A Safety IoT-Based System for a Closed Environment

El-Hadi Khoumeri(✉), Rabea Cheggou, Mohamed El-Amine Bekhouche, and Sofiane Oubraham

LTI Laboratory, Ecole Nationale Superieure de Technologie, Dergana, Algiers, Algeria
{elhadi.khoumeri, rabea.cheggou, m_bekhouche, s_oubraham}@enst.dz

Abstract. Nowadays, the storage of large volumes of data became possible and affordable. In the same way, the computing power of microprocessors has multiplied tenfold, and digital cameras became extremely efficient at an increasingly low cost. With the generalization of the use of digital images, motion analysis in video sequences has proved to be an indispensable tool for various applications such as video surveillance, medical imaging, robotics etc. The security of people and property is a complex issue. Monitoring an environment to better prevent the danger and act accordingly in real time has led us to carry out research in this direction. We present a system for monitoring, authenticating and counting people in a public space. The basis of our application relies on cameras and motion sensor, all centralized in a single interface.

Keywords: Safety · Security · Counting people · Raspberry pi
PIR sensor · Fire detection

1 Introduction

Estimating the flow of people in real time can be very useful information for several applications such as security management or people. Thus, due to the advancement of image processing algorithms and computer technology, video cameras are used extensively in recent years to track and count people. The management of security and surveillance requires considerable attention in the Smart Cities, errors must be very limited. Fires, thefts or intrusions are undesirable events that could lead to a great loss of social wealth and human life. To avoid these losses, various alarm systems have been developed by the industry such as smoke detectors, temperature sensors, intelligent surveillance cameras, and this with the development of technologies at affordable prices. Among the new technologies is the Internet of Things (IoT), which consists of connecting all devices to the Internet in order to communicate with each other. The integration of this technology will create practical and effective means in the area of surveillance and security.

The system proposed in this document includes the use of affordable instruments based on the Raspberry Pi card, including a camera module, a motion sensor and an ultrasonic sensor. Three main functions are performed. Firstly, individuals and vehicles

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flow control, into the entrance of a building or a public institution using a facial recognition and read the license plate. Secondly, the camera is designed to detect fire, it is linked to an alarm system to alert user. Thirdly, detection of movement and intrusion in the building. A web page has been developed to manage the building entrance (real-time information on vehicles and individuals, database manipulation, history of the inputs and output). The design and the implementation of a facial recognition, license plate identification, people counting and fire detection algorithms are based on image processing. The use of the OpenCV and Python is largely in line with our solution with a high level of reliability.

1.1 Internet of Things (IoT)

The Internet of Things was first introduced in 1999, the IoT is an essential part of modern embedded systems which describes a network of physical objects connected to the Internet in order to communicate and share data between them. The purpose of the IoT is to make use of these large amounts of data to make the systems more efficient and automated. There are several examples of IoT solutions to various problems, such as the use of light beams and IR sensors to analyze the occupancy level of a home and to adjust the airflow of the ventilation system, using video streams and location data to better count the number of people in an area [1].

IoT systems often have to deal with large quantities of sensors and data. It is important that a system be able to develop its performance in order to manage an increased workload, such as more users, multiple sensors and actuators, or additional functionality. The architecture of the IoT systems can be described as being divided into three distinct layers (sensor, network, and application layer). The sensor layer includes sensors, the network layer processes data from sensors and the application layer that represents applications such as smart home. Lee and Kim [2] also point out other aspects that must be taken into account when designing IoT systems. It is important that the communication between the devices works correctly regardless of the scale of the area of application.

