A New IoT Combined Body Detection of People by Using Computer Vision for Security Application

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***Abstract*— In recent years, the security constitutes the most important section of our lives. Automation of a home is an exciting field for security applications. This area has developed with new technologies like Internet of things (IoT). In IoT, each device behaves as a small part of an internet node and each node communicate and interact. Currently, security cameras are used in order to construct safety areas, cities, and homes. The camera records the images and, when a problem occurs, the problem is detected by monitoring the old record. In this study, an IoT-based system is combined with computer vision in order to detect the people. A Raspberry PI 3 card with the size of a credit card was used for this purpose. A motion is detected by the PIR sensor mounted on the Raspberry PI. PIR sensor helps to monitor and get alerts when movement is detected. Afterward, human is detected in the captured image and sends images to a Smartphone by using telegram application.**

***Index Terms*—Human detection, Internet of things, telegram, Computer Vision, Raspberry PI.**

I. INTRODUCTION

In recent years, people live in the information era. There are numerous ways in everyday life for getting to the Internet and ready to create our daily life easier and more agreeable such as computers, Smartphone, Smart TVs, tablets, and some smart cars. The new devices can run any programs, in much best and more effective way for doing different tasks such as turning on or turning off the device, making alerts via the built-in or external sensors. These objects can be defined as Smart Objects. Likewise, smart systems can be provided Internet of Things (IoT) and furthermore permits making either large or small network due to get a collective intelligence via the processing of objects' knowledge [1].

The IoT can be applied in Smart Cities in order to give variation benefits that enhance citizens [2- 3]. In other terms, smart homes can be made by utilizing the IoT which has the ability to control and automate exact things of our houses such as lights, doors, fridges, distributed multimedia, windows, and irrigation systems.

Computer Vision provides face detection and recognition and body detection for people that are a very interesting application for the IoT. Computer Vision fusions can present more security system in an IoT platform for smart homes since they have abilities to recognize a person in the incorrect area and at the false hour because this person may be a bad person for the environment [4].

Surveillance plays a vital role to satisfy our safety. Security system sensors play a very important role in this field. There are two principle types of sensors: outdoor sensors which protect the interior of the home border and sensors that protect the indoor of the home. The most common sensors are Passive Infrared Sensor (PIR), microwave sensor, ultrasonic sensor, noise detector, and photo-electric sensor. The wireless system gives a proficient, elegant and robust solution for the issue of remote home access, security, and surveillance with human detection. Real-time human detection systems are vital for security applications [5]. Generally, it is recognizing and track persons in public areas such as houses, offices, airports, shopping centers, bank, in areas with limited access sensors.

There are some papers proposed for the security system. All security applications are utilized for various purposes, and in the literature, there are a few studies by using a camera in IOT and sensors. Computer Vision is programmed for recognizing some particular sections in maps: such as buildings, roads, water, or fields. This is a case of how to apply Computer Vision in Smart Earth [2]. A smart monitoring system utilizing PIR sensor, Raspberry Pi, and mobile device have been proposed [6]. They utilize smoke detector for detecting fire. After capturing the picture to client mail by Wi-Fi, the client will be notified about the burglar or fire. They utilized smoke detection algorithm and background subtraction algorithm for movement detection [6]. In [7], a security system has been performed and the user will be notified by email and twitter if any person comes at the door. They let the proprietor control the door remotely and for preventing unauthorized access [7].

In this study, Raspberry PI is utilized and Raspberry Pi camera connected to it, the system will take an image when PIR sensor detects any movement. Afterward, we apply histogram of oriented gradients (HOG) algorithm to detect the humans in the captured image, then we send this image to a Smartphone via the internet, in this case, IOT based telegram application utilized to see the activity and get the images and notifications. The Support Vector Machine (SVM) learning classification is used to detect the human from the HOG features. Generally, the human detection techniques are based on the Dalal and Triggs techniques offer better detection rate by comparison to the skin color model methods. The computation cost of the Dalal-Triggs technique is relatively low. So, this human detection method becomes the most famous method [8].

