Enhanced Smart Doorbell System Based On Face Recognition

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Abstract— **In recent years considerable progress has been made in the area of face recognition. Through the work of computer science engineers, computers can now outperform humans in many face recognition tasks, particularly those in which large databases of faces must be searched. A system with the ability to detect and recognize faces has many potential applications including crowd and airport surveillance, private security and improved human-computer interaction. An automatic face recognition system is perfectly suited to fix security issues and offer flexibility to smart house control. This project aims to replace costly image processing boards using Raspberry pi board with ARMv7 Cortex-A7 as the core within Opencv library. This project is mainly based on image processing by porting the Opencv library to the Raspberry Pi board. Algorithm for face recognition, based on principal component analysis (PCA), is programmed and implemented on the platform. The system is based on the criteria of low power consumption, resources optimization, and improved operation speed.**
This paper reviews the related work in the field of home automation systems and presents the system design, software algorithm, implementation and results.

Keywords— face recognition; security; home automation; intelligent; Principal Component Analysis; low cost; OpenCv; domotic;

I. INTRODUCTION

The human face has a particular shape that requires complex calculations in order to recognize it. Individuals are distinguished by their faces, with which they are being identified. We can memorize many faces during our life journey and get to know them immediately, even after years. Aging and distractions like glasses, beard or change of skin color may gradually vary face recognition rates. Face identification represents one of the most used types of biometry. It proceeds as follows: Starting with calculating and subtracting specific characteristics, then verifying them with the already existing database, in addition to obtaining a positive correspondence between the compared faces. After getting the face shape details, the system adjust them by using some algorithm models, finally face images are stored in the database and resolved using other algorithm. The face recognition embedded systems are very practical to be used in different applications such as terrorist's identification, security systems and identity verification access. In fact it is implemented in many public and even dedicated areas. Thanks to the well-developed technologies related to computer science, we can obtain considerably good and satisfying results of face identification and reveal. The extracted details from faces, will be analyzed and compared with the already existing similar face operated details in the database. For example in monitoring systems the detection of an anonymous face more than once leads to saving this face traits in the database for further identification. This strategy is very efficient in detecting criminals and thieves.

In this paper, face recognition is initiated by pressing the doorbell button. Indeed, an integrated camera will capture several pictures of the visitor. The face recently scanned will be verified in the present database. In case of unknown face, a template will be generated then stored. Otherwise, in case of known face, actual template is matched with templates stored in the database. Furthermore, the owner will be notified, through his mobile phone, speakers and an administrative secured website, about all the visiting details. Comparing to old face recognition systems that are already commercialized, this project is more efficient in real time response with better recognition rate.

The system design and project process are detailed in section 2 of this paper. Section 3 is dedicated for the corresponding implementation architecture and experimental results.

II. DESIGN CONCEPT AND WORK PROCESS

A. Design concept

The main goal of this work is to create an intelligent doorbell system mainly based on human face identification. The first part involves face detection using haar-like filters [1], then seek likeness in the database entries. A flowchart of the control procedures is shown in Figure 1.

To achieve the described functioning, we subdivide the face recognition process into three sections: Face Detection, Trait Extraction and Face Recognition (Figure 2).

