Project report submitted in partial fulfillment for the Degree of B. Tech in Applied Electronics & Instrumentation Engineering under Maulana Abul Kalam Azad University of Technology

TITLE OF THE PROJECT:

Home Security System using Raspberry Pi

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CERTIFICATE OF APPROVAL

The project report titled "Home Security System Using Raspberry pi" prepared by **Sangbit Chakraborty**(11705515038),**Satwik Poddar**(11705515040),**Ankur Roy**(11705515005) and **Soumya Dhali**(11705515043) is hereby approved and certified as a creditable study in technological subjects performed in a way sufficient for its acceptance for partial fulfilment of the degree for which it is submitted.

It is to be understood that by this approval, the undersigned do not, necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the project only for the purpose for which it is submitted.

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RECOMMENDATION

We hereby recommend that the project report titled "Home Security System Using Raspberry pi**"** prepared by **Sangbit Chakraborty**(11705515038),**Satwik Poddar**(11705515040),**Ankur Roy**(11705515040) and **Soumya Dhali**(11705515043) be accepted in partial fulfillment of the requirement for the Degree of Bachelor of Technology in Applied Electronics & Instrumentation Engineering, RCC Institute of Information Technology.

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ABSTRACT

With the advancement of modern technologies areas related to robotics and computer vision, real time image processing has become a major technology under consideration. So here a try has been made for a novel approach for capturing images from the Pi Camera in real time environment and process them as we are required. This project portrays an machine learning approach for face recognization to accomplish this process very quick with high identification rates using OpenCV. Here in this project depicts a basic and simple equipment execution of face location framework utilizing Raspberry Pi, which itself is a minicomputer of a small estimate and is of a low cost. The framework is modified utilizing Python programming language. The destinations of the face recognization are to recognize appearances and its spatial area in any pictures or recordings .The proposed framework distinguishes the faces present in a grey scale and colored image. This project center around usage of face detection framework for human recognizable proof in light of OpenCV library with python. Here in this project the idea of identification has been built up by composing distinguishable code for dataset generator, trainer and indicator. Effectiveness of the framework is examined by ascertaining the Face recognization rate for every one of the database. The outcomes uncover that the proposed framework can be utilized for face detection even from low quality pictures and shows incredible execution level. At last the data that will be shown alongside recognized photograph has been put away on database. This concept has a higher scope on security and surveillance projects and various operation.

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INTRODUCTION

Home automation alludes to the use of computer applications and information technology for control of home and residential appliances. Its application changes from basic remote control of lighting to complex microcontroller based systems including changing degrees of insight and automation. Home automation results in ease of work, increased efficiency, and security benefits prompting improved personal satisfaction. The prevalence of system empowered home automation has been expanding incredibly as of late because of straightforwardness and a lot higher affordability. Also, with the fast development of the Internet, there is the potential for the remote control and checking of such network enabled appliances. Notwithstanding, the new and energizing chances to expand the availability of gadgets inside the home is the end goal of home automation. Modeling of a home automation system for controlling all the various devices in

Remote locations can be achieved through a variety of communication options such as wireless LAN technologies, dial-up modems, satellite communication, cellular network, Internet and so on. The main virtue of home automation can be stated as its security facilities where one can be notified and one can be alarmed by this home automation if there is any threat caused to someone's privacy. Home automation enables human beings to take advantage of high-tech functionality that was almost impossible to visualize a few years back. The convenience factor here is huge. Having the capacity to keep the majority of the automation inside home associated through one interface is a huge step forward towards innovation and home automation. Theoretically, all one has to do is simply figure out how to utilize one application on a cell phone and tablet, and one will have the capacity to take advantage of incalculable capacities and gadgets all through the home. This reduces the expectation to absorb information for new clients, makes it simpler to get to the usefulness someone really need for their home. Smart home systems tend to be wonderfully flexible when it comes to the accommodation of new devices and appliances and other technology. No matter how state-of-the-art your appliances seem today, there will be newer, more impressive models developed as time goes on. Beyond that, you'll probably add to the suite of devices as it will replace the older ones or discover new technology to accompany indoor and outdoor spaces. Being able to integrate these newcomers seamlessly will make everyones job as a homeowner much easier, and allows to keep upgrading to the latest lifestyle technology. Home automation frameworks can associate motion detectors, surveillance cameras, automated entryway locks, and other substantial safety efforts all through the home so

one can enact them from one cell phone before making a beeline for bed. It will provide security cautions on different gadgets relying upon the time of day an alarm goes off, and watch activities continuously whether someone is in the house or most of the way around the world. A very important part of this security virtue of home automation is keeping surveillance through cameras and survilliance on the entryway automated and which can be only open by certain identities which are granted permission to enter. For this doing face recognization where if the face is recognized then the door will open otherwise not. In this proposed scheme face recognization which generally involves two stages which are face detection and then face recognization is done. Face Detection where the picture is searched to feed a face, then the picture is processed to crop and extract the person's face for easier recognization. Face Recognization is the part where that detected and processed face is compared to a database of known faces, to decide who that person is. Here face detection is performed on Intel's open source framework called OpenCV. OpenCV (Open Source Computer Vision) is a library that can be imported in almost all computer languages like python, C, Java etc. python. Raspberry pi-cam has been used to capture the picture of the faces that we are going to store in the database. Here in this proposed scheme one will basically go through three stages which are face detection, data gathering(where we will click picture of the faces of the respective identities) and the final stage is going to be the face recognization part which will match the live faces with the pictures of the faces in the database and give us the identification details of the given entity and work further for extra requirements. If the matching index is 50% or more then only it can be said that it is a successful facial recognization process. OpenCV has got lot of algorithms but in this particular project. Here Haar-Cascade algorithm Haar Cascade Algorithm has been used mainly. This whole setup is done on the operating system of Raspberry Pi which is known as Raspbian. Python has been used here as the platform to perform the functions and keeping OpenCV the main domain. Finally home automation can be summed up as the most convenient form of modern day technology. Home automation is actually a mixture of a lot of virtues coming together like safety, control, comfort, convinience and most importantly peace of mind. This form is a very flexible form of technology which is growing in the market very rapidly and is on the upsurge for being a game changer in the field of modern day automation.

CHAPTER 2: LITERATURE REVIEW

2.1 EARLIER DEVELOPMENTS:

The idea of home automation has been revolving around for around for some time. It's very recent that actual smart homes have come into existence. Keeping in mind the advantages related to home automation research and development projects already started from a long time back but due to the absence of standard networking of the home appliances nobody could move forward with this concept. The major roadblock was removed in 1992 with the development of the consumer electronic bus by Electronics Industries Association of America. The CEBus standard includes specification for a layered network architecture based on open system interconnection model with network layer protocols for the physical, Data Link, Network layer and application layer [1]. A proposed scheme by Cross & Douligeris states that fiber optics might be the best medium for home automation network because with fiber, the limitations of the home automation system can be reduced and capabilities can be increased to include many more functions, leading to complete home integration. They observed that although CEBus includes fiber optics as one of the physical media but it is not specifying the configuration of the fiber optic network. After that they designed a fiber optics network which offered various advantages such as (i) increased bandwidth, (ii) immunity to electromagnetic noise, (iii) ease of installation, and (iv) safety from electric shock hazards. There were a few drawbacks as well that the cost was high and as fiber optics cannot carry direct current they had to use an alternate source of energy [2-3]. In early 1990s, the consumer electronics devices was evolving into digital format, henceforth the need was felt to interconnect these home appliances through digital links to preserve the fidelity of information transmitted. Chen proposed a home automation network which will serve the above purpose. Other than the digital link main feature of the proposed home automation network was the Digital access system which due to which the home automation network could communicate and with the outside world also. Chen researched the use of IEEE 1394 for the proposed network as it could handle both data and isochronous traffic well at a data rate above 100 Mbps [4]. Fujieda sensed for thriving and achieving complete marketability. Home networks should be installed easily which will require network buildup without extra wiring. Therefore he proposed the scheme for wireless media in home networks and named it as wireless home networks. Fujieda suggested the use of 400MHz special low

power band for wireless home networks. He developed a small and low power microwave oven, air conditioner and washing machines, Bluetooth access point and home terminal in a home. All appliances had the Bluetooth unit embedded within them and wee connected to internet [5]. In 2005 Hayong Oh and others, mentioned the importance of energy efficiency for the routing scheme of the sensors placed at home. In the upcoming automated home, sensors are required to be placed everywhere in the house which will collect various physical data such as temperature, humidity, and light to provide information to various appliances. The authors discussed that in the conventional sensor routing scheme every sensor node detects an event and then broadcasts the event to all sensor nodes within one hop range from where all the nodes broadcast the message to the next nodes. This process is repeated until the event reaches the base station. This scheme generally cause drainage of battery power and the batteries have got limited power so the routing scheme needs to efficient enough for successful implementation of home networking. Henceforth they advised a new sensor routing scheme for home automation networks and called it as RDSR (Relative Direction based Sensor Routing). This scheme divides the home area into sectors and locates a manager node to each sector. The sensor devices transfer the data to manager nodes in its sector and then the data is transferred to the base station through the shortest path of two dimensional coordinates resulting in an energy efficient scheme [6]. In 2006 Mario Kolberg and Evan H.Magill mentioned the control of complex networked appliances. Presently computer interface is most used to configure and remotely control these appliances. However the authors discussed that this will be unsuitable for the target audience who are not that much familiar with the use of computers. Therefore they proposed Anoto-enabled pen and paper as a suitable alternative as users are highly familiar with pen and paper and they will find it suitable for control. In the suggested system data is transferred to the service provider through Bluetooth communication and mobile processed and sent to the user's home. Using this approach appliance can be controlled in the home and outside the home [7].

