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# Design and Implementation of IoT Based Class Attendance Monitoring System Using Computer Vision and Embedded Linux Platform

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**Abstract.** To provide reliable, time-saving and automatic class attendance system, the concept of Internet of Things (IoT) based class attendance monitoring system using embedded Linux platform is presented in this paper. The study is focused on the design and implementation of face detection and recognition system using Raspberry Pi. The system takes images of students, and analyzes, detects and recognizes faces using image processing algorithms, where the Haar cascade classifier algorithm is implemented to detect faces and local binary pattern histogram algorithm is used to recognize these faces. After collecting image processing data, the system generates a final attendance record and uploads it in a cloud server. The cloud server has been implemented using python based web framework. The record can be accessed remotely from a user-friendly, web application using the Internet. Finally, the system is also capable of sending an email notification with the final record to the teachers and students in a specific time. Tests and performance analysis were done to verify the efficiency of this system.

**Keywords:** IoT · Embedded Linux platform · Haar Cascade Classifier · Raspberry Pi · Class attendance

## 1 Introduction

The Automated Attendance System is the progress that has taken place in the field of automation replacing the attendance marking activity traditionally. The traditional method of attendance marking is very time consuming and becomes difficult when the strength is high. Automation of attendance system has boundary over the conventional approach as it saves time and also can be used for security purposes. This system also helps to prevent fake attendance. So automating the attendance process will increase the productivity of the class and make good attendance records.


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To overcome the disadvantages of the manual system, an automatic attendance recording system is implemented using Raspberry Pi, which is an embedded Linux platform. The system is applied on the credit card sized Raspberry Pi board which is connected to a camera for image capturing with the extended capability of open source Computer Vision (OpenCV) software which is used for image processing operation like face detection and recognition. We propose a method that takes the attendance using recognition of face based on the Internet of Things.

Internet of Things (IoT) enables us to develop a system without human interference and errors. In other words, IoT is an environment that can transfer data over a network without the human to human or human to computer interactions. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for direct integration between the physical world and computer-based system and it provides more efficiency, accuracy as well as economic benefits. Keeping the above statement in the forefront, the method includes a Cloud server that is implemented using Raspberry Pi. The server is used to store the final record of attendance which can be accessed using a web application. The system also includes an email notification feature for students and teachers. For developing the system, we have used Haar Cascade Classifier algorithm to detect faces and Local Binary Pattern Histogram (LBPH) algorithm to recognize these faces. All needed programs were written in Python. Thus, the development of IoT based class attendance system provides an easy way to keep track of student attendance data and monitor their progress and productivity automatically.

## 2 Related Work

In this section, we reviewed some related technologies, innovative and previous works on the topic of attendance monitoring system based application.

The most widely used location-based technologies are GPS, Radio Frequency Identification (RFID), Bluetooth and so on. Researchers work on these technologies for improving the services for its accuracy, reliability, and efficiency [1]. A lot of application exists in different ways to adequately monitor the attendance of every student. Usually, attendance management uses student ID for authentication. Many researchers [2] have designed and implemented an ID-based authentication system. This kind of system required improvement as IDs can be shared or tampered.

Other attendance monitoring techniques use face detection based student attendance system. Problem with face detection based systems is that individuals have to carry face detection which is not a cost-effective solution [3]. However, the improvement of the system has been discovered by M. Wong. By introducing palmprint which developed an attendance system to record employee attendance [4]. Meanwhile, a similar project has been implemented which applied wireless Iris recognition attendance management system. Biometric identification security is the primary concern as if one lost its biometric identification from the database then the user of the system has to face many challenges. Mohammad et al. have defined location based time and attendance system, that use location as the key of attendance [5]. The employees in an organization can be determined with the help of a GPS device if both

coordinates match then the employee is present in the organization. Which can be extended for different applications and on all mobile phones.

## 3 System Architecture

The architecture of our class attendance system based on the IoT is shown in Fig. 1.

