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REAL-TIME HOME SECURITY USING RASPBERRY PI

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ABSTRACT

Nowadays, fast and automatic identification of personal identities has become important in the factors that disrupt social dynamics such as increasing theft and extortion. In the identification of personal traits, biometric recognition systems such as facial, fingerprint, vascular recognition systems can be identified. Thanks to these systems, rapid interventions can be made to the suspicious people in the institutions where there are busy crowds such as customs gates, banks, public offices, and security. In this study, using a Raspberry Pi based camera system, a personal security system with the face recognition is designed. The Raspberry Pi is a microprocessor-based minicomputer that can connect a camera, memory card, monitor, keyboard and similar peripherals. Raspberry Pi camera is used to compare the faces taken with OpenCV. The accuracy of the matching faces was determined by using some statistical methods and it was decided whether the person was recognized or not. In this designed system, it is decided whether the person is a safe person by taking the image with the camera when the operation sensor detects the person. If it is not safe, it is designed as a system that allows the host to be alerted by sending SMS and e-mails as real adverbs. This study constitutes an example for home automation in order to make human life easier and safer and to provide home security by observing some works done in-house in daily life with sensors and camera. The experimental studies carried out in this developed system have achieved great success.

KEYWORDS: Real Time Home Security, Raspberry Pi, Open CV, Quality of Life & Home Automation

INTRODUCTION

Today, the diversity and characteristics of crimes have become very different. With the development of technology in the modern world, the quality of the crimes has increased. Every day, many incidents such as burglary, extortion, terrorist incidents and kidnapping occured. Therefore, it has become important for people and institutions to ensure their safety in daily life. For this purpose, many technologies have been developed to ensure personal or institutional security and the work in this field is still ongoing. Biometric recognition systems stand out among the security systems. These systems are algorithm-based software developed for the identification of such individual characteristics as the face, fingerprints, palms, retinas and so on. In order to identify these features, image processing, video processing, feature extraction, feature reduction, and machine learning techniques are used together. Individual characteristics are deduced by the algorithm needed and subjected to training with an artificial intelligence method. With the same system being asked to the system again, the matching feature will return the required data about the person who has the matching feature in the database. This gives the system an alarm or gives an output according to the desired target. Alarm systems can be used to detect suspected people or crimes such as robbery.

In recent years, the perception of the human face in images has become interesting for researchers. One of the reasons behind this growing interest is the need for a more secure, advanced and safer order in order to ensure safety in

airports, stadiums, hospitals, and factories. Many applications that use face detection with computers as a fast and effective tool have been an essential part of life.

In parallel with the rapid developments in today's automation technologies, people's need for safety and a more comfortable standard of living has led to the emergence of the concept of intelligent life system. Home automation provides many benefits in human life. Remote control or monitoring can be done with this system. Thus, life can be more comfortable and safer. This system also provides additional security for people. For example, he can detect the intruder entering his house and give information in real time. It can be used to perform various functions that protect human life. For example, it provides extra security for the home while using motion detectors. The entrance gate and other specific areas can be monitored from the outside for security purposes. Unwanted guests trigger automatic alarm lighting and discourage them from going further. Through door and window contacts, alarm messages are displayed at home or outside. All these measures make human life and the house even safer.

Face recognition problem is one of the most important and difficult problems that researchers working on image processing, computer vision, and pattern recognition are working on. Although many scientists have been working on this issue for a long time, face recognition systems with sufficient success to solve problems encountered in real life have not been developed due to the difficulty of the problem. Increasing security requirements, especially as a result of recent and current attacks, have increased the need and interest in face recognition as in other biometric methods. In this study, Open CV was used as the image processing tool. Background estimation methods and the application of background extraction methods with OpenCV, which is the most commonly used approach to identifying and detecting moving objects in real-time images, are described.

With a camera connected to the computer, it is a high-potential technique to improve vision, human and computer interaction. With various algorithms, objects can be tracked and defined and many interesting applications can be built upon these possibilities. In addition to various commercial purposes, there are many applications such as the defence industry, medicine, robotics industry, biometric applications, websites and facilitating the lives of people with disabilities.

Studies with real-time image processing techniques reveal the extent to which computer science makes life easier for human beings. Some of these studies are such applications as traffic and security applications with road surveillance cameras, object tracking, object counting, object identification, face recognition, plate reading, text reading, control of agricultural land. Algorithms are being strengthened every day in this area, which can perform arithmetical and logical operations, make decisions, learn by artificial neural networks and be able to move with electrical signals.