1.2 Related Works

Surveillance and security research generally proposes a unique solution for each module. Our solution offers a global solution with several modules in one application. In [3] a novel filters which is unified to detect either the vehicle license or the vehicles from the digital camera imaging sensors of urban surveillance systems in the smart cities. Another example [4] an intelligent system for facial recognition. In [5] they describe the development of visualisation application software used to control operational and technical functions in the Smart Home system or Smart Home care system via the wireless control system. In these articles [6–8] a system with different means of communication is proposed for the smart home. Al-Audah et al. proposed a system that uses the Lab-VIEW software based on a camera vision [9]. Another system called ALPR (Automatic License Plate Recognition) is developed for the detection and recognition of vehicle license plates [10]. A real-time system based on FPGA that provides an optimal solution for facial recognition is presented in [11]. In [12] they

propose a specific face recognition system designed around ARM9 platform. Premal and Vinsley presented a mobile camera for real-time detection of forest fires [13].

Several studies have been conducted on how to count people. Today, there are lot of methods to accomplish this task. The researchers have previously shown that, when several sensors are combined, greater accuracy can be achieved either with cameras or with other optical sensors of persons [14]. In [15] they have set up a network counting sensors inside a building in order to determine the occupancy levels of the room and use the data to control a ventilation system, by increasing the air flow if occupancy of the levels by persons increased. One of the main issue with computer vision systems is the need to separate objects of interest from the remaining pixels. Several proposed counting systems, like the ones described in [14–16], use two cameras to help with this process, a method also known as stereovision. Another common procedure is to use background subtraction, as seen for example in [17]. Using this method, the acquired images are subtracted to a previously saved background of the same capture scene and the resulting image contains the pixels of newer objects which might be people.

2 Methodology

The solution proposed in our project, security and surveillance with Raspberry Pi consists of different systems: facial recognition, vehicle license plate recognition, fire detection with access control and people counting.

2.1 Hardware Design

The proposed solution is based on a real-time processing video sequences, which requires the use of a powerful tool to ensure constraints (speed and real time). We choose the Raspberry Pi 2 card that meets our needs. It is a small single-board computer that was originally developed for computer science education and has since become popularised by digital hobbyists and makers of Internet of Things (IoT) devices. Raspberry P is about the size of a credit card; it has a 64-bit quad-core ARMv8 processor and uses a Raspbian Linux distribution as operating system (OS) (Fig. 1).

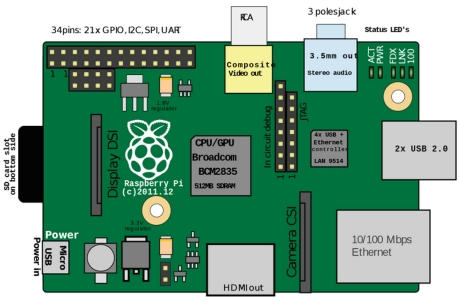

Fig. 1. The raspberry Pi 2 components.

The Raspberry Pi is contained a single circuit board and features ports for: HDMI, USB 2.0, composite video, analog audio, power, internet, and SD card. All sensors used in this project shows in the Fig. 2.

			
Camera	**Ultrasonic Sensor**	**PIR Sensor**	**Servomotor**

Fig. 2. The hardware used

2.1.1 Facial Recognition

Lot of algorithms for extracting face characteristics are proposed in the OpenCV library, such as the LBP (Local binary patterns), Eigenface and Fisherface algorithms. We chose the LBP algorithm [18] as a solution in our project. The facial recognition process can be divided into three main phase's shows below (Fig. 3):

Fig. 3. Facial recognition process.

2.1.2 License Plate Identification

The developed algorithm consists in three primary steps: Step 1: Finding the license plate, Step 2: Segmenting each of the individual characters from the license plate. And Step 3: Identifying and recognizing each of the characters. The following diagram in Fig. 4 shows the different phases of recognition [19].

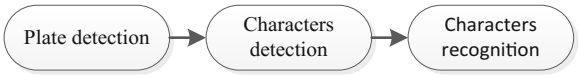

Fig. 4. Plate identification process.

The detection of the plate is the most important and difficult phase, it determines the rapidity and the robustness of the system. Steps represented in Fig. 5.

Fig. 5. Block diagram of Plate identification Module.

The detected characters require an optical character recognition (OCR) system to identify the vehicle's license plate, steps shows in. OCR is a technology that automatically recognizes characters using an optical mechanism. There are several OCR algorithms that are open source and written in deferent languages (C++, Python, or Java). We choose the "Tesseract" algorithm because of its extensibility and flexibility, that makes the recognition operation simple and reliable [20] (Fig. 6).