Figure 2. Face recognition procedures

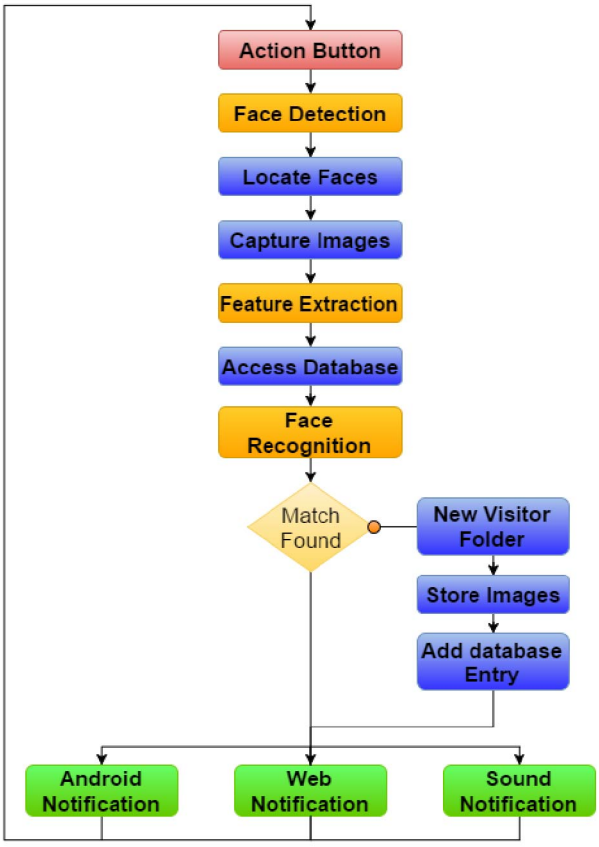

Figure 1. Flowchart of system procedures

B. *Face detection*

The fundamental role of this section is to resolve the images in order to determine whether human faces appear, and pinpoint the location of faces to prepare for cropping. The resulting output of this process are patches characterizing each face image, to improve the effectiveness of the algorithm, face alignment and scaling filters are applied to the input image. Face detection is used also for region-of-interest detection, video classification, retargeting images, etc.

By applying the Haar-like features, the system could recognize the presence or the absence of a human face. As shown in Figure 3.

Figure 3. Face detection filters and masks

In order to retrieve all faces present in the picture, a loop all around the image with conditional structures comparing the filters with the content is established. Figure 4 shows, as an example, Haar-Like features applied on LENA picture.

Figure 4. Haar-Like features applied on LENA picture

C. *Feature extraction*

After detecting the face in the image, human-face patches are extracted from images. To avoid environmental deficiencies like illuminations, face expressions, occlusion and clutter [2], feature extractions are implemented to extract information from the image in order to reduce dimension, conspicuous extraction, and noise decreasing. After this step, the face image is extracted and transformed into a vector with fixed dimension with space vector containing points and their corresponding locations in a XML file (training file) or as a PCD file (Point Cloud Data). Faces are described as polygons or objects. Figure 5 shows face detection and feature extraction process.

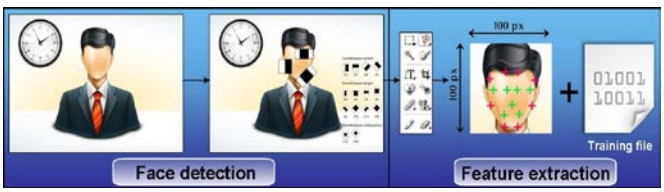

Figure 5. Face detection and feature extraction process

D. Face recognition

After preparing the training file and interpret the face vector, the next step is to apply the matching algorithm between the stored data and the input image [3]. The process of the system is working as follows: as an input image comes in, face detection will pinpoint the traits of a face, then feature extraction will apply the filters to extract only the face and then compare the traits extracted to the ones available in the database, major previous works were infirm with low recognition rate or with undefined time response. In this branch two main applications are established: the first is identification [4] and the second one is verification [5].

On one hand, using face identification, the system could recognize the person through a given face image, or, in worst case, could precise the most probable identification using the Eigen Face algorithm, too many issues of face stimulus appeared in previous work in face recognition field, especially when the camera is exposed in the outdoor to environmental changes, this lead us to create a new approach in order to determine the real unique traits of a human face, this may have important implications for the use of identification tools such as Eigenface, the algorithm represents every image as vector, compute the mean of all images, eigenvectors, and then represent each face with a linear combination of the best eigenvectors calculated.

On the other hand, systems using face verification could differentiate if a given face image matches or not with a guess face to improve the verification. Steps of face recognition are shown in figure 6.