Computer vision and real-time image processing are the application that requires processor power. Being aware of the importance of this situation, the processor company Intel has created a project called "OpenCV" by targeting real-time applications. The basic image processing library is a large and famous Computer Vision library licensed with an open source BSD license developed by OpenCV Massachusetts Institute of Technology (MIT) and some other universities with the support of Intel and written by C and C++. This library, which is free of academic and commercial use, can be used in different platforms such as Windows, Linux, MacOS X. The Open CV Library with nearly 500 functions has a wide range of ready-to-use functions from machine learning to robotics, camera calibration, image processing in medicine, automatic identification and tracking technologies.

Many studies have been done in the literature on security systems. Security-oriented system researches, which combine electronics with software like GSM/GPRS based wireless home security system (Lee, et al.. 2007, Zhao and Ye, 2008), face recognition based on automatic switching magnetic door lock using microcontroller (Hassan, et al. 2012, Assaf, et al.. 2012), sensor-based home automation and security system (Ibrahim and Zin, 2011), are often done. In this study, a face recognition system was designed with Raspberry Pi system, motion sensor, and camera. The database of the face recognition system consists of images taken at certain distances and angles. Recorded face images were compared with images taken with Raspberry Pi camera.

In the study by Hassan et al., a face recognition system and Graphical User Interface have been developed as an input/output controller in order to open/close the magnetic lock for the door lock security system. Furthermore, it is suggested that the system will be developed in order to make it a fully automatic face recognition system by adding image capture feature with a sensor automatically to the input area(Hassan, et al. 2012).

In the study by Padmapriya and Kalajames, advanced face detection and recognition method based on knowledge of skin color have been developed. The AdaBoost algorithm was used to detect the face. Using the principal component analysis (PCA) algorithm, it was proposed to perform a specific face mapping by comparing the main components of the current face with the data in a previously created face database (Padmapriya and Kalajames, 2012).

Prasad et al. designed and implemented a smart surveillance monitoring system for mobile devices using Raspberry Pi and PIR sensor. Raspberry Pi, motion detectors for remote sensing and monitoring and video camera for instant video streaming and recording was used. The system records the video, captures the images, then transfers the data to a smartphone(Prasad et al., 2014).

In the study by Usecheet al., a face recognition access control system in which the faces were detected and monitored on a video was developed, users were identified in real time using convolutional neural networks and a 96% accuracy rate was obtained (Useche et al. 2018).

In the study by Szabo and Gontean., they prepared a robotic arm control system using Raspberry Pi. They used Raspberry Pi, robotic arm, two webcams and two IP cameras in their study. Raspbian was used in the system and Python language and openCv libraries were used in the operating system (Szabo and Gontean, 2016).

Khelbude and Shelkehave made the iris-controlled robot using Raspberry Pi, camera module, Arduino and stepper motor in their study. The Pi camera transfers the image of an eye to Raspberry Pi in real time. Using the OpenCV library, you can determine the direction in which data is processed and then transfer to Arduino via wireless communication. Arduino is a system that enables the operation of the motors by taking the data from Raspberry Pi (Khelbude and Shelke, 2016).

In the study by Yang et al., they have made the line following robot by using Raspberry Pi and camera. By recognizing and monitoring the line with image processing methods, they have provided the movement of the robot accordingly (Yang et. al. 2016)

In the study by Pereira et al., they have listed objects in three different shapes and colors using the Raspberry Pi, Pi camera module, IR sensor, Arduino and a robotic arm. Initially, the IR sensor detects the object. If the object is detected, the Pi camera module opens to display the object. The image is sent to Raspberry Pi. The captured image is recognized and saved in a text file by recognizing the color and shape of the object. Arduino uses servo motors with control card to move

the robotic arm to the desired area (Pereira et. al. 2014)

Sirovich and Kirby used the PCA technique, which is the standard linear algebra technique for the face detection problem. This technique is considered to be a turning point because it requires less than a hundred to accelerate and normalize the face accurately and appropriately (Sirovich and Kirby, 1987).

Yang et al. studied a face detection and recognition system with a series of color images in their article (Yang et. al. 2008). Singh et al. studied on face detection with single gallery images in their article. The authors used the dynamic neural network architecture to extract the features of the facial tissue phase using a two-dimensional daily polar Gabor transformation (Sing et. al. 2009). Wang et al. designed a face detection using fuzzy maximum distribution separation analysis (Wang et. al. 2009). Kaminski et al. proposed a system that calculates the position of the face and view perception using a single face image in their article (Kaminski et. al. 2009).