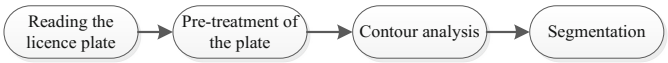

Fig. 6. Block diagram of Plate identification process

2.1.3 Fire Detection

Fire detection is performed in several ways, for example, by using temperature, humidity and smoke analysis. However, these techniques are not reliable because they cannot provide other information such as the location of the fire, the size of the fire, and these techniques can lead to false alarms. There are many types of color schemes such as RGB, CMYK, YCbCr, YUV, HSL, HSV. However, each of the color spaces has their advantages and disadvantages. Before you can detect a fire with a camera, you must know the specific properties of a fire that distinguish it from the other objects that the camera sees. The YCbCr color space is used here because of its ability to effectively distinguish luminance information from other color models [21]. The diagram in Fig. 7 shows the diagram of the proposed algorithm.

Fig. 7. Fire detection process.

2.1.4 People Counting and Tracking

Features of an image containing objects to be detected are extracted uses a method called BLOB (Binary Large Object) analysis. This method is used so as to identify the objects/regions called BLOBs using pixel connectivity and further more parameters like area, centroid, and number of BLOBs available in the test image. Preprocessing of the input test image is done prior to the BLOB analysis like thresholding to get a binary image. BLOB analysis is one of the fundamental techniques and it consist a set of related (connected) pixels in a binary image. In image processing a BLOB is described as area (region) of connected pixels. Our goal is to design a system capable of counting the number of people entering or leaving an area in a video sequence. The general scheme of the design of our system is represented by the following diagram Fig. 8:

Fig. 8. People counting system

3 Proposed Model

The proposed design of our system is presented in details, then we discuss the results of the tests in order to evaluate the functioning and the reliability of system. Our target is to design a system that meets the proposed solution, the general diagram of the prototype design of our system, is presented in Fig. 9.

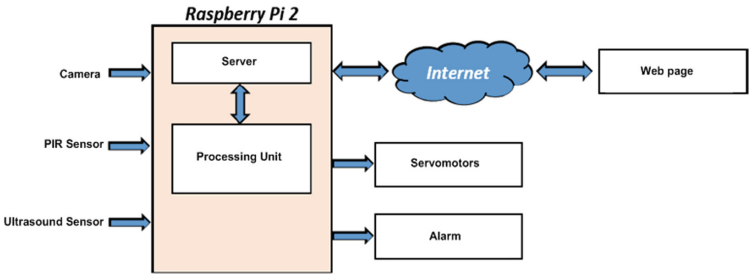

Fig. 9. Architecture of proposed solution.

The Raspberry Pi is the master device of our system, equipped with a camera that presents the video acquisition device and interfaced directly with the Raspberry Pi module via a USB interface, a PIR sensor that is connected directly with the Raspberry Pi ports. The PIR is able to detect movement. The ultrasound sensor is dedicated to managing the camera, acts as a presence detector, so it activates the shot as soon as it detects the presence of a vehicle or person. The processing of the data acquired by the input devices is carried out by the Raspberry Pi, which is responsible to make the decision to actuate the actuator, and then trigger an alarm, and to record the data. For the detection of people pedestrians go into a well determined field, the video stream is captured with a camera placed at height with head view, this video is separated into several frames (images), and one image by 30 ms, each image is processed separately so that people can be detected. For tracking people in video sequences, people will be tracked in the video sequences by memorizing their coordinates and their movements (incoming or outgoing). Thus, in the step of counting people, we will count the number of people who have entered and who are out.

The Webpage developed with PHP, JavaScript and HTML. Figure 10 shows the login page. First, every user must identify himself by entering the password and username.