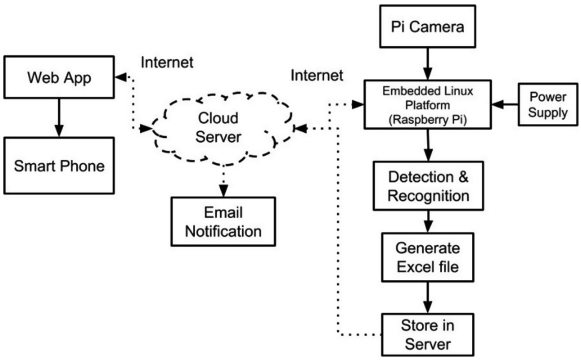


**Fig. 1.** The block diagram of proposed system.

The whole system is implemented on the embedded Linux platform using Raspberry Pi board. Raspberry Pi is used as core processor, complete final processing of images, data storage, real-time face detection and recognition and data server, after that the data will be present on the network eventually. The power supply is given to the Raspberry Pi which is the central part of the proposed system. The Pi camera is connected to the Raspberry Pi CSI port. The camera captures the images of the students who are present in the class. Raspberry Pi takes those images as input images and compares the input images with the existing image dataset. This process happens due to importing the open CV packages at the initial stage of the development of the system. After detection and recognition, the system generates an excel sheet containing student attendance result. All of these processes can be controlled by using a web application. The system collects Excel file and uploads the data into the cloud server which has been developed by flask web framework in Raspberry Pi. Real-time data visualization can be accessed and downloaded directly from the cloud server through the web application.

As a part of the Internet of Things, it requires network connectivity through WiFi which is connected with Raspberry Pi. The web application can be used by the internet and collect attendance result with minimum human intervention. The system is also capable of sending the result by email to respective teacher and student.

## 4 Proposed Approach

The proffered system management will use three step mechanisms: Dataset creation, training dataset, testing.

In dataset creation, the system Initialize the camera connected to Raspberry Pi, get image and user id as input. After converting the image into grayscale, it detects the face's images of the students in a specific class, who are present in the classroom and store it in the dataset.

In training dataset part it initializes LBPH face recognizer and gets faces and ID's from dataset folder to train the LBPH face recognizer. After training data, it is stored as XML or YML file. In testing part the system load Haar classifier, LBPH face recognizer and trained data from XML or YML file. Then capturing the image from a camera, it converts it into grayscale, detects and predict the face using the above recognizer. If the system recognizes a student's face, it will be reported or recorded as present and all those not in the class or not recognize will be absent.

Then, the system collects these attendance data and generate an Excel file and upload the file in the cloud server. Finally, it sends email to teachers and students containing attendance data from the process. The flow chart of the proposed approach is given in Fig. 2.

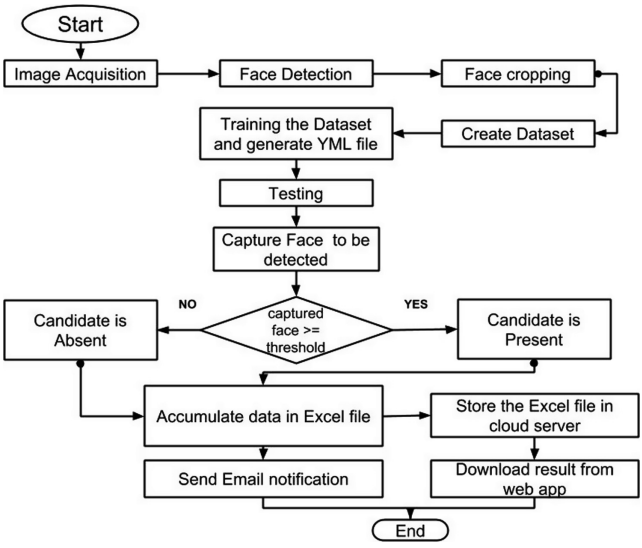


**Fig. 2.** Flow chart of the proposed approach.

The Raspberry Pi is the central part of the project. All the data and algorithm has been processed and programmed with python language in Raspberry Pi. The Pi camera has been used to capture photos. A cloud server has been developed by using the flask web framework of python. To access the class attendance system from smartphone or PC, a user-friendly web application has been developed using HTML and

Bootstrap. The main aim of this proffered management system: giving a vivid and accurate attendance record of the students, it prevents human intervention concerning the attendance record, mailing students and teachers using the easiest way of checking attendance of students in a specific classroom.

## 5 Hardware Requirements

### 5.1 Raspberry Pi 3 Model B

Raspberry Pi is an ARM-based single board computer. The Raspberry Pi 3 Model B is used in this paper, which is the third generation Raspberry Pi [6]. The operating system used for Raspberry Pi is Raspbian as it is open source. Raspbian is a Linux-based computer operating system. It has 40 pins in which 24 are GPIO pins and these pins are used for general purpose.

### 5.2 Pi Camera

Pi Camera is a custom designed add-on for Raspberry Pi. This interface uses the CSI interface designed especially for interfacing to cameras [7]. The sensor has 5 megapixels of resolution and has a fixed focus lens on board.

## 6 Software and Algorithm

### 6.1 OpenCV

OpenCV is a computer vision software library. The library has a lot of optimized algorithms, which can be used in many IoT related sectors including face detection and recognition. As the libraries of our project, we use the Haar classifier and LBPH face recognizer.