2.2 RECENT DEVELOPMENTS:

In recent years the Internet of Things (IOT) have enabled innovation to make daily lives easier and comfortable. From refrigerators, to apparatuses, to home security and many others can be controlled with smart home innovation. When home devices are remotely controlled from anywhere irrespective of anything through internet it becomes a important virtue of the IoT

(Internet of Things). Security and living greener are the main features of the present homes. Current patterns in home automation includes remotely controlled appliances and computerized gadgets, portable/email/content warnings, and remote video observation Sensors are the most important part of this home automation system as it acts as the eyes of the system. There are sensors for an extensive variety of uses, for example, measuring temperature, dampness, light, fluid, and gas and recognizing development or commotion. In case of Java Based Home Automation System the World Wide Web is used by the home appliances to control and monitor then the software engine is written in Java code that can be portable and also can be used on any platform. The embedded system board is connected to the pc home server and serves the java pages and java beans [8]. In case of the Integrated Residential Gateway Controller for Home Energy Management System, high performance is derived from compact OS and to reduce the memory space than the three steps plug & player mechanism is used for reducing installation engineering [9]. In case of the Remote Controller for Home and Office Appliances by Telephone, the home based design and the development of the phone based remote controller for the home and office automation, in this advanced technique the remote controller is used for time and energy consuming [10]. The verification of the proposed algorithm, several LED's were used to indicate the proper execution. The Rpi has received an email through the user from a system connected to the internet. Gmail has been used in order to conduct mail communication. The corresponding results were generated by a series of e-mail communication. For example an E-mail sent as "ON=1 ON Time=7:00. OFF Time=8:00 to the RPi account from the user account. The algorithm that is used starts its process by scanning the mail [11]. According to R.A. Ramlee, smart home system via Wireless Bluetooth is the is the new virtue of this automated technologies where it is acting as a motivation for disable persons making it possible for them to carry out the daily activity, safely and comfortably [12]. Girish Birajdar and Shrikant Mahindrakar have developed a way in to automate home appliances using an Embedded Web Server combined with a Raspberry Pi. Embedded Web Server (EWS). is the embedded system which can serve the web documents on request from the client. It generally deals with management of dynamic content and is very easy to use and operates at a fast speed. EWS design includes a complete web server with TCP/IP support, running different OS, memory, application wise [13].

Android based home automation makes the system more flexible and provides attractive user interface compared to other home automation systems. In this system mobile devices are integrated into home automation systems. A novel architecture for a home automation system is proposed using the relatively new communication technologies. The system consists of mainly three components is a Wi-Fi module, raspberry pi board and relay circuits. Wi-Fi is used as the communication channel between android phone and the raspberry pi board [14].

2.3 FACE RECOGNIZATION:

Face detection is one of the current research topics in the computer vision field. It is very easy for human beings to detect faces on the other hand it is difficult for computers to detect faces.. The difficulties associated with face detection are variations in scale, pose, orientation, lighting condition, facial expression etc. Many approaches have been implemented but each has its own advantages and limitations. The proposed system is relay on the appearance based approach. Here the face detection is done by extracting facial features like eye feature, bridge of the nose feature, mouth feature etc. which are present in a grey scale image. These features are proportional to the change in contrast values between adjacent groups of pixels but not to the intensity values of a pixel. The features used in this system are named as rectangular features and are reminiscent of Haar basis functions [15] [16]. The suggested face detection system detects the faces with low false positive rate. Initially the face detection is done with 10 and 12 stage detector but it gives poor detection accuracy and high false positive rate. The 14 stage detector gives good accuracy in face detection and very low false positive rates. The detector works well on Raspberry Pi with a 5MP camera and detects the faces of captured image with the lowest resolution of 640x480 and the highest resolution of 2560x1920pixels with acceptable detection speed [17]. Patel and shah introduced a research on facial feature extraction techniques for automatic face annotation. A vital role is being played by automatic face annotation role in multimedia information. The method to identify human faces from image and assign appropriate human name is known as automatic face annotation. In face annotation face detection and face recognition are the two most important virtues. An author also discuss the phases of the automatic face annotation and surveyed various techniques of facial feature extraction [18]. Patoliya and Desai developed ATM Security System using Embedded Linux Platform which is being based on the face detection system. Raspberry pi is being used for the implementation of

this system with the extended capabilities of Computer Vision (OpenCV) software which is used for Image processing operation. One tine password technique is used in this system which increases the security of the system. In an unauthorized condition ATM door has been locked and it's only when the OTP password is entered my watchman [19]. Heshmat et al. introduced Face Identification system in Video. An author proposed CIE-Luv color space, facial feature extraction and variance estimation. In surveillance, human machine interfacing, Database management system can be implemented and is of great use as it is creating a proper visual interface here. The experimental results shows the efficiency and the usefulness of the system where the system can recognize different faces and work accordingly and this one is highly advantageous due to it high security advantages [20]. Intensive research work and detailed study on implementation of smart door lock system using GSM network by Jie-Ci Yang [21]. Pi Camera Module is a add on with Raspberry Pi which acts as a visual interface in case of face detection or Recognization, This interface uses the dedicated CSI interface, which was designed especially for interfacing to cameras [22]. An algorithm known as Haar Cascade classifier is used for detection of the object which it has been trained for, from the source. This proposed system uses Haar Cascades classifier as a face detection algorithm [23]. Face preprocessing is the module which lessens the issues that makes the image vague to perceive the face. for example, less brightness and complexity issues and noise in the picture and ensure the facial highlights dependably be in a consistent position. In this task we use histogram leveling for face preprocessing. For proficiency we utilize separate preprocessing which is histogram evening out for left and right face. So histogram leveling is completed multiple times, right off the bat for the entire face and the other two for side appearances [24]. For better working, each stage of the cascade must have a low false negative rate, because if the actual object is classified as a non-object, then the classification of that branch stops, with no way to correct the mistake made. However, each stage can have a relatively high false positive rate, because even if the n-th stage classifies the non-object as actually being the object, then this mistake can be fixed in n+1-the and subsequent stages of the classifier[25-26]. The purpose or objective of the suggested work is to implement a working model of a smart door and to give solutions to the problem faced by people in day to day incidents of burglary or losing the key and also to promote and ignite the work being done on IOT systems and implementing it with the help of key research areas of Neural Networks and IoT APIs and protocols[27].

After the detailed study of the previous works, here in this proposed scheme developing a home automation system using a Raspberry Pi with which one will be able to control home appliances and the most important virtue of this project will be the home surveillance where the face recognization technology which will be used as a part of security in this project. The main platform which is being used is OpenCV which is a open source computer vision library a part of python and will be used in Python.