After logged on, the user will be redirected to the display webpage as shown in Fig. 11. This webpage allows displaying in real time all functionalities cited before. It is also used to stream video online i.e. we can see the live streaming anywhere through internet. An error message appears if the login is wrong

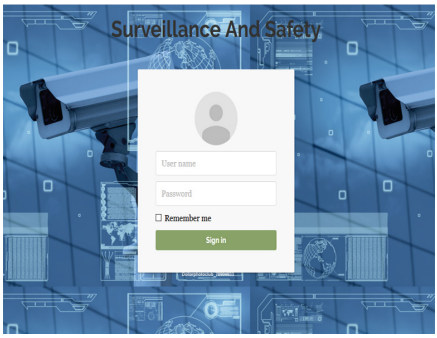

Fig. 10. Login page

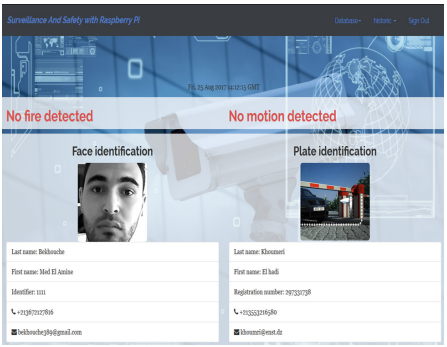

Fig. 11. Home page

4 Algorithms

4.1 Facial Recognition

The flowchart in Fig. 12 presents the different phases of the facial recognition system, which are learning and recognition. The learning module is designed for the purpose of creating or adding faces of new person to the database. First the user must enter an identifier, and then the video acquisition begins. If the camera detects a face, a calculation of the detected face biometrics is performed using the LBP (Local binary patterns) algorithm. When the acquisition is done, the biometrics characteristics are stored in a database. The recognition phase is necessary to verify the existence of the biometrics characteristics of an individual in database. First the ultrasonic sensor detects the presence of the person, then the video acquisition starts and the face detection begin. When a face is detected the LBP model starts calculating different face characteristic. The resulting calculation will be compared with the database to find a similarity.

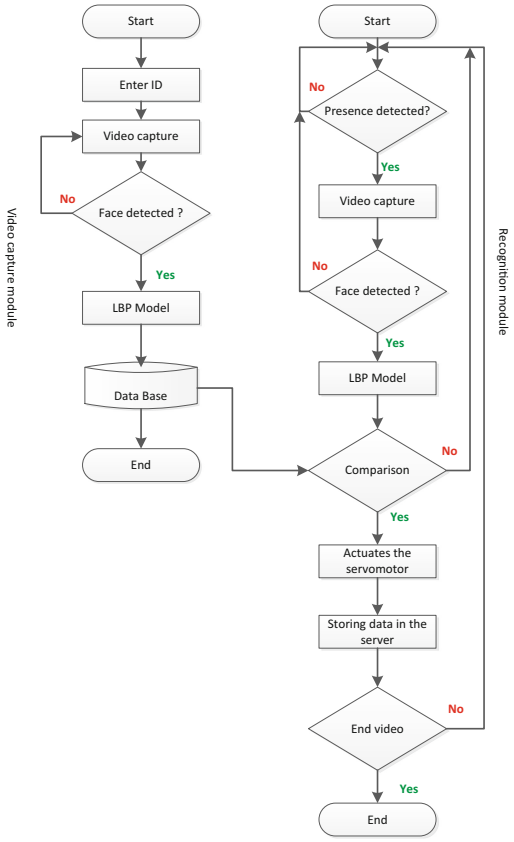

Fig. 12. Facial Recognition

If the authentication is done (the face is known in the database), the Raspberry Pi card actuates the servomotor for opening the door. All the information about every operation is stored on the server and it is accessible via the web page.

4.2 License Plate Identification System

The Fig. 13 shows the flowchart of the license plate identification system. When the ultrasonic sensor detects a vehicle, the camera is triggered by initiating the detection of the license plate. A portal can be opened by controlling a servomotor if the license plate number is authenticated

4.3 Fire Detection System

The fire detection system is shown in Fig. 14, first the camera begins to capture the video in order to do the processing on the Raspberry Pi card, using the fire detection algorithm. If the fire is detected, the alarm will warn the user.