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II. THE INTERNET OF THINGS

Nowadays, the IoT is quickly growing technology with business circumstance. It is the confluence of wireless networks, computing, and the internet. Recently, the IoT is one of the most utilized technologies with interest for a few countries. Internet of Things connects the physical things such as buildings, vehicles and different gadgets with embedded smart sensors and enables these things to exchange and gather information [9-12].

Our objective in utilizing IoT is to share our information and knowledge to everyone in everywhere around the world, from food to PCs and automate various procedures to enhance our daily life [2, 13]. The IoT is a dynamic worldwide network of daily things connecting to the internet, and IoT is the interconnection of virtual and physical objects accessed through the Internet. These things can be objects of the physical world or data of the virtual world [14].

A Wireless Sensor Network interconnects sensors, so as to get information, with a server or unique system to work and might be, automate tasks in one place [15]. The objective of the IoT is to interconnect the entire world via the making of various smart places to automate, enhance, and facilitate our day to day life [16]. IoT is nowadays becoming a part of each side of our lives. Not just IoT applications are improving the convenience of our lives. Additionally, it gives us more than control by simplifying style job life and duty of personals.

III. THE PROPOSED METHOD FOR HUMAN DETECTION

In the proposed system, we utilize a camera to achieve the image when a movement detected through PIR sensor. Then we will apply computer vision module to the captured images to detect the humans, then we will send it to a smartphone. This system is very useful and important if we want to secure a place. The algorithm can be separated into two sections which are movement detection and human detection. If there is no movement detected, the program will not go to human detection. Fig.1 illustrates the flow chart for the proposed system.

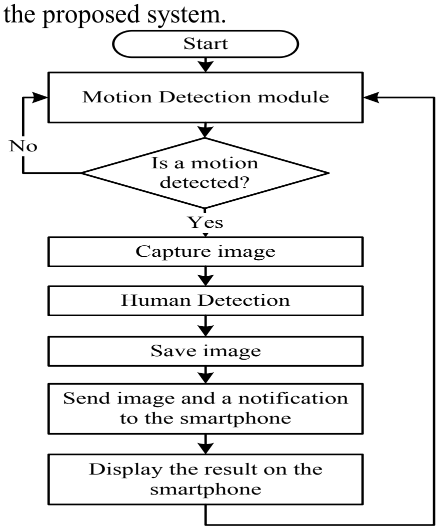


Fig. 1. Flowchart for Proposed System

In Fig. 1, the motion detection module detects any motion by using PIR sensor. Afterward, the human is searched in the detected image. If the human is detected in the image, the image will be sent to the mobile device.

A Raspberry Pi 3 is a microcontroller, which has four USB modules. PICAMERA and PIR sensor connected to Raspberry Pi. The central platform for image processing and signal alerting can be utilized as Raspberry Pi board. The images are captured through a Pi camera. The system has the ability to detect movement of an object through the PIR sensor. When the moving object is detected, the decision signal passes into the embedded board GPIO port. PICAMERA will be turned on through the python script for capturing images and the system can check whether a human is detected or not. Fig. 2 shows the embedded system block diagram.

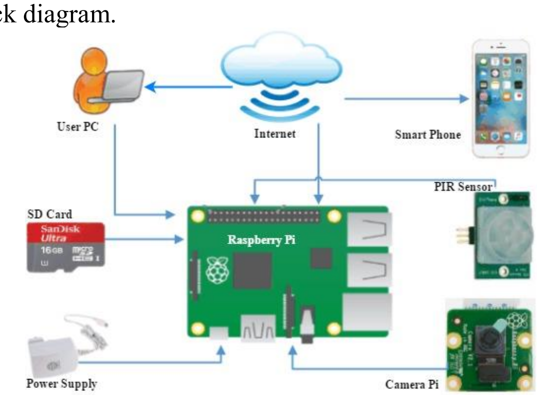


Fig. 2. System Design

In Fig. 2, when a PIR sensor detects any movement, the camera will take an image and search the human. If a human is detected, it will be sent to a smartphone. PIR detectors are the most general movement detector [17-18]. PIR sensor sends a signal to the microprocessor when a movement is detected.