CHAPTER 3: OVERVIEW OF THE PROJECT

3.1 BLOCK DIAGRAM:

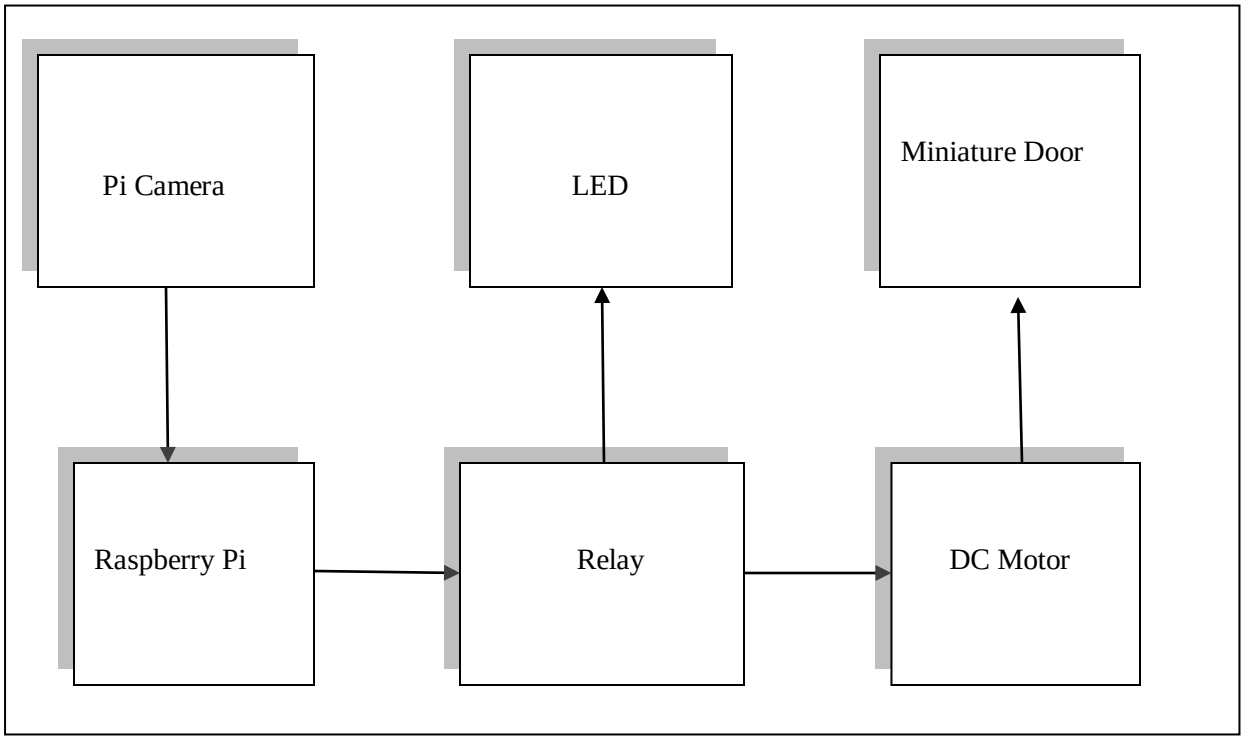


Figure 1: Block Diagram

3.2 HARDWARE REQUIREMENTS:

- **RASPBERRY Pi**
- **RASPBERRY Pi CAMERA**
- **4 CHANNEL 2 SLOT RELAY**
- **DC MOTOR**
- **LED**
- **BREADBOARD**
- **CONNECTING WIRES**
- **MINIATURE DOOR**

3.3 CIRCUIT DIAGRAM:

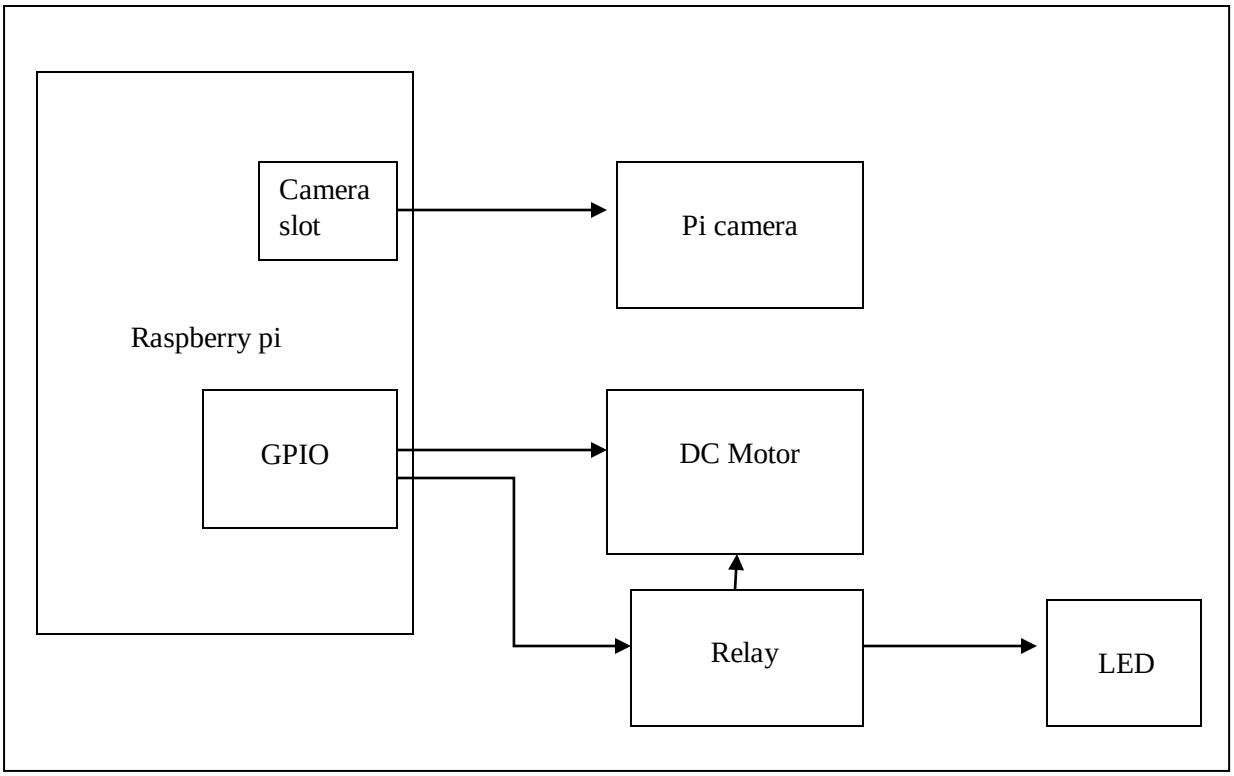


Figure 2: Circuit diagram

Here one can see that the Pi camera is attached to the camera slot and the DC motor and Relay is attached to the GPIO pins of the Raspberry Pi. As it is a two channel relay so it is connected to the LED and the DC motor which helps in driving the DC motor.Here the DC motor drives a miniature door which is being used for a door locking system for surveillance purposes. The door only opens after a successful recognization process, when the face is stored previously in the database and that image has got the access to open the door then it will work otherwise it won't open.

CHAPTER 4: COMPONENT DESCRIPTION

4.1 RASPBERRY Pi:

Figure3:Raspberry Pi

In the above figure no.3 the Raspberry Pi is a low priced, small sized computer that plugs into a computer monitor or TV, and uses a normal peripherals like keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. The Raspberry Pi was first launched in 2012, and there have been a few changes and variations performed from that point forward. The first Pi had a single core 700MHz CPU and simply 256MB RAM, and the most recent model has a quad-core 1.4GHz CPU with 1GB RAM.All over the world, individuals use Raspberry Pi to get the skills of programming abilities, , do home automation, and even use them in modern applications.The Raspberry Pi works in the open source environment: it runs Linux (diverse distribution), and its principle supported working system, Raspbian, is open source and runs a suite of open source programming. The Raspberry Pi Foundation adds to the Linux part and

different other open source extends just as releasing its very own lot programming as open source.

Here Raspberry pi is being used as a main controller to derive other features like face recognization and detection which we are doing in our project.

Figure 4: Pin diagram Raspberry Pi

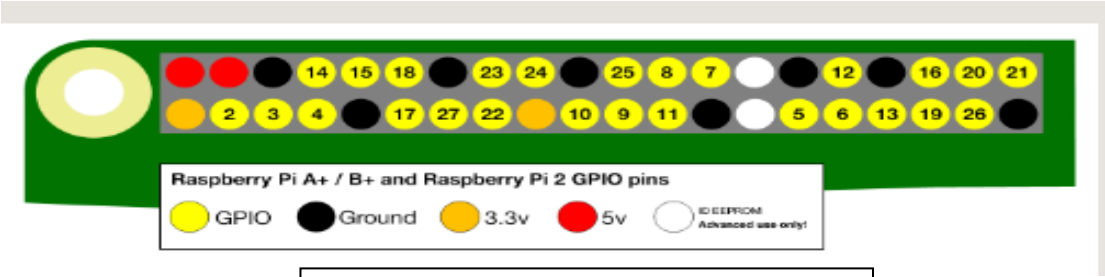


Figure 5: Pin Diagram of Raspberry Pi(2)

A powerful feature of the Raspberry Pi is the row of GPIO (general-purpose input/output) pins along the top edge of the board. A 40-pin GPIO header is found on all current Raspberry Pi boards.

Voltages:

Two 5V pins and two 3V3 pins are present on the board, as well as a number of ground pins (0V), which are unconfigurable. The remaining pins are all general purpose 3V3 pins, meaning outputs are set to 3V3 and inputs are 3V3-tolerant.

Outputs:

A GPIO pin designated as an output pin can be set to high (3V3) or low (0V).

Inputs:

A GPIO pin designated as an input pin can be read as high (3V3) or low (0V). This is made easier with the use of internal pull-up or pull-down resistors. Pins GPIO2 and GPIO3 have fixed pull-up resistors, but for other pins this can be configured in software. The GPIO pins can be used for other functions also. Some are available on all pins and others on some specific pins.