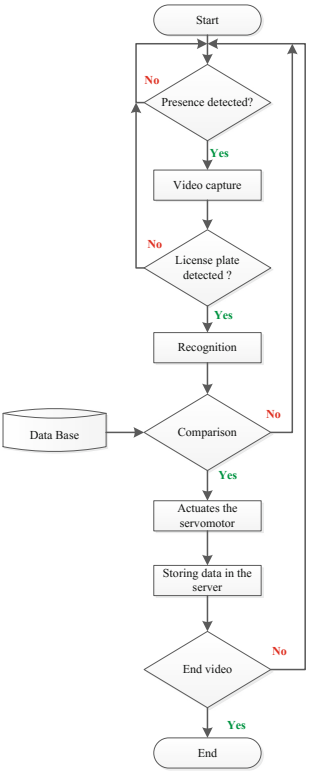

Fig. 13. License Plate Detection

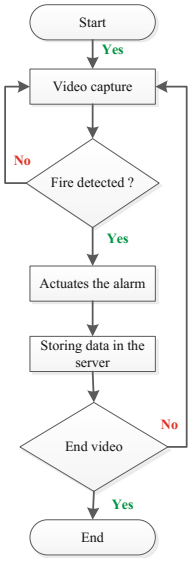

Fig. 14. Fire Detection

4.4 People Counting

For this part we take H as the height of the image and L as the width (see Fig. 15). For each contour we have a person, that will be detected, we have the center of gravity Cg (Cx, Cy) of this contour. To select the detected person entering or leaving, proceed as follows: if Cy is greater than H/2, then the person will exit, nevertheless if it is lower than the person will enter i.e. in the other meaning.

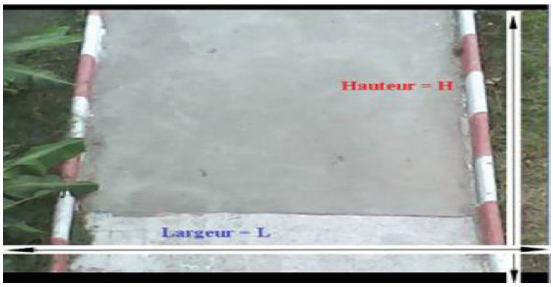

Fig. 15. Image dimension

So that we can count the number of people exactly, after each disappearance of a contour which had already existed in the preceding image, the Cg coordinates are compared with two thresholds Min and Max, these two thresholds determine the accuracy of the input or the output of the persons, if cy is lower than the threshold Min

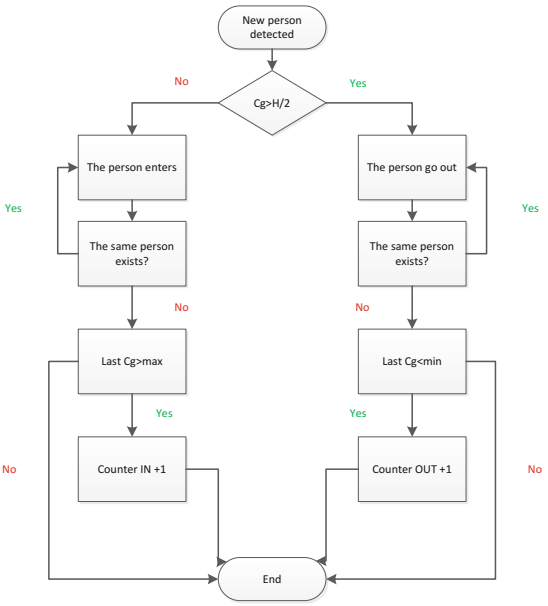

Fig. 16. People counting algorithm

then the person is out, otherwise if cy is above the threshold Max so the person is entered. The algorithm of people counting shows in Fig. 16.

Our prototype is illustrated in Fig. 17. Beforehand, all the identification data of the individuals and vehicles must be saved in the data base via the registration page.

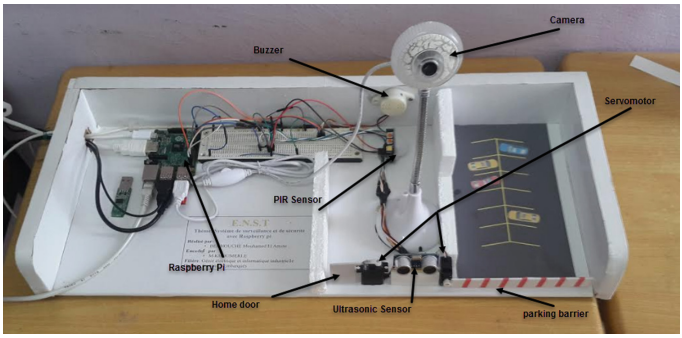

Fig. 17. System design

5 Experimental Results

5.1 Facial Recognition Test

To be able to recognise new face, the system takes 20 photos for the same person and save them in a data base. This person is associated with an identifier previously defined in the database (Fig. 18).

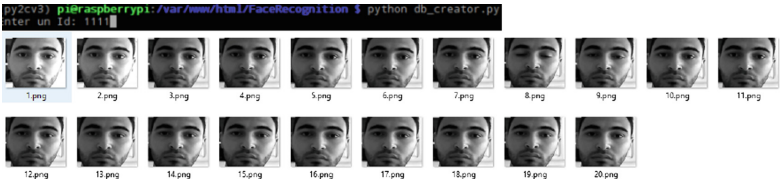

Fig. 18. Creation of the database for facial recognition

Now the system can identify the person, it displays on the screen the identifier and the index of confidence (Fig. 19). This index is calculated by the LBP model. More than the confidence value is minimal, and then recognition is better.

When an unidentified person is detected, the unknown message is displayed on the screen and the door will not open.

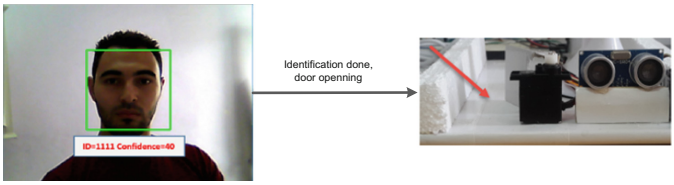

Fig. 19. Door opening with Facial recognition

5.2 Plate License Recognition Test

The raspberry Pi waits for an input from the ultrasonic sensor to activate the camera. The image will be displayed on the webpage as shown in Fig. 20.

Fig. 20. Reading license plates

The barrier will be lifted if the license plate is recognised like demonstrated in Fig. 21. Otherwise the portal will remain closed.

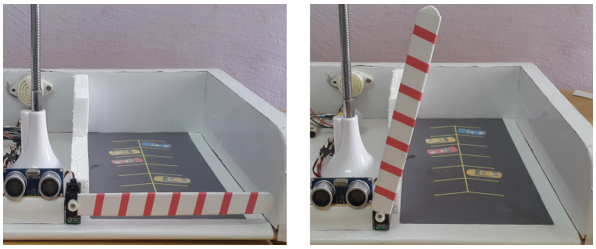

Fig. 21. The opening of the portal when the plate is recognized

5.3 Fire Detection Test

The fire alarm warms the user by sending a sound alarm and submitting a message alert (Fig. 22).

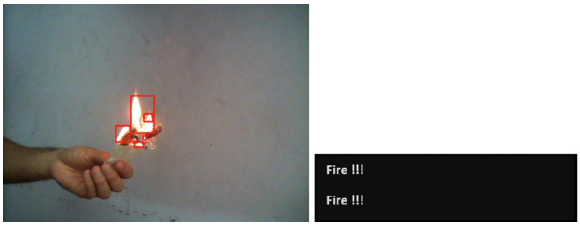

Fig. 22. Fire detection

5.4 Motion Detection Test

Motion detection involves the presence of an intruder in the field of view of the PIR sensor. A sound alarm alerts the user and a message is sent by Raspberry Pi is displayed on the webpage (Fig. 23).