Figure 6. Steps of face recognition

III. IMPLEMENTATION AND RESULTS

Dependencies needed to build a smart doorbell based on the face recognition algorithm are detailed in this section.

A. Technical specifications

Since this work is based on the Raspberry Pi model B embedded board: the operating system need to be configured. Thus, an easy access to the system and control all the hardware related to the board could be possible. For such applications, Raspbian OS is opted to be installed since it runs on a Linux kernel and programming the face recognition algorithm will not be tough and this differs from prior work in time execution and developing tools [6]. This project only entails few hard devices: wireless network adapter, memory card, push button and a webcam, which offers better manipulation with the wireless flexibility, and the low cost of equipment.

Besides, we need software tools to facilitate the work and the build of the project. Also, pre-compiled libraries and source files should be installed on the board to access the GPIO pins, perform SSH connexion, drivers for the Wireless network adapter and sound output software.

B. Software and dependencies implementation

1) Essential dependencies

To completely afford a functioning smart doorbell system, installing useful dependencies such USB Camera, Wireless adapter and screen drivers in the Linux operating system is needful. Then, OpenCv library which is used to allow developers to flexible manipulation of the camera flux and to create a proper algorithm based on computer vision is installed. Python and C compilers are needed also for programming. Finally SQL, PHP and Apache dependencies should be installed in order to access the local website to view camera streaming.

2) Software

To access the Raspberry Pi Graphic User Interface (GUI), it is highly recommended to use XRDP: a small software that provides simple way to remote control raspberry pi. For the sound output, Espeak library that pronounce a text given as an input is installed. For external access to the raspberry pi local website we need to configure the access on NO-IP software so it redirect all external requests to the main website of the project.

3) Administration and website

The main page of the administration panel of the smart doorbell website is secured with login and password access in order to give permission only to the owner to take control of the entries.

The main idea is to access the database and differentiate between the visitors, show their details, pictures, time of their last visit, and full flexible manipulations: adding details, deleting entries, modifying names, dates, number of visits, etc.

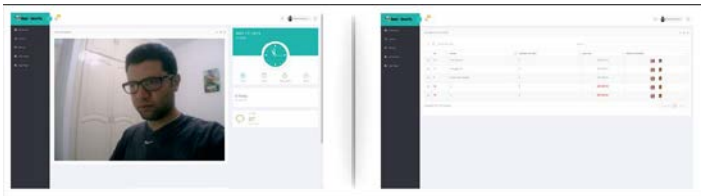

Figure 7. Data table of visitors

4) Android Notification

To inform the owner of new visitors when the doorbell is pushed, an android application providing to the user a notification showing the name and the last visit time is created.

C. Result

This project uses the Eigen faces algorithm in OpenCV library to perform face recognition. The script will capture an image which is converted to grey scale image, then apply the Eigen face approach and detect a face then crop the image in N^2 dimensions.

To reduce the amount of information stored in database, face images are converted into two-dimensional array with 8 bit intensity values, with the exact trait extraction the algorithm calculate the average face image (in grey-scale mode for more information reduction) and subtract the resulting vector from each eigen face vector to finally obtain the essential vector in order to identify a person, this normalization of each vector is called principal component and helps to find the appropriate vector within the shortest possible time, the purpose of using principle component analysis is to create a linear combination of a vector that optimally represent the input image with less memory footprint.. [7]

Figure 8. Set of 100x100 grey scacale images for training

Database for various illumination, contrast and expression condition is stored. In this step we evaluate the system under different constraints like variations in illumination, face rotation and scale variation, even with these changes the feature extraction algorithm extracts the mean image and an eigenface image as shown in Figure 9.

Figure 9. Mean image of eigen faces

At this step, the training data is stored in an XML file "training.xml", which will be loaded by the main software to configure the face recognition model.

The Raspberry low memory process and the low focus performances of the camera could limit multi scaling recognition. To overcome this, it is better to be distant in the range of 40 cm to 1 meter of the camera. These tests were conducted with fairly uniform lighting and were smoothly done and the mean recognition accuracy was approximately 94,53%.