PWM (pulse-width modulation)

-Software PWM available on all pins

-Hardware PWM available on GPIO12, GPIO13, GPIO18, GPIO19

SPI

-SPI0: MOSI (GPIO10); MISO (GPIO9); SCLK (GPIO11); CE0 (GPIO8), CE1 (GPIO7)

-SPI1: MOSI (GPIO20); MISO (GPIO19); SCLK (GPIO21); CE0 (GPIO18); CE1 (GPIO17);

I2C

-Data: (GPIO2); Clock (GPIO3)

-EEPROM Data: (GPIO0); EEPROM Clock (GPIO)

Serial

-TX (GPIO14); RX (GPIO15)

4.2 RASPBERRY Pi CAMERA:

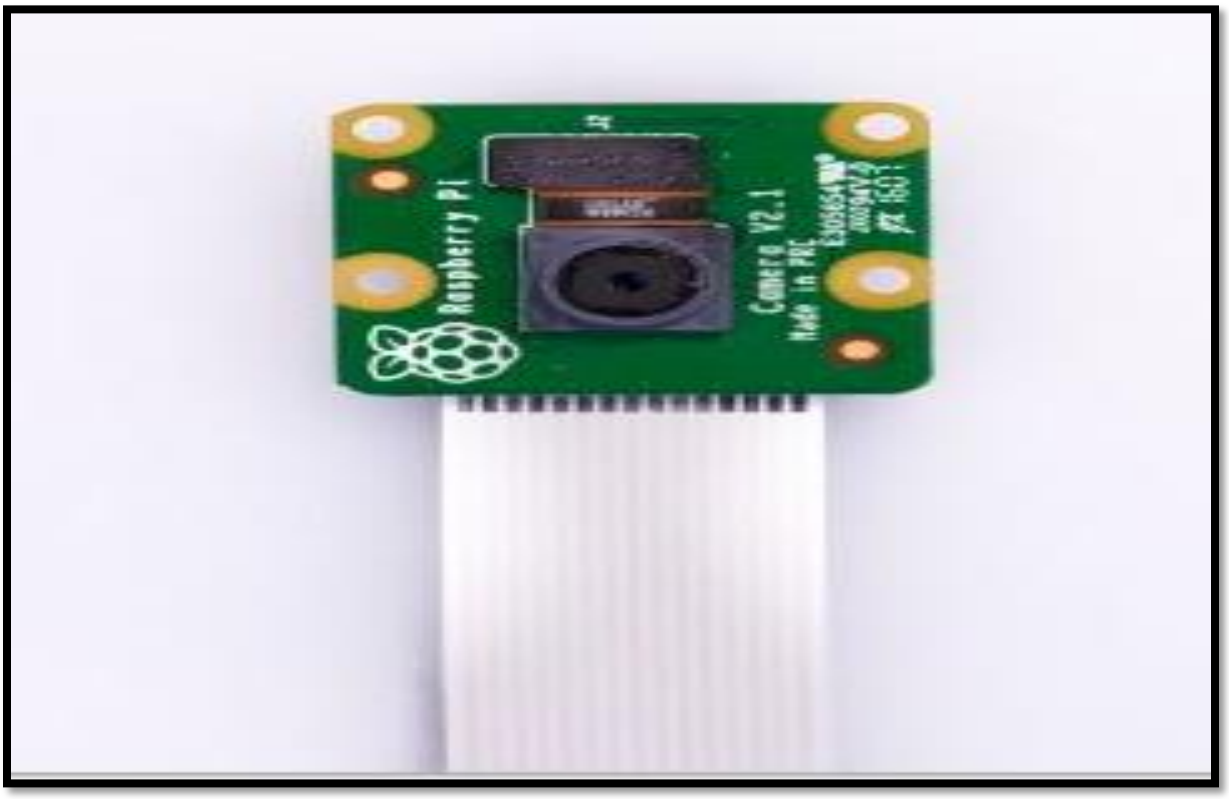


Figure 6: Raspberry Pi Camera

The Pi camera comes with a flex cable. The flex cable is inserted into the connector which is located between the Ethernet and HDMI port with the silver connectors facing the HDMI port. The flex cable connector is opened by pulling the tabs on the top of the connector upwards then towards the Ethernet port. The flex cable then is inserted firmly into the connector. The top part of the connector then is pushed towards the HDMI connector and down, while the flex cable is held in place. Here the Pi camera is being utilized for the face detection and the face recognization process where firstly are captured and stored it in the database using python and then again using the camera while the automation and the surveillance part.

4.3 TWO CHANNEL RELAY:

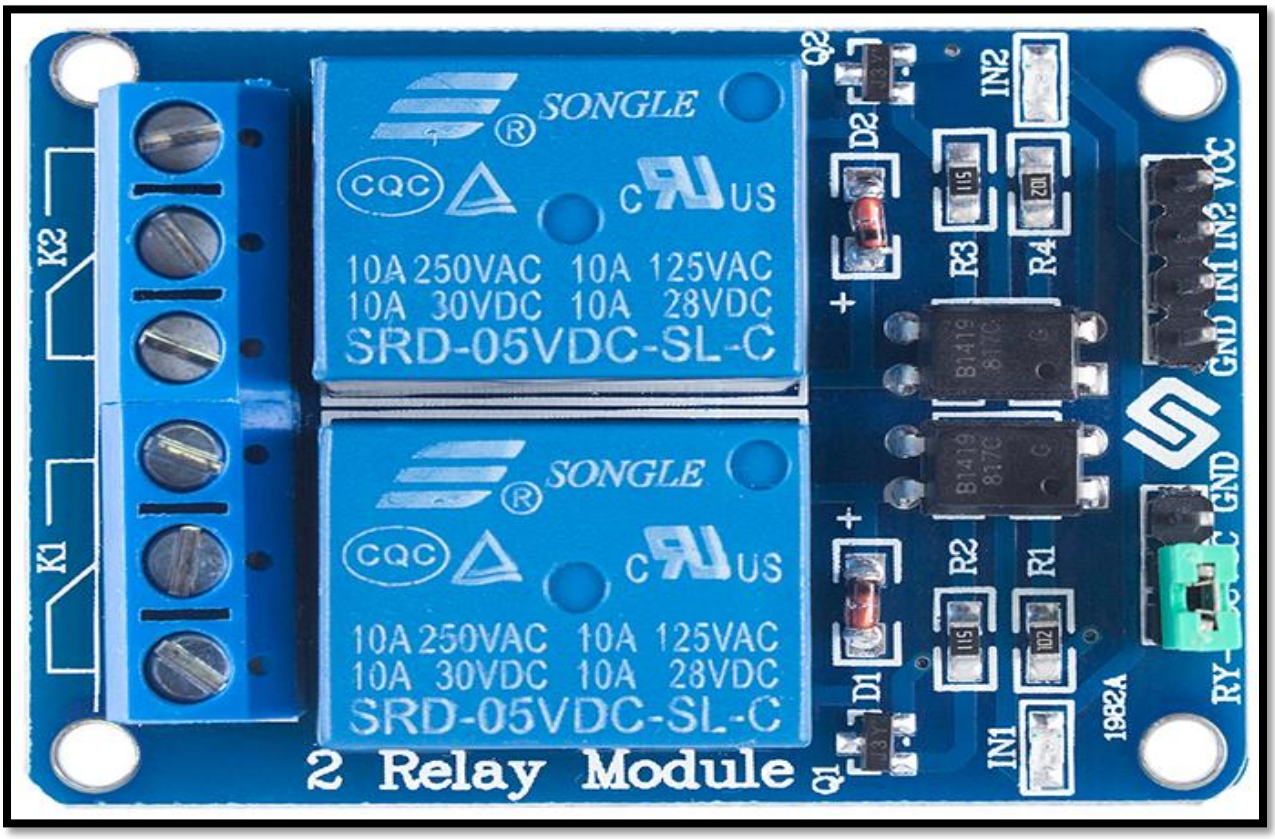


Figure 7: 2 channel Relay

This is a LOW Level 5V 2-channel relay interface board, and each channel needs a 15-20mA driver current. It is used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller. Relay is being used here as a driver circuit to drive other appliances through the relay.

FEATURES:

- Relay maximum output: DC 30V/10A, AC 250V/10A.
- 2 Channel Relay Module with Optocoupler LOW Level Trigger expansion board, which is perfect with arduino.