Human detection is utilized in different applications. Body features are detected and others are ignored. Histogram of oriented gradients (HOG) is the most popular algorithm for human detection. It is utilized to detect single or multiple humans. OpenCV library is utilized for human detection because they are the best open source library obtainable to perform image processing and they are not too much complex. Dalal and Triggs [19] proposed an efficient method for the human detector. They utilize a dense grid of Histograms of Oriented Gradients and find the humans in terms of a Support Vector Machine.

In practice, an image is densely examined by a detection window which moves to any conceivable position and with any conceivable scale, searching for humans. The task is then to build a superior classifier that can separate humans and non humans in a short time and with low false positive since an image can contain from 10^4 to 10^5 detection windows relying on the intensity of the search [20].

There are two main steps for human detection: features extraction and classification learning. The first algorithm consists of extracting the most important info from the data accessible by applying HOG algorithm and the second algorithm to classify humans by applying SVM algorithm.

HOG is a kind of feature descriptor algorithm. The whole body is required to be detected. HOG algorithm provides a good representation of borders and silhouettes. Also, HOG is invariant to small image movement and to light difference changes and HOG can be processed in a constant time independently of their size.

HOG feature descriptor is computed for a 64*128 detection window of an image and come backs a vector of size 3780 for human detection. The image could be encoded in five stages: pre-processing and normalizing of the image, computing gradients, weighted vote into spatial and orientation cells, contrast normalize across overlapping spatial blocks, and HOG across detection window. The image could be preprocessed to get the gradient and orientation images which are required to compute the HOG in the initial two stages. The last three steps are very important parts of HOG [21-22]. The stages for computing the HOG descriptor for a 64*128 patch is given as follows.

The first step is calculating HOG features which are necessary to normalize and preprocess the image for a fast HOG calculation. For human detection, an image might be of any size but HOG feature descriptor is computed on a 64*128 patch of an image. For example to illustrate this step, image of size 625*451 will be processed. A patch of size 193*399 has been selected for computing our HOG feature descriptor. This patch will be crop out of an image and resize to 64*128.

Also, the similar result could be achieved after gamma normalization. Gamma normalization is an image enhancement technique. And also the contrast of images could be improved by gamma normalization. The gamma normalization is well done by (1).

$$y(n_1,n_2) = x^{\gamma}(n_1,n_2) \tag{1}$$

In (1), $x(n_1,n_2)$ equal to input image, and $y(n_1,n_2)$ equal to output image. Good detection performance will be produced when we set the parameter γ = 0.5. The preprocessing and gamma normalization is shown in Fig.3.

Fig. 3. Preprocessing image and gamma normalization

In Fig.3, a part of the image is corpped and gamma normalization is applied to the cropped image. The normalized image gives a superior contrast that is very helpful for the next processing. The second stage is to calculate the gradient scales and orientations using the horizontal and vertical convolution masks $[-1,0,1]$ and $[-1,0,1]^T$ in the subimage covered by detection window. HOG descriptor is based on oriented gradient. The bellow equations are utilized to calculate the gradient:

$$y_i(n_1,n_2) = h_i(n_1,n_2) * x(n_1,n_2), i = 1,2 \tag{2}$$

In (2), $h_i(n_1,n_2)$ is the derivative mask and it taken as

$$h_1(n_1,n_2) = \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}, h_2(n_1,n_2) = [\,-1 \;\; 0 \;\; 1\,] \tag{3}$$

$h_1(n_1,n_2)$ *and* $h_2(n_1,n_2)$ is utilized to calculate the horizontal gradient and vertical gradient, respectively. Also, the overall gradient and orientation image can be obtained as

$$y_m(n_1,n_1) = \sqrt{y_1^2 + y_2^2};\; y_\theta(n_1,n_1) = tan^{-1}\,(y_2/y_1) \tag{4}$$

A lot of inconsiderable data is removed by the gradient image such as highlighted outlines and constant shaded background. The gradient image is shown in Fig.4 for a human.

