected an object that enters the house.

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