- Standard interface that can be controlled straightforwardly by microcontroller (8051, AVR, *PIC, DSP, ARM, ARM, MSP430, TTL rationale)

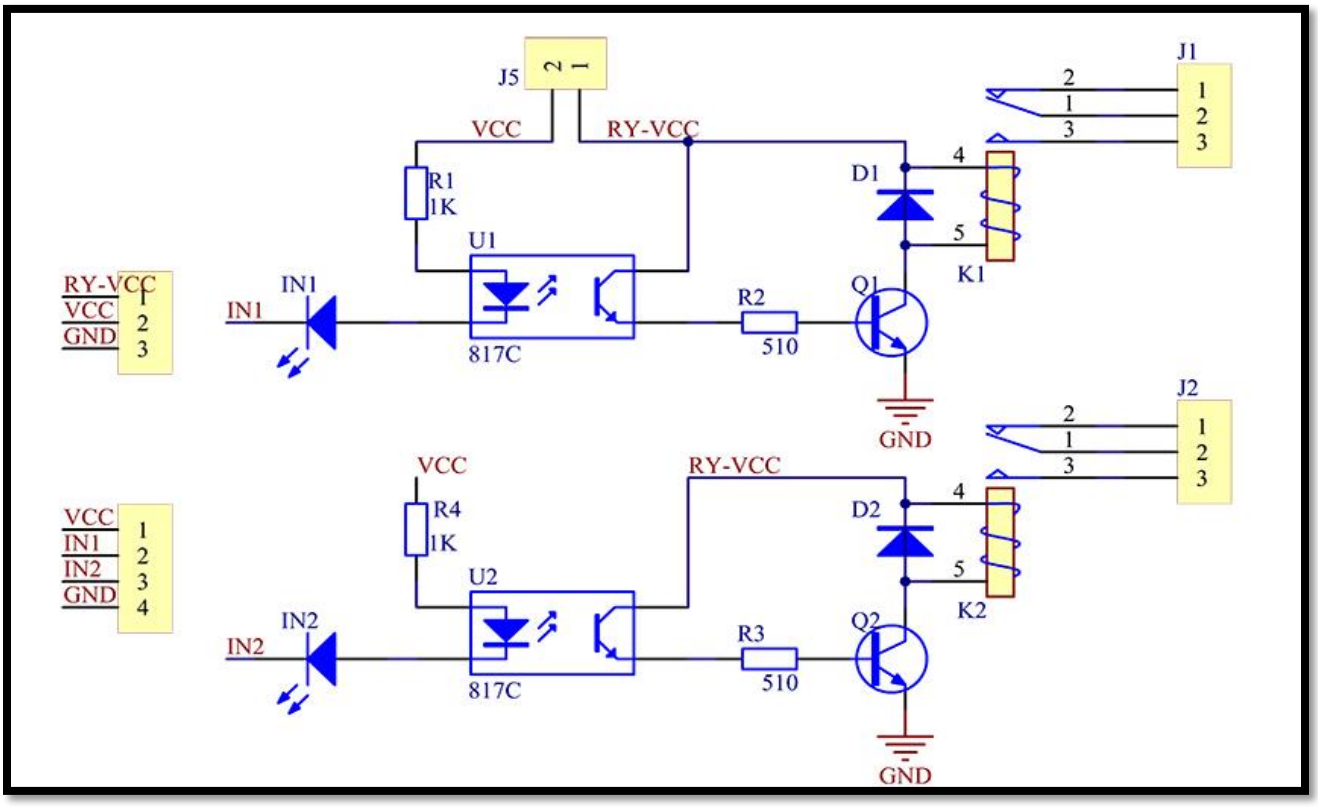


Figure 8: Schematic diagram of 2 channel Relay

INPUT:

- VCC: Connected to positive supply voltage
- GND: Connected to negative supply voltage
- IN1: Signal triggering terminal 1 of relay module
- IN2: Signal triggering terminal 2 of relay module

OUTPUT:

- There is one NC(Normal-close), NO(Normal-open) and COM(common) in each sub-modular of the relay so there are 2NC,2NO and 2COM.

4.3.1 RASBERRY Pi with TWO CHANNEL RELAY:

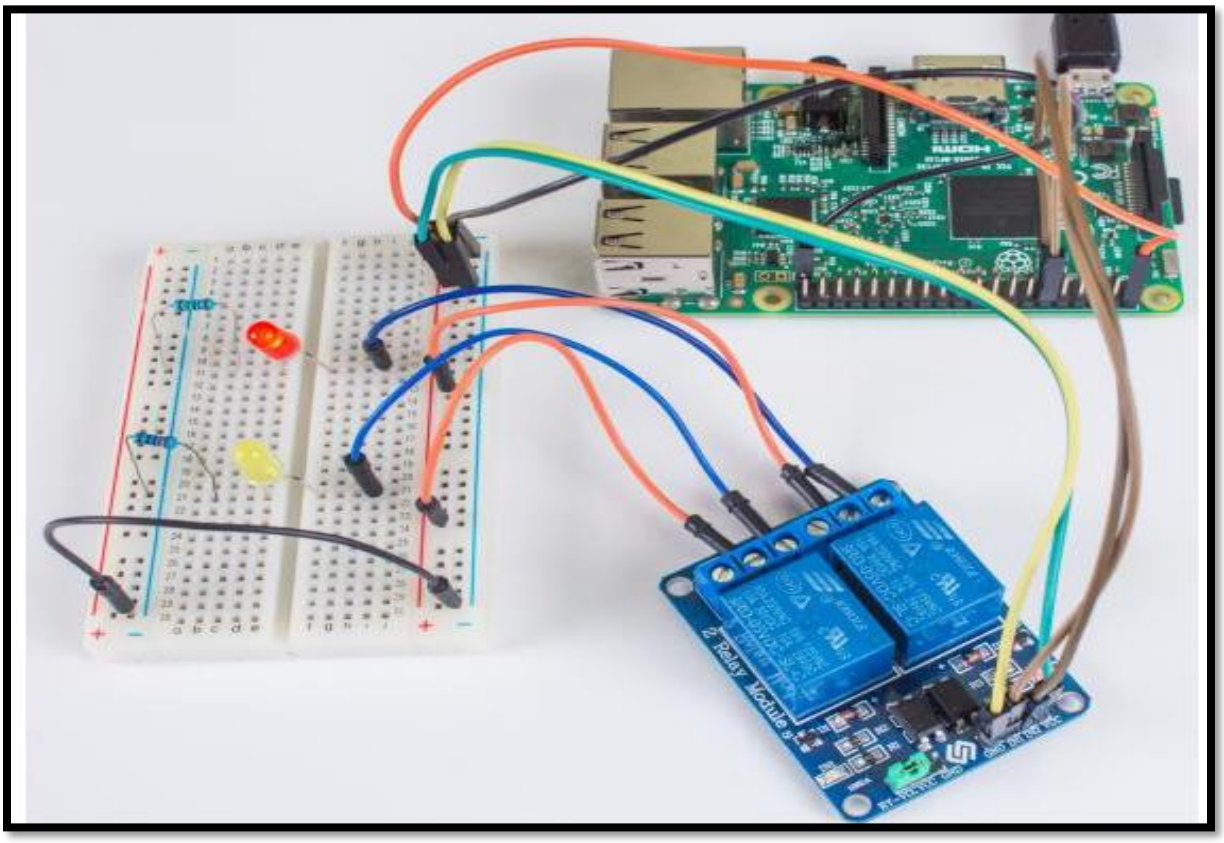


Figure 9: 2 channel Relay with Raspberry Pi

- Connect the signal terminal IN2、IN1 of 2-channel relay to port 17、18 of the Raspberry Pi, and connect an LED at the output terminal.

  2-channel relay----------Raspberry Pi

  IN2----------17

  IN1----------18

4.4 DC MOTOR:

Figure 10: DC Motor

A DC motor is a class of rotary electrical equipment which converts direct current electrical energy into mechanical energy. The most common types depend on the forces produced by magnetic fields. Almost all types of DC motors have some internal mechanism, either electromechanical or electronic, which periodically changes the direction of current flow in part of the motor. A coil of wire with a current running through it generates an electromagnetic field aligned with the center of the coil. One can change the direction and the magnitude of the magnetic field by changing the direction and magnitude of the current flowing through it. In this proposed scheme the DC motor is connected to the relay and drives the miniature door after successful recognization process.

4.5 LED(Light Emitting Diode):

Figure 11: LED (Light Emitting Diode)

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. Here the light emitting diode is used just post face recognization where it will indicate whether the face is recognized. If the face is recognized the LED (Light Emitting Diode) will glow otherwise it will not glow which will in turn unlock the door.

METHODOLOGY

5.1 Installing Raspbian on the Raspberry Pi:

Installing Raspbian on the Raspberry Pi is really clear. Raspbian will be downloaded and writing the disc image to a micro SD card, at that point booting the Raspberry Pi to that microSD card. For this undertaking, one needs a microSD card (with no less than 8 GB), a PC with a space for it, and, obviously, a Raspberry Pi and fundamental peripherals (a mouse, console, screen, and power source). This isn't the main strategy for introducing Raspbian (more on that in a minute), yet it's a valuable method to learn on the grounds that it can likewise be utilized to introduce such a significant number of other working projects on the Raspberry Pi. When one realizes how to compose a circle picture to a microSD card, we open up a great deal of alternatives for Raspberry Pi projects.