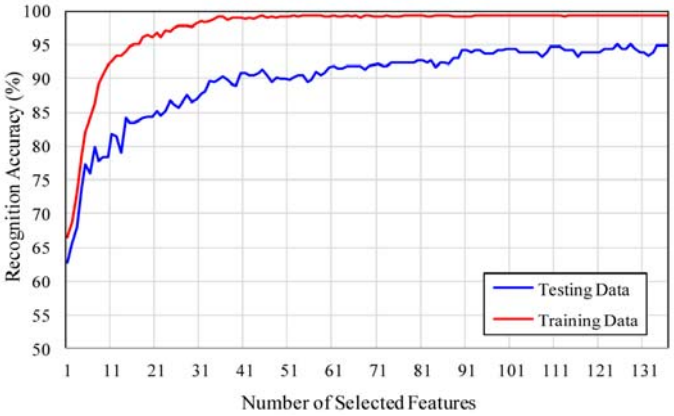

Figure 10. Analysis of recognition accuracy

The proposed algorithm operate friendly with the raspberry pi board and provides a better result.

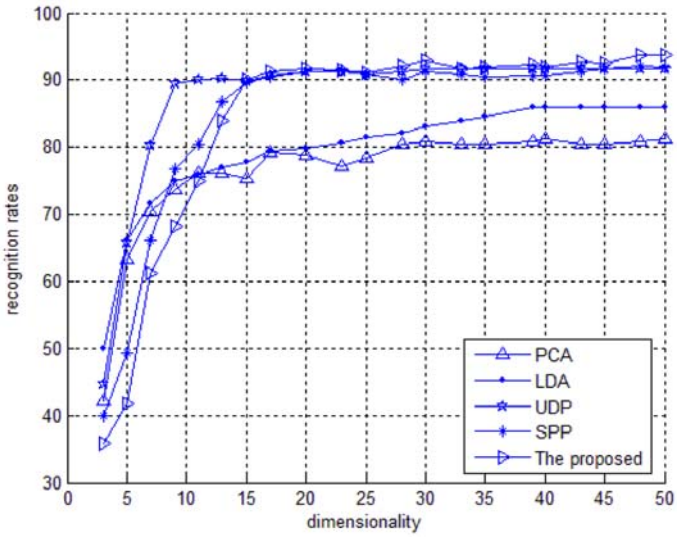

Figure 11. Evaluation of propsed algorithm with prior work

In order to evaluate the performance of face recognition in different lighting conditions we tested the algorithm with different filters under a broad range of variations in lighting shown in table 1. A database of 4 persons was generated with 6 images for each individual. One of these images was taken under standardized lighting normalization and used to train the recognition system. The remaining images were taken under various lighting conditions.

As a second Test, images were taken in the range of 30cm to 80cm distant from the camera, the computed result is described in table 2.

Table 1. Intra-facial distances for different lighting filters

Lighting filter	Intra-facial distance	time
None	0.130	0.154
L2 norm to unity	0.110	0.095
L2 norm to unity and mean to zero	0.101	0.075
Histogram equalization	0.104	0.124
Non-linear block processing	0.125	0.131
Sobell filter	0.120	0.178

Table 2. Intra and extra facial distances for different lighting filters

Extra/Intra-facial distance	Extra-facial distance	time
9.61	1.251	0.134
12.12	1.340	0.156
12.20	1.233	0.139
7.70	0.804	0.226
10.50	1.318	0.188
2.81	0.337	0.275

IV. CONCLUSION

This work is aimed to be a complete system for face recognition: easy to build, cheap cost and effective. Its utility is to be set as an alert for home visitors and provide information about the visitors in a dynamic website and phone application, could be used in other fields like industries, offices and even air-ports for identifying wanted people.

In this paper, face recognition system has been developed in order to study the potential application for home automation door security with real time response and better recognition rate. Among the other bio-metric techniques, face recognition approach offers one great advantage which is user friendliness.

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