MATERIALS AND METHODS

This study consists of two parts of software and hardware. In the software section, the algorithm used in face recognition on the Python language is coded for comparison and performance analysis. All coding system is embedded on Raspberry Pi platform and communication protocols with peripherals are provided. The hardware part consists of three parts: Raspberry Pi, motion sensor and camera.

Figure 1: Our System Pieces

The Raspberry Pi embedded system platform is a minicomputer, developed by the Raspberry Pi foundation in England, whose primary purpose is to develop computer-based education in schools and teach children computer. Raspberry Pi, which is used mostly in applications that require embedded system application and operating system, is frequently preferred because it can be developed to be independent of the computer and easily portable systems. Raspberry Pi is available in a variety of models with some hardware modifications. Keyboard, mouse, and screen can be used as a mini-computer connected to this card can be installed on the operating system and there is no internal hard disk to store data. For this purpose, after inserting a memory card into the microSD card slot on the card, the operating system can be installed and the desired storage can be performed. Raspberry Pi is a non-fanminicomputer with ARM architecture that can be installed in various Linux and Android distributions. Thanks to the 26-pin GPIO connector on the board, the required equipment can be connected to Raspberry. The pins on the card are composed of 8 GPIO, I2C, SPI, UART parts. 5 V and

3.3 V power can be taken from the pins. The logic level of the I / O pins available on the Raspberry Pi is 3.3 V. There are USB ports that can be connected to peripherals and ethernet output. Figure 2 shows the model Raspberry Pi (Yağanoğlu and Köse, 2018). In this study, our system was created by installing the Raspbian operating system.

Figure 2: Raspberry Pi

The camera module in Figure 2 with 5MP resolution is designed to be connected directly to the CSI connector on the Raspberry Pi circuit board to receive images.

Once the operating system was installed on the Raspberry Pi circuit board, the recognition and location of the object in the image taken by the camera were performed with the software developed in Python with the help of object finding and recognition algorithms using the OpenCV library. OpenCV is an open source library released by Intel in 1999 for academic and commercial applications in the field of computer vision. The OpenCV library, which is free to deploy and develop, is written in C and can run on such platforms as Windows, Linux, Mac OS, iOS and Android platforms with the interfaces of C++, C, Python, and Java.

ARCHITECTURE OF THE SYSTEM

An image was taken from the camera as an introduction to the system. Face recognition was done with the image processing code prepared with Python in Raspberry Pi. The faces of the recognition were compared with the recorded images. In case of suspicious face recognition, the Wi-Fi module on Raspberry Pi 3 connects to the device and sends e-mails and SMS to the system administrator.

It is first detected by the motion sensor coming into the door and the camera module captures the image of the person. If it doesn't match with any user in the database, it gives information with through SMS and e-mail. If the one coming is not recognized by the system, it sends a message to the user.

One important step in real-time images is the detection of moving objects. Foreground-background separation is a common method for detecting moving objects in real-time images. The moving object tracking in the real-time image is used in areas such as traffic control, defense, security, auto guidance from vehicle technologies, overtaking, tracking, fatigue of the driver. Due to the fact that the usage area is important and widespread, different methods have been developed in foreground-background separation.

Four basic steps in foreground-background separation algorithms are as the following: pre-processing, background modeling, foreground detection, and data validation. Frameworks that create a real-time video that comes in the pre-treatment phase can be processed in a number of processes by making them available in the next sub-steps. The aim

here is to get rid of the negative effects of noise and to reduce the processing load.

In the background modeling stage, the background model is created and updated using pre-processed frames. Background modeling is done by statistical definition of backgrounds. In the foreground detection stage, the video frames have pixels that are not fully explained by the background model and these pixels, which will form the foreground mask, are produced in binary components. In the data verification stage, the foreground mask created in the previous stages is discussed. Pixels that don't match the actual objects moving in this mask are separated and the mask to be used in the foreground is obtained.

OPENCV

Computer vision and real-time image processing are applications that require processor power. Being aware of the importance of this situation, the company Intel has created a project called "OpenCV" by targeting real-time applications. OpenCV (Open Source Computer Vision Library) is a library developed by Intel that covers real-time computer vision programming functions. The library works on multiple platforms. The library concentrates on real-time image processing.