Fig. 4. Computing the gradients

In Fig.4, a gradient image of a human is shown. In the third step, the image is divided into 8*8 cells and a histogram of gradients is computed for every cell. Compute the weighted vote of each pixel to the orientation histogram which has several bins evenly spaced over 0°~180° in each cell divided from the sub image and then accumulate all votes as the cell's feature vector. At every pixel in an 8×8 cell we know the gradient direction and gradient magnitude, and in this case, we have 64 directions and 64 magnitudes which are 128 numbers. Next, we will change these 128 numbers to a 9-bin histogram. Gradients directions 0, 20, 40, 60, 80, 100, 120, 140 and 160 degrees corresponded by the binaries of the histogram. Fig.5 illustrates the computation of HOG.

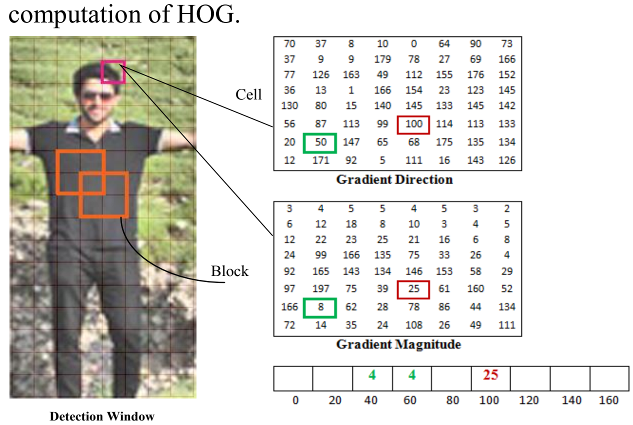


Fig. 5. Compute Histogram of Gradient Orientation

In Fig. 5, HOG calculation is shown for one block. The commitments of each pixel in the 8*8 cells are added upword to make the 9-binaries histogram. Sequentially, after computing histogram across an 8*8 cell, the image will be normalized across a 16*16 block. Collect the cells into larger overlapping blocks and each of it contains several cells. Normalize a vector of length 3, for example an RGB color vector [128, 64, and 32] will be computed as $\sqrt{128^2+64^2+32^2}=146.64$.

Dividing all component of this vector via 146.64 gives us a normalized vector [0.87, 0.43, and 0.22]. Normalizing a vector will remove the scaling. Each 16*16 block has four histograms which can be linked to form a 36 * 1 component vector and it can be normalized like a 3*1 vector is normalized. The window is then moved via 8 pixels and a normalized 36*1 vector is computed across this window and the procedure is repeated. Finally, after computation and normalization of the histogram, computation of the final component vector for the image will be processed.

After the feature extraction of each training samples, the detector is trained by linear Support Vector Machine (SVM). SVM is one of the generality common supervised binary classification algorithms. The image will be scan at various scales. Then, HOG feature is computed in each sub-image and utilized the learned SVM detector to build a classify the image: human or non-human.

IV. Experimental Results

Smartphone application was integrated with the proposed system to develop a smart movement and human detection for offices and homes. The experimental hardware setup of the proposed system is given in the Fig. 6. Apart from the hardware configuration, the required software should also be installed. We used python script and installed Raspbian OS which is good with the Raspberry Pi.

Fig. 6. Experimental Setup

The Raspberry Pi camera has been successfully captured the image when any movement is detected by PIR sensor and human detection is implemented. The system was able to successfully identify the humans in the captured images. The algorithm has been applied to all the images. The real-time human detection is done by means of HOG. The human detection algorithm is more reasonable for real-time human detection because they need less CPU resource and low costs.

This study performs four operations such as motion detection, capturing images, human detection and sending output images and notifications to the user's smartphone. The setup begins working after importing and running the code. The system will be activated just when the movement detected. Whatever the movement is detected, the output screen shows the message “motion detected” which is appeared in Fig. 7.