Step1: Download the Raspbian

Turn on the PC and download the Raspbian disc image. One can locate the most recent variant of Raspbian on the Raspberry Pi Foundation's site here. It will take some time, particularly in the event when one intends to utilize the conventional download alternative as opposed to the other download sources. It can without much take a stretch of half hour or more to download.

Step2: Unzip the file

The Raspbian disc image is compressed, so it should be unzipped. The file uses the ZIP64 format, so depending on how current built-in utilities are, one needs to use certain programs to unzip it. Linux users will use the appropriately named Unzip.

Step3: Write the disc image to microSD card

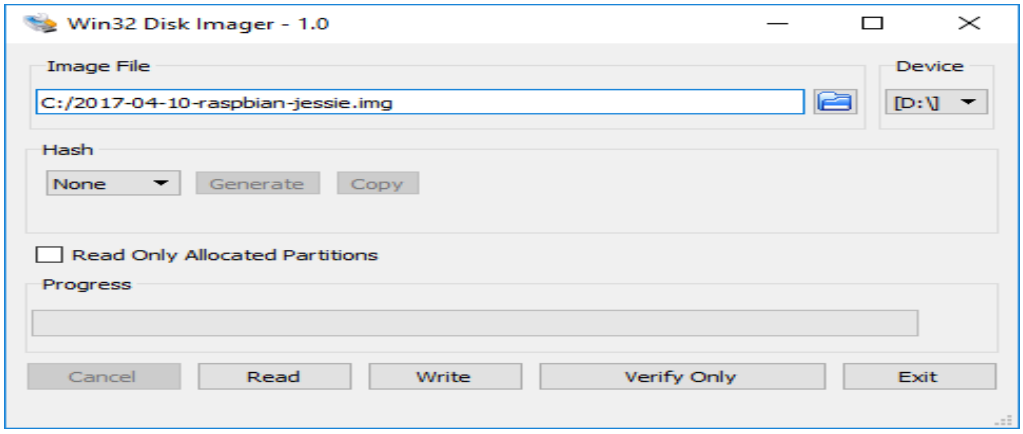


Figure 12: Installing Raspbian on Raspberry Pi

One has to pop the microSD card into our computer and write the disc image to it. The process of actually writing the image will be slightly different across these programs, but it's pretty self-explanatory no matter what is being used. Each of these programs will have us select the destination and the disc image (the unzipped Raspbian file). Choose, double-check, and then button to write.

Step 4: Put the microSD card in your Pi and boot up

When the disc image has been kept in touch with the microSD card, it is prepared to go. Put that microSD into your Raspberry Pi, plug in the peripherals and power source. The present release to Raspbian will boot straightforwardly to the desktop. Our default credentials are username pi and password raspberry.

5.2 Installation of OpenCV:

Step1: The first thing to do is to expand our file system to include all available space on our micro-SD card.

```
sudo raspi-config
```

Step2 (install dependencies): The first step is to update and upgrade any existing packages.

```
sudo apt-get update && sudo apt-get upgrade.
```

Step3: Download the OpenCV source code

After having the dependencies installed we will now grab the 3.3.0 archive of OpenCV from the official OpenCV repository

```
cd ~
wget -O opencv.zip https://github.com/Itseez/opencv/archive/3.3.0.zip
unzip opencv.zip
```

Step4: Python2.7 package manager

Before the start of compiling OpenCV on our Rasapberry Pi 3,one needs to install a python package manager

```
wget https://bootstrap.pypa.io/get-pip.py
sudo python get-pip.py
sudo python3 get-pip.py
```

Step5: Creating Python virtual environment

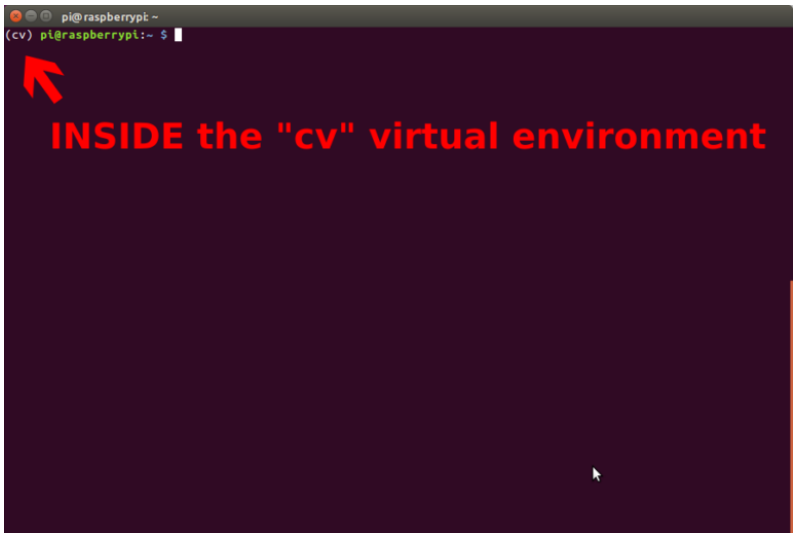
Creating a Python virtual environment that will be used for computer vision development Python2.7 is used.

```
mkvirtualenv cv -p python2
```

Step6: Checking whether we are in the “cv” virtual environment

In the event that Raspberry Pi is ever booted; log out and log back in; or open up another terminal one needs to utilize the "workon" order to re-get to the "cv" virtual environment.

```
source ~/.profile
workon cv
```



Step7: Installing NumPy on our Raspberry Pi

The only Python dependency is NumPy, a Python package used for numerical processing:

```
pip install numpy
```

Step8: Complile and install OpenCV

OpenCV needs to be compiled and installed .First one should check whether one is in the virtual environment then "execution of the command "workon" will be done.

```
workon cv
```

After being sure that one is in the "cv" virtual environment then one needs to setup the build using CMake.

```
cd ~/opencv-3.3.0/
 mkdir build
 cd build
 cmake -D CMAKE_BUILD_TYPE=RELEASE \
    -D CMAKE_INSTALL_PREFIX=/usr/local \
    -D INSTALL_PYTHON_EXAMPLES=ON \
    -D OPENCV_EXTRA_MODULES_PATH=~/opencv_contrib-3.3.0/modules \
    -D BUILD_EXAMPLES=O
```

Step9: We will now compile OpenCV

```
make -j4
```

```
sudo make install
sudo ldconfig
```

Step10: Finishing installing OpenCV on our Pi

```
ls -l /usr/local/lib/python2.7/site-packages/
total 1852
-rw-r--r-- 1 root staff 1895772 Mar 20 20:00 cv2.so
```

```
cd ~/.virtualenvs/cv/lib/python2.7/site-packages/
ln -s /usr/local/lib/python2.7/site-packages/cv2.so cv2.so
```

Step11: Testing our OpenCV 3.3.0

Open a new terminal, execute the source and workon commands, and then finally attempt to import the Python + OpenCV bindings.

```
source ~/.profile
$ workon cv
$ python
>>> import cv2
>>> cv2.__version__
'3.3.0'
```

5.3 FACE RECOGNIZATION

To create a complete project on Face Recognition, we must work on 3 very distinct phases:

- Face Detection and Data Gathering
- Train the Recognizer
- Face Recognition

Step1: Instaling OpenCV 3.3.0

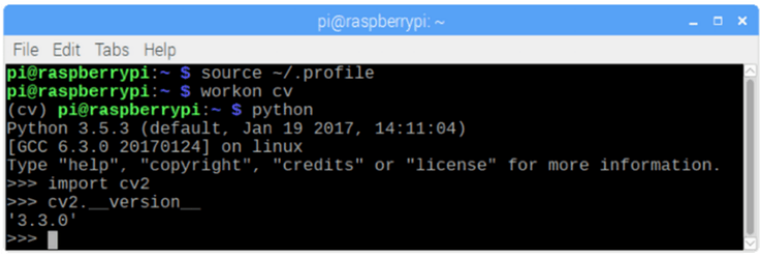


Figure 13: Installation of OpenCV

Step2: Checking Pi cam

After the installation of open cv library, the first and foremost thing is to test whether the pi camera is working properly or not. If the camera is properly installed the to ongoing steps are to be performed. The camera must be aligned in the correct manner to detect and recognize the features of the face.

Step3: Face Detection and Data Gathering

Detecting faces and after that gather data. The most common way to detect faces is by using Haar Cascade Algorithm. In this algorithm real time face detection is performed.

Step5: Trainer

On this second phase, we must take all user data from our dataset and "trainer" the OpenCV Recognizer. This is done directly by a specific OpenCV function. The result will be a .yml file that will be saved on a "trainer/" directory.