While developing OpenCV, C and C++ languages have been selected and the advantages of multi-core architectures have been tried to be used here. Integrated Performance Primitives was developed for high-performance operation of OpenCV on Intel processors. The OpenCV Library, with nearly 500 functions, has a wide range of ready-to-use functions machine learning to robotics, camera calibration, image processing in the glass, automatic identification and tracking technologies. OpenCV also has a very advanced Machine Learning Library (MLL). This library contains many functions and algorithms.

Today, using computer vision and image processing algorithms in OpenCV, Human-Computer Interaction, Object Identification, Segmentation, and Recognition, Face Recognition, Gesture Recognition, Motion Tracking, Ego Motion, Motion Understanding, Mobile RoboticsApplications can be improved.

OpenCV is optimized to take advantage of multi-core processors in real-time applications with sufficient speed and efficiency and the library continues to be developed. If desired, IPP (Intel Integrated Performance Primitives) libraries optimized by Intel especially for its own processors can be used. The IPP library contains various optimized low-level procedures for the more efficient operation of various algorithms. If IPP is installed, it will be automatically detected by OpenCV and used at runtime. If the project is not commercially developed, Intel provides this library free of charge for Linux users.

OpenCV contributes to the development of many image processing applications from industrial products to security products, game consoles to city surveillance cameras, artificial intelligence products to medical products, document processing to astronomy through its functions. The OpenCV library consists of 5 basic components;

CV Component

CV Component is one of the five basic libraries that incorporate high-level algorithms used for basic image processing functions and Computer Vision. It is the basic library that provides high-level image processing algorithms on externally read moving and non-moving image data. The basic functions of the CV library are based on image processing such as basic operations, structural analysis, motion analysis, and object tracking.

MLL Component

MLL Component is the library in which the basic functions and tools are defined by making the computer library and other machines to make inferences from the functions in the CV library. The MLL library conducts appropriate data analysis for decisions that are the ultimate goal of image processing such as the classification of data and presenting of statistical inferences with its functions and tools. It is a further library that contains the functions/tools used to reach the statistical data required for the machine learning branch and to classify the available data.

High GUI Component

Although High GUI Component is a graphical interface that allows us to create many objects such as floating forms, it is a library that contains the input/output (I / O) functions required to save, load, delete pictures and videos.

CX Core Component

CC Core Component is a library that contains various data structure of the Open CV library (cvPoint, cvSize, cvRect, IplImage, cvHistogram, cvMat) and also provides XML support. It is the library that provides various data structures for image processing and XML support.

Cv Aux Component

Cv Aux Component is the standard library that defines many experimental algorithms such as shape matching, face recognition, motion recognition, and body movement.

OPENCV Structures

OpenCV provides a variety of functions for morphological processing. Morphological processes have a wide range of uses; removing noise, isolating some elements, combining broken elements can be given as examples. They are generally used in binary images.

Applying an expansion filter to a digital image means enlarging the image with the structural element as much as the sections that it intersects. In order to do this, the structural element is filled by pixel by pixel on the image. If the center of the structural element meets a “0” with a pixel, there is no change. If a pixel with a value of “1” is encountered, the pixels that are equal to the structural element and fall under it are subjected to the logical “or” process.

Wear may be seen as the opposite of expansion in a way. Again, in the same way, the structural element is filled pixel by pixel on the image, but this time, if the central pixel of the structural element encounters the value “1”, the state of the pixels in the structural element is looked at. If there is a “0” value of the image under any of the pixels “1” in the structural element, this pixel is converted to “0” with the ones under the other “1”s of the structural element. This image is eroded by abrasion. In other words, the objects in the image become smaller, space expands if there is space and the connected objects tend to leave.

Thresholding is usually a technique used to convert an official binary image (i.e. either black or white). It can also be used for different purposes such as preventing noise or identifying objects. The general purpose is to compare all the pixels of the picture with the specified limit value one by one and to transform the image into zero and one according to a certain rule.

It has such goals as reducing noise and using processing time and computer resources efficiently. They eliminate undesirable elements in the picture such as brightness and noise. Linear and non-linear filter versions are available. The filters are generally based on the fact that a kernel matrix is traversed throughout the entire image and the sum of the products for each pixel is taken. This calculates a new value for each pixel value. According to the size of the matrix and the values included in it, such wide variety of operations as picture softening, sharpening, edge detection can be done.

With the OpenCV library, real-time applications are developed by capturing images from a USB or internal webcam. If more than one camera is used in the system, the required camera ID should be determined and entered as the parameter in the related method.