### 6.2 Haar Cascade Classifier Algorithm

A Haar Cascade is a classifier used to detect the object for which it has been trained from the source. The proposed system uses Haar Cascades classifier as a face detection algorithm [8]. Firstly, to train the Haar cascades classifier, the algorithm needs 300 positive images and negative images. Positive images are images with clear faces where negative images are those without any faces. Haar cascades are similar to the convolutional kernel which are shown below in Fig. 3(a).

From the difference of the sums of pixels in the white and black rectangle, each feature is represented as a single value obtained. For calculating of plenty of features, all different possible sizes and locations of the classifier are used. The arithmetic computations become time-consuming as the number of classifiers increases. Instead,

the concept of integral image has been used. The integral image is derived by using the following equation:

$$I_{\Sigma}(x,y) = \Sigma\, i(x',y')$$
$$x' \leq x$$
$$y' \leq y$$

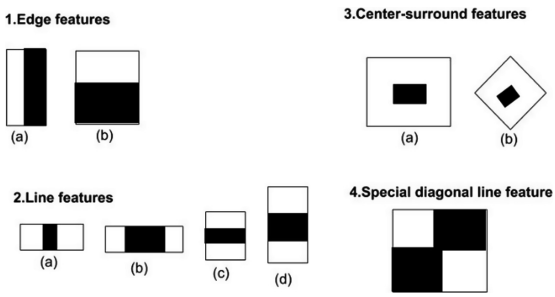


**Fig. 3.** Haar Cascades.

To avoid the complexity of calculation, we use the Adaboost machine learning algorithm, an OpenCV library to eliminate the classifiers redundancy. A weak classifier has the probability of 50% of detection. The Sum of weak classifier provides a strong classifier. Classification takes place in stages, if the selected region fails in the first stage, it will be discard. The classifiers will not be used on that region which is discarded. The region which passes all the stages i.e. all strong classifiers is treated as the detected face. Detected Faces are passed to the face recognition phase.

For face recognition, the Local Binary Patterns histogram algorithm (LBPH) has been used. This Local binary pattern subjects the detected integral image. Face recognition is much vulnerable to changes like facial expressions, brightness, and position. For reducing this problem face preprocessing technique is used. For face preprocessing, we use histogram equalization. For efficiency we use separate preprocessing which is histogram equalization for left and right face. So histogram equalization is done three times, firstly for the whole face and the other two for side faces [9]. Stages of the cascade classifier [10] are followed according to Fig. 4.

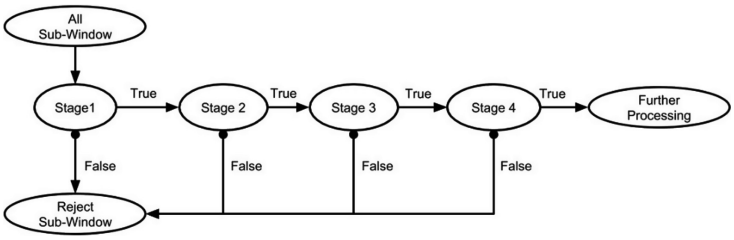


**Fig. 4.** Stages of the cascade classifier formula

### 6.3 Python

Python is a high-level programming language which is an open source working for a general purpose language. It can be embedded into any application and can run on all current operating systems. Overall Python is suitable as a development language for customizable applications.

### 6.4 Numpy

Numpy is a library for scientific computing in Python. It provides a high-performance multidimensional array object and matrices, and along with an extensive collection of tools to operate on these arrays. For converting images of our project into multidimensional or 2D-array representation, and conversions from grayscale to color images.

### 6.5 Flask Framework

Within the Python community, Flask is a very popular web framework [11]. It provides simplicity and flexibility by implementing a bare-minimum web server, and thus advertises as a micro-framework. Flask web applications is a simple solution for IoT based monitoring system. In this paper, it has been used to develop a cloud server in Raspberry Pi.

### 6.6 HTML and Bootstrap

HTML is a standard markup language used for creating web pages and web applications. In the system, it is used for displaying the final result on the web page. On the other hand, Bootstrap is a popular CSS framework for web development [12]. Bootstrap is used to make the web application responsive and user-friendly.

## 7 Experimental Result

The IoT based class attendance monitoring system using an embedded Linux platform functionally implemented, and results obtained successfully.