Step5: Recognizer

Here capturing a face will be done on the camera and if this person had his face captured and trained before, our recognizer will make a "prediction" returning its id and an index, shown how confident the recognizer is with this match.

Here face recognization has been done using one kind of classifier which is known as Haar Cascade classifier. In this process of face recognition the most important part is of image processing. Image processing is a numerically serious task and one of the greatest territories of research for a major information field. It is a procedure on the picture to change it into desired looking or which the info is a picture and the output might be a picture or set of characters related with the specific picture. It alludes to variety of techniques that are utilized to augment the data output from an image.

5.4 HAAR-CASCADE CLASSIFIER ALGORITHM

It is basically a classifier which is being used to detect objects for which it has been trained for. First and foremost, the algorithm needs a lot of positive pictures and negative pictures to prepare the Haar cascade classifier. Positive pictures are pictures with clear faces where negative pictures are those with no countenances. Each feature is represented as a single value obtained from the difference of the sums of pixels in white rectangle from the sum of all pixels in the black rectangle. All different possible sizes and locations of classifier is used for calculating of plenty of features. As the number of classifiers increase the arithmetic computations seems to take a long time. Instead of it, the concept of Integral Image has been used. Image Processing Integral image is a data structure which is a summed area table and algorithm for quickly and efficiently generating sum of values in a rectangular grid subset. To avoid the complex calculation we use Adaboost machine learning algorithm, which is inbuilt in OpenCV library that is cascade classifier, it eliminates the redundancy in the classifiers. Any classifier which has a probability of 50% of more in detection is treated as weak classifier. The Sum of all weak classifier gives a strong classifier which makes the decision about detection. Classification takes place in stages, if the selected region fails in the first stage, we discard it. One doesn't use the classifiers 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. Local Binary Patterns histogram algorithm (LBPH) has been used for face recognition. Local binary patterns are simple at the same time very efficient texture operator which assigns the pixels of the image by comparing with the adjacent pixels as threshold and which results in a binary result.

There are four types of features in Haar Cascade classifier algorithm:

- EDGE FEATURES
- LINE FEATURES
- CENTER-SURROUND FEATURES
- SPECIAL DIAGONAL LINE FEATURES

a) EDGE FEATURES:

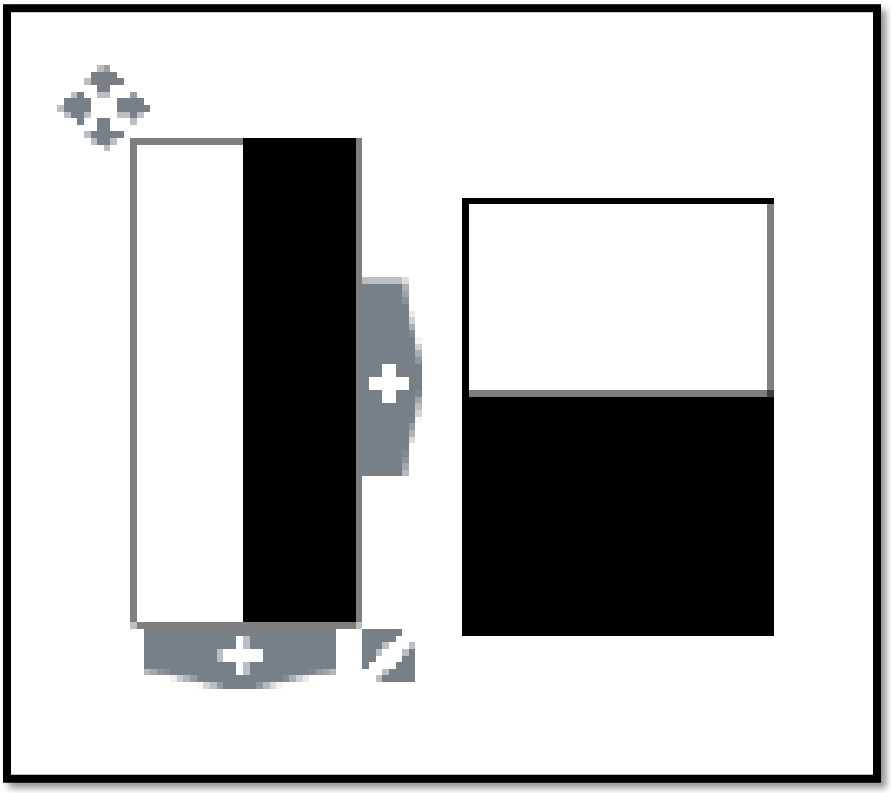


Figure 14: Edge Features

b) LINE FEATURES:

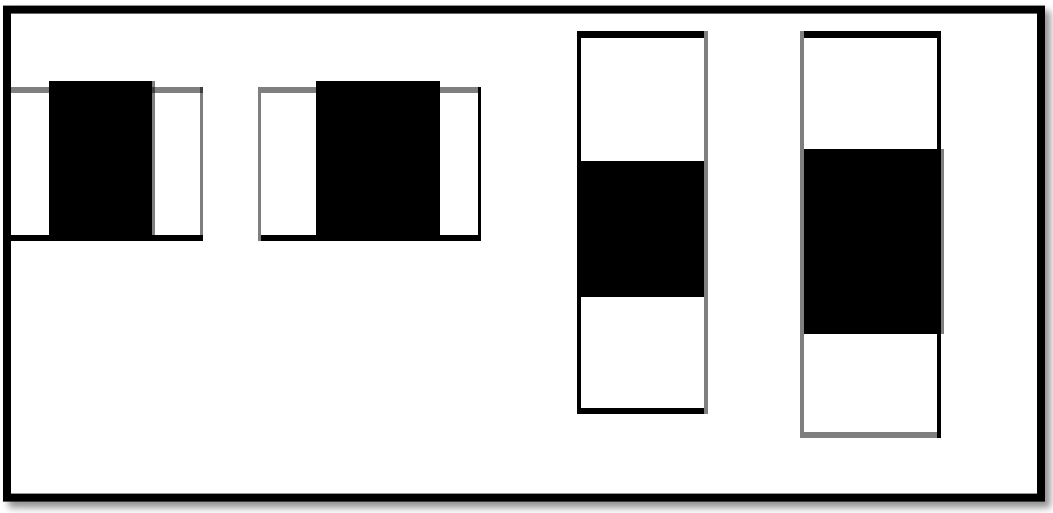


Figure 15: Line Features

c) CENTER-SURROUND FEATURE:

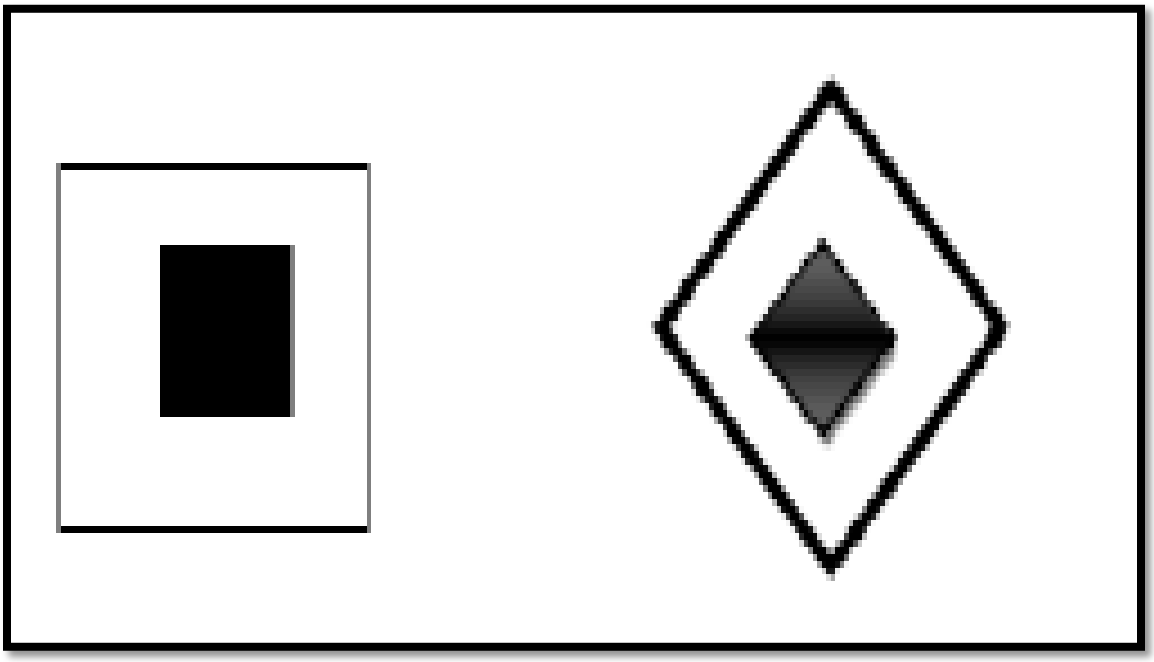


Figure 16: Center-surround feature

d) SPECIAL DIAGONAL LINE FEATURES:

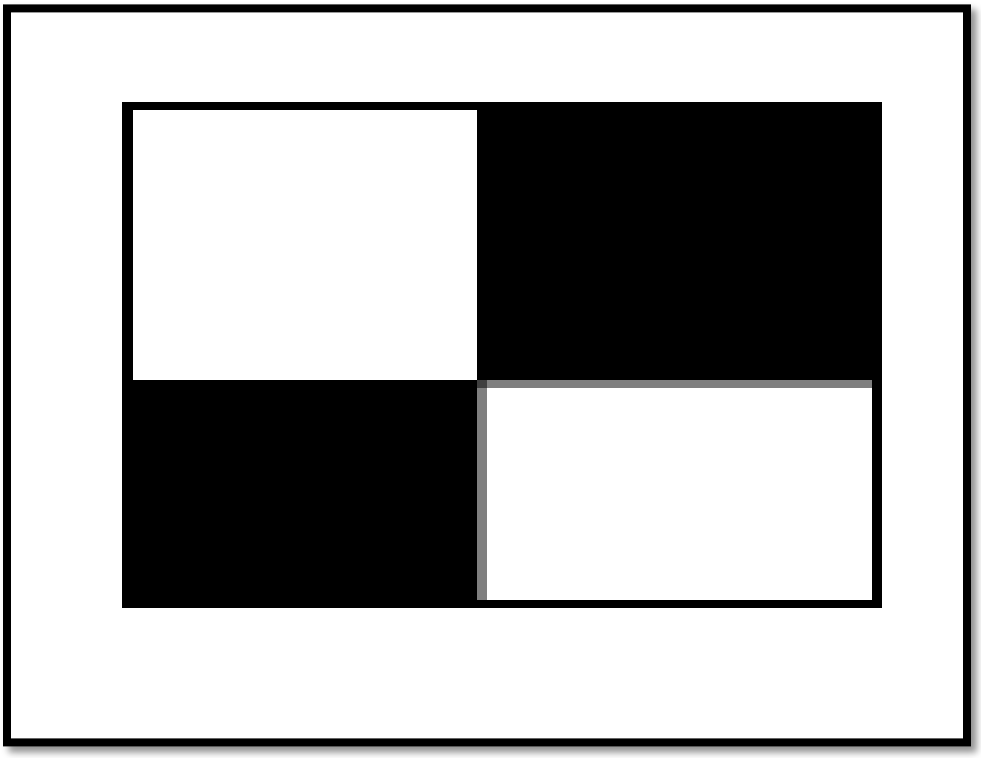


Figure 17: Special Diagonal Line Features

In this proposed scheme it has been decided to bring on a normal dc motor and connect it with a relay which will be connected to the main controller Raspberry Pi. The DC Motor will also connected to any of the pins of Raspberry Pi. DC motor here is helping the miniature door to open after the face is recognized in Face Recognization process. This whole system is a post part of the surveillance of Home automation.

RESULTS AND DISCUSSIONS

The main objective of the proposed work here is to create a system where it will be easy to operate home appliances and equipments very easily by making this system user friendly. Developing a smart home system was not easy at first. The most important part of this proposed work is human surveillance which is important due to the security issues of smart homes. For surveillance using face detection and face recognization is being used which are the most modern form of surveillance. For this purpose Raspberry Pi is being used camera and OpenCV which is a open source which is a part of Python language. Python here acts as the main platform where most of the work is going to be done. Image processing needs to be done for the Face recognition. OpenCV is an open source 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 liked to use the Haar classifier, LBPH (Lower Binary Pattern histogram) face recognizer. Face recognization is ought to be successful if the matching index after recognization is more than 45%.

Figure 18: Setup of the whole system for face recognization

In figure no 15 the whole system is depicted where one can see there is a box like structure which is holding the Pi camera upright so it could take clear and proper pictures for the purpose of face recognization.

Figure 19: Connection of the PC and Pi camera with Raspberry

Figure 19(a): HDMI cable and Pi camera connection with Raspberry Pi

In figure 16 and 16(a) it can be seen that how the PC, HDMI and the Pi camera is connected with the main controller Raspberry Pi. The box like structure is holding the Raspberry Pi camera which is used for capturing pictures of faces to store in the database and then later detect those faces and recognize those faces.

6.1 FACE RECOGNIZATION

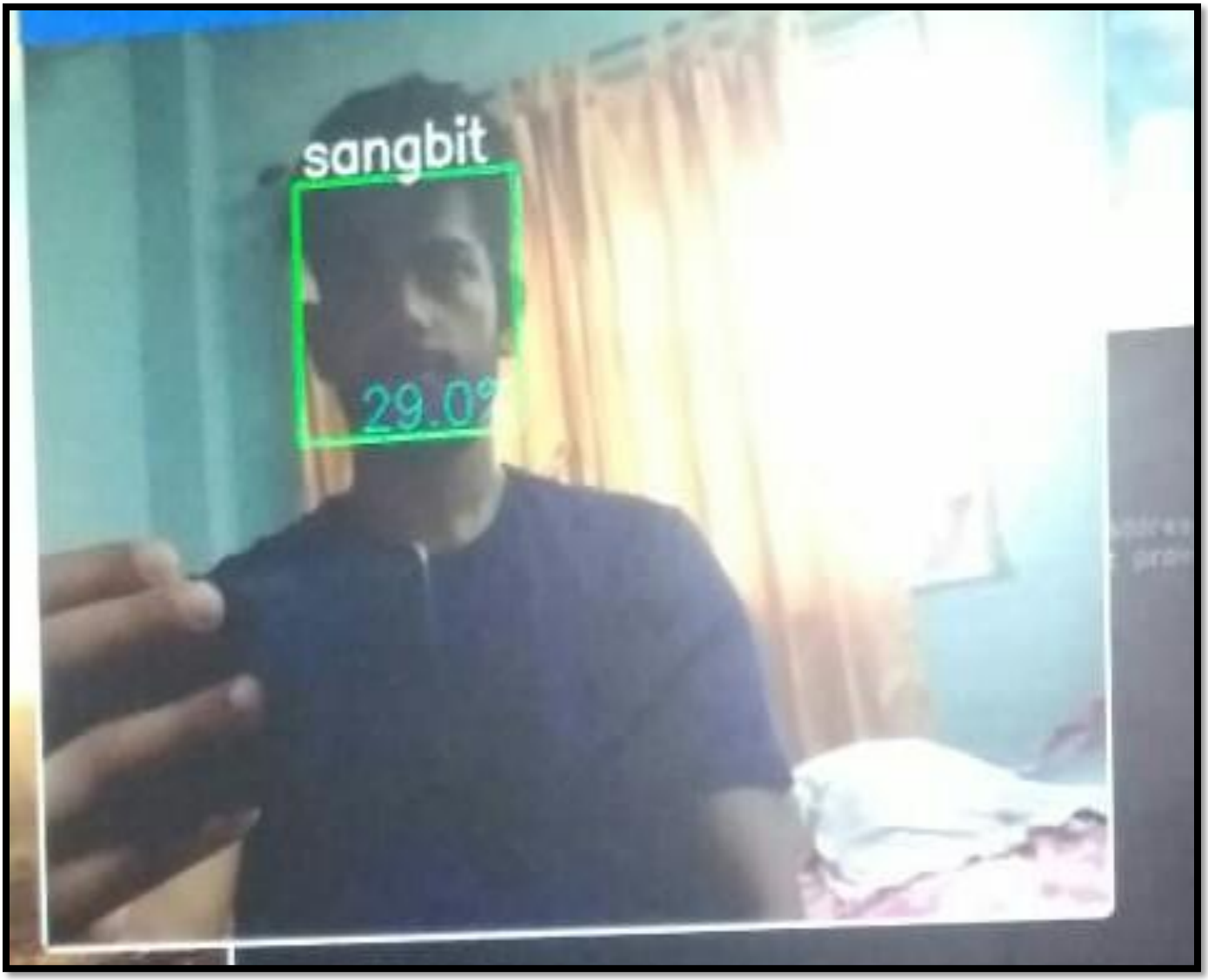


Figure 20: Output of Face Recognization

The above figure is the outcome of the Face Recognization. This picture is taken by the Raspberry Pi camera which is used for the face recognization. Firstly taking the pictures and storing it in the database then during the recognization process the outcome shows the name of the identity if it is stored in the database and it also shows the matching index which is previously mentioned that if it is 45% or more then it is successful otherwise not. Here clearly it is not the case as the matching index is showing 29.0%.

Figure 20(a): Output of the Face Rcognization

In the above figure it is the output of the face recognization and the person is identified properly. The matching index here is 44% which is almost 45% (the desired matching index) so one can say here that it is approximately successful.