Fig. 23. The screenshot of the message sent by Raspberry Pi

5.5 Tracking and Counting People

To test our system of tracking and counting we placed the camera at the entrance of a building, the background of the plan shows in Fig. 24.

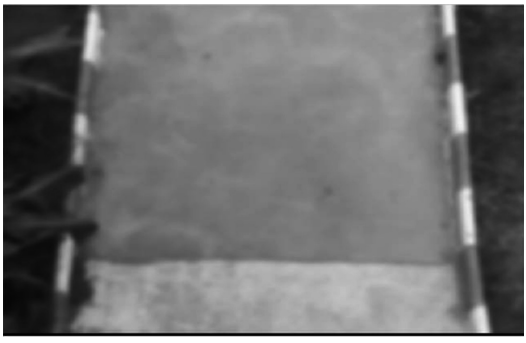

Fig. 24. The detected background

The following figure (Fig. 25) shows the principle of detection of movement while keeping their center of gravity.

When the person overtakes the yellow virtual line (out) the counter increases by +1 (Fig. 26).

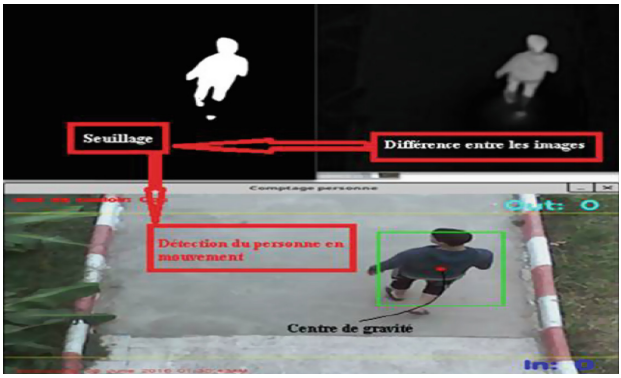

Fig. 25. Detection of a person going out

Fig. 26. Increase the out counter

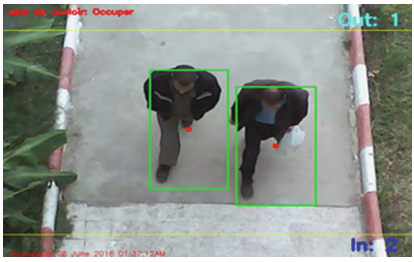

Fig. 27. Detection of two incoming persons and IN = 2

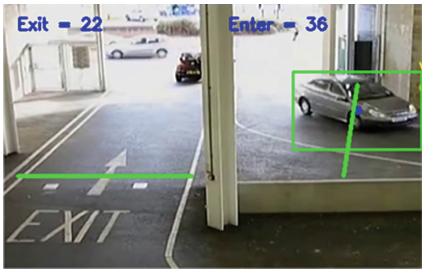

Fig. 28. Car counting at the entrance

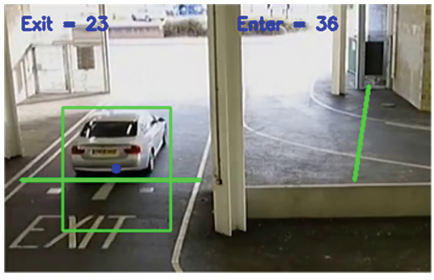

Fig. 29. Car counting at the exit

Figure 27 shows when two people enter at the same time and increase the entrance counter +2. The results of the surveillance camera from the parking entrance for car counting gives us the following results (Figs. 28 and 29):

6 Conclusion

In this paper, a design of an advanced security and safety system for Smart Cities has been presented. It reduces the human interactions, by using Internet of Things (IoT). It is absolutely an affordable system that can be used in various areas like supermarket, street, parking, official building, school, etc. This system is dedicated to be used in Smart Cities bringing together three modules in one package. Our system offers a new platform that brings together several solutions in one. The platform can support other sensors like earthquake, carbon dioxide and radiation.

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