The purpose of separating the object or object parts from the remaining parts of the image is to pay attention to the required part and gain time and speed instead of seeing the entire image. For example, the camera generally looks at the same background in video security systems. Dealing with the same background demands a constant labor and causes time and performance loss. Taking care of parts where people or vehicles enter the image instead of taking care of background or leaving something that has never been there before will provide time and performance gain.

Training the Algorithm

As a first step, the algorithm is trained using the face images of our targeted test subjects. An image data set was created with these images. All images of a given person are given the same ID to distinguish between sets. This ID used to identify a specific image. After the labeling of the images is completed, the LBP process is applied as the nextstep. Then, Extracting the Histograms is done. The image values in each grid will be plotted as a separate histogram and all histograms combined to create a new and final histogram. This histogram represents the features of the original image. Then, histograms created for each image in the training data-set using the method in the previous step. When a new input is given, a histogram created for that image and compare it with the dataset. There are such various approaches to do it as Euclidean distance, absolute value, chi-square.

The identity of the nearest image is taken into account with the calculated distance. The distance is called confidence. The accuracy of the algorithm was determined by confidence and threshold values. If trust is less than the threshold, then the face can be said to be correctly recognized.

The step of face recognition takes the feature vectors as input and identifies faces. In order to achieve this, a face database was created with people's images more than one. These images are used to extract the characteristics of the person. The features extracted in the last step are compared with each face class in the database and a match is defined. Over the past two decades, facial recognition has been widely studied. The most common one of many algorithms developed are Eigen faces, Fisher faces and local binary patterns histograms.

Once the dataset is created with the feature vectors and the training phase is completed, the identifiers are calculated to assign the object in a given test image to an appropriate class and after the identifiers are calculated, these identifiers are matched separately with each of the identifiers stored in the dataset. By determining the smallest distance between the paired identifiers, the object class that belongs to the object image with the most matching is determined after the matches below the determined threshold value are determined and the object in the test image is classified. After the object is assigned to the appropriate class, the mismatched dots are filtered by the homography estimation to determine the most accurate matches between the object with the most matching and the test image and the recognized object is labeled

with the class label to which it is assigned and enclosed in a delimiting box.

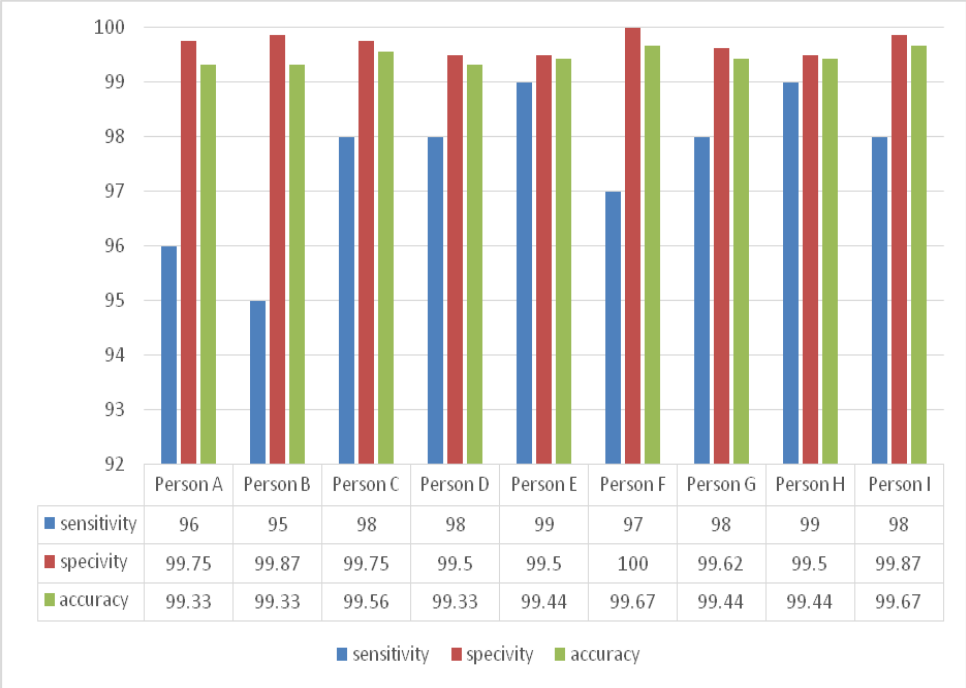
RESULTS

Confusion Matrix (CM) is used to measure performance in classification systems. CM is a table structure that allows the evaluation of classification results to measure the performance of an algorithm for classification in machine learning. It is also referred to as the error matrix in the classification models using CM-educated learning and as the mating matrix in the classification models using uneducated learning (Yağanoğlu et. al. 2018)

Each row in the table contains the actual class of the data samples and each column contains the class estimation by the classifier for the data samples. The total number of instances in a class can be found in the row sum for that class. However, how many of the samples are classified by the classifier can be followed from the intersection of the rows and columns of each class along the corner of the table.