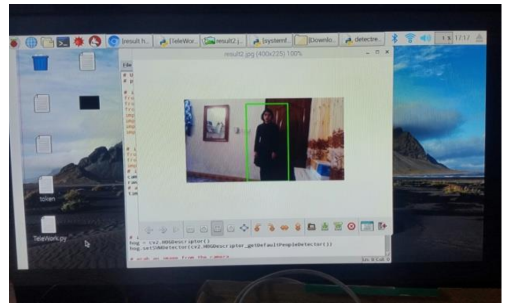


Fig. 7. Display output on the PC Screen

In Fig. 7, the implementation of the proposed human detection system is shown on a PC screen. For this purpose, the Raspberry PI is connected to a monitor. At the same time, the camera captures the events and the notifications and images are sent to a smartphone application utilized here is “Telegram” as shown in Fig. 8. Raspberry Pi has Wi-Fi wireless technologies and Bluetooth and this is useful to "view activity" and show images immediately on the smartphone gadgets.

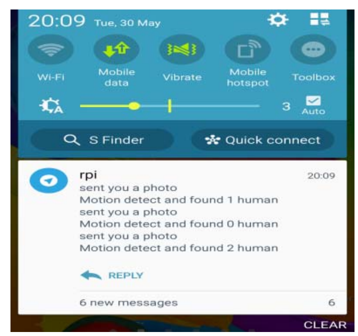
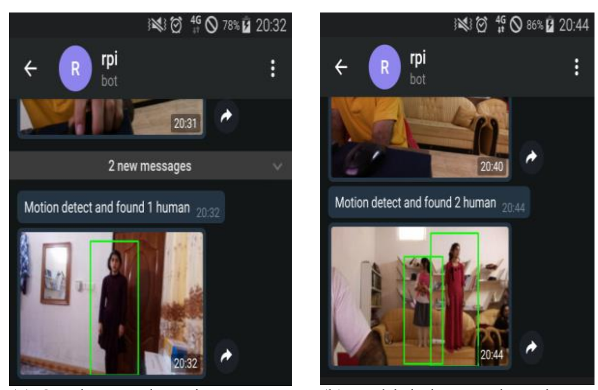


Fig. 8. Screenshot of Received notification on the Smartphone

The received output images and notification on the smart phone are given in Fig.9.



(a) One human detection (b) Multiple human detection

Fig. 9. The output of the algorithm for one and multiple human detection

In Fig. 9, the algorithm detects both single and multiple humans successfully. The execution time and the detection rate performance of the proposed method are given in TABLE I.

TABLE I. The detection rate and exectution time of the proposed method on raspberry Pi 3

Detection Rate (%)	**Execution time(second)**
93.89±5.3	0.41±0.09

A shown in TABLE I, the detection rate and execution time of the proposed method is good for real time application. The results show that the proposed scheme can be applied in an embedded platform.

V. Conclusions

We have designed embedded human detection with a smart security system which is able to capture image and sending them to a smartphone. We have proposed a possible solution to utilize Computer Vision in the IoT in the proposed system. This could permit utilizing Raspberry Pi cameras and sensors. The real-time monitoring of the home is required for a security system. In this paper, a security system is proposed and a real-time human detection is implemented. It will alert the client if any person has entered the house or office. The smartphone is the main device of the system that is utilized by the client to obtain notifications with the captured images. Thanks to computer vision, we could simplify the use of the IoT in our everyday life and we could make a new path to communicate us with our environment. To enhance and automate the security of our industries, cities, homes, towns, and the Earth, this methodology can be used. Raspberry Pi 3 has very good features and low cost embedded hardware platform. The Raspberry Pi 3 has Pi Camera module precisely designed for the Raspberry Pi. For executing the home automation, it is proved that Raspberry Pi is an effective device. Therefore, we have utilized PIR sensor and Raspberry Pi camera module to capturing the activity when any movement detected.

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