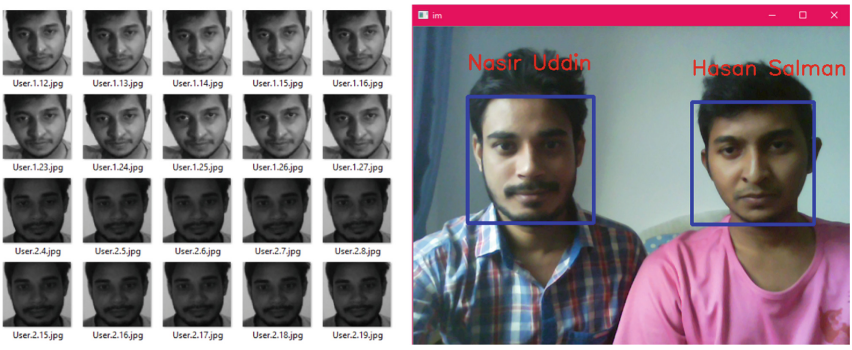


**Fig. 5.** Result of face detection (Data set) and face recognition (Right side).

**Table 1.** System accuracies

| Face count | Detection rate | Recognition rate |
|---|---|---|
| Single face | 98%+ | 96% |
| Multiple faces | 95%+ | (88–90)% |
| Group faces | 95%+ | (80–88)% |

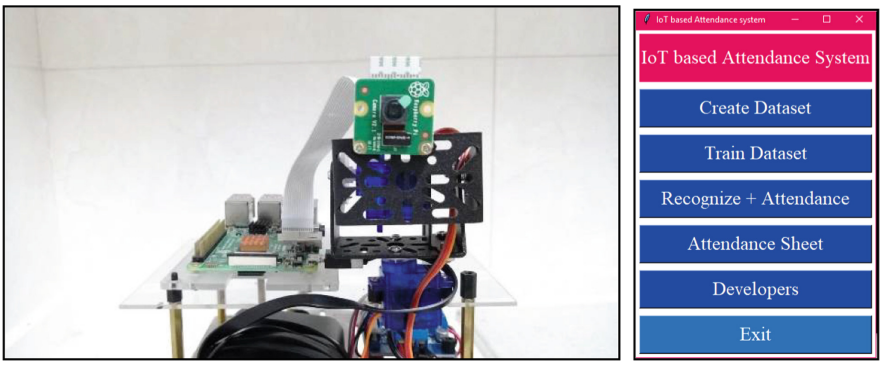


**Fig. 6.** Class attendance system based on IoT (Left side) and python application (Right side).

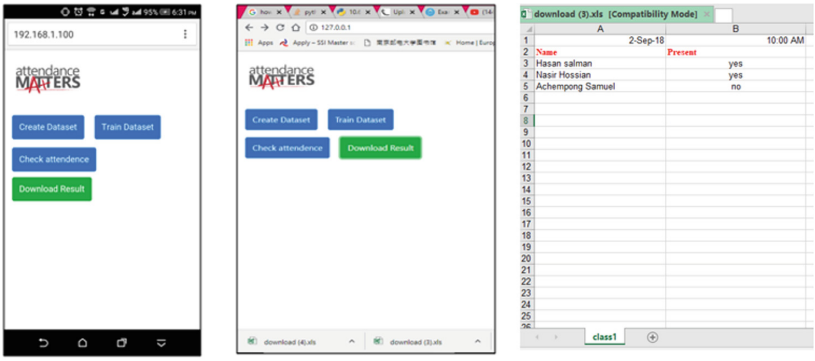


**Fig. 7.** Web application for user interface and result of attendance system.

Figure 5 shows the system create a dataset for face detection and recognition and the result of multiple face recognition. In Table 1, the system accuracies data are given. The data has been collected and verified among 30 students. Figure 6 shows completion of smart attendance system based on IoT and python application. Figure 7 shows the web application for user interface and result of attendance in excel sheet which can be downloaded from the application using Internet from smartphone or

computer. The user can register and check attendance for smart class attendance by clicking buttons of the web application. The system uses SMTP protocol for sending email to the students and teacher in a specific time. All of these features make the IoT based system efficient enough for taking attendance of any class. This approach is done so that in future as the number of students increases the system does not fails and can provide backup and remain accurate and reliable in the long run. Also, to use the most efficient algorithm for the system with the use of upcoming enhanced algorithms in future, the accuracy of the system can be enhanced.

## 8 Conclusion

IoT based class attendance monitoring system is a time-saving, reliable and useful technique for taking attendance instead of the manual technique. There are many systems which can be used for managing attendance, but the implementation of face detection and recognition system with the IoT and Raspberry Pi technology make the system economy. Since the proposed system gets integrated with the cloud server, it becomes system independent, fast, provides data storage and accessed quickly. The web application and email notification make the system user-friendly. In the future, we will improve the attendance record system according to the following:

(1) There will be an automatic printing of student's attendance record for the teaching staff.
(2) To monitor students during an examination.
(3) To trace a particular student in an organization quickly with the help of this system and can be utilized for several security applications where authentication is required to access the privileges of the respective system.

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