Accuracy, sensitivity, specificity values are used as performance measurement criteria. Sensitivity refers to an estimation of how many of the class X samples actually belong to the class X for the classifier. The selectivity refers to the fact that the examples that the classifier predicted to belong to the class X are in fact the class X. Accuracy refers to the ratio of the number of instances from which the classifier makes a correct estimation of belonging to a class or not.

Success rates for 10 people are shown in Figure 3. As seen in the figure, Our average success rate is 99%.



	Person A	Person B	Person C	Person D	Person E	Person F	Person G	Person H	Person I
sensitivity	96	95	98	98	99	97	98	99	98
specivity	99.75	99.87	99.75	99.5	99.5	100	99.62	99.5	99.87
accuracy	99.33	99.33	99.56	99.33	99.44	99.67	99.44	99.44	99.67

Figure 3: Real Time Values of Sensitivity, Specivity and Accuracy

CONCLUSIONS

Face detection and monitoring have been a common topic in recent years. In order for a face to be classified, the section of "face" in the image must first be determined. The images are usually drawn from the front faces of people. The most important problem here is the correct removal of the part of the face area in the image. Because the position and size of the face area can vary for each image, it is not possible to use the same type of template to remove the facial part from the images.

Nowadays, different areas of face detection and analysis are used. Computer vision and all kinds of image processing applications have a wide place from defense industry (robotics) to security systems (smart camera systems), robot industry (artificial intelligence) to medical sciences (optics), commercial purposes (signal processing) to web page filtering (machine learning).

The face recognition problem is one of the most important and difficult problems that researchers working on image processing, computer vision, and pattern recognition are working on. Although many scientists have been working on this issue for a long time, face recognition systems with sufficient success to solve problems encountered in real life have not been developed due to the difficulty of the problem.

Face-finding is one of the toughest problems of artificial vision. The aim of the face finding problem is to determine the regions containing the face without being dependent on the 3D transformation and lighting conditions when a single or sequential image is given.

One important step in real-time images is the detection of moving objects. Foreground-background separation is a common method for detecting moving objects in real-time images. The change of application areas and image environments of real-time images has led to the development of various algorithms in foreground-background separation. Although some of these algorithms are good in terms of memory usage, they have high complexity and process power. Some algorithms have high memory usage, even though their complexity is low. In the background extraction of real-time images, the background of the image from which the image is taken, that is, the motion of the image, or is mobile or periodic mobility, influences the choice of foreground-background separation algorithms. There are long-lasting algorithms to adapt to the changing background. Algorithm speed and robustness in algorithm selection in foreground-background extraction and the correct algorithm should be selected according to the application.

The Debian-based Raspbian operating system used in the study has many advantages. It is open source and doesn't require a license and can be developed. The use of Python language on the side of software development and the ability to run Python scripts without having to compile create a substructure that can be easily used in other systems. In addition, the OpenCV library is integrated into the embedded system and its capability is increased.

For many years, automation systems have been used in different fields. However, in recent years, home automation has gained importance with its solution against many problems. Many companies considering the advantages of automating some of the routine processes that have to be done have initiated R & D studies and received successful results from these studies. Studies on this subject are considered as smart home technology. It is thought that this technology will provide a wide range of services to people and will have a wide range of users in the near future. It is possible for people to receive service in such many fields as security, communication, comfort, saving, control thanks to automation systems created by using modern technologies in their daily or business lives with Smart Home technology.

The fact that this technology, which makes life easier, can be easily applied to buildings is seen as an important advantage. This system can be used in buildings, workplaces, etc. from a small home environment. By applying to many areas, it is possible to control the systems (heat, light, gas, alarm, security, recording etc.) that are wanted to be controlled here and if desired, the control operations are provided to the people by monitoring them from a different environment. When the person is on vacation and there is someone approaching the house, devices such as lights, stereo or TV can be turned on with the help of scenarios and the impression of the fact that the house is full is given and the thief is removed. In this study, the people who entered the house with a motion sensor and camera were identified and the people who were not previously recorded in the home environment were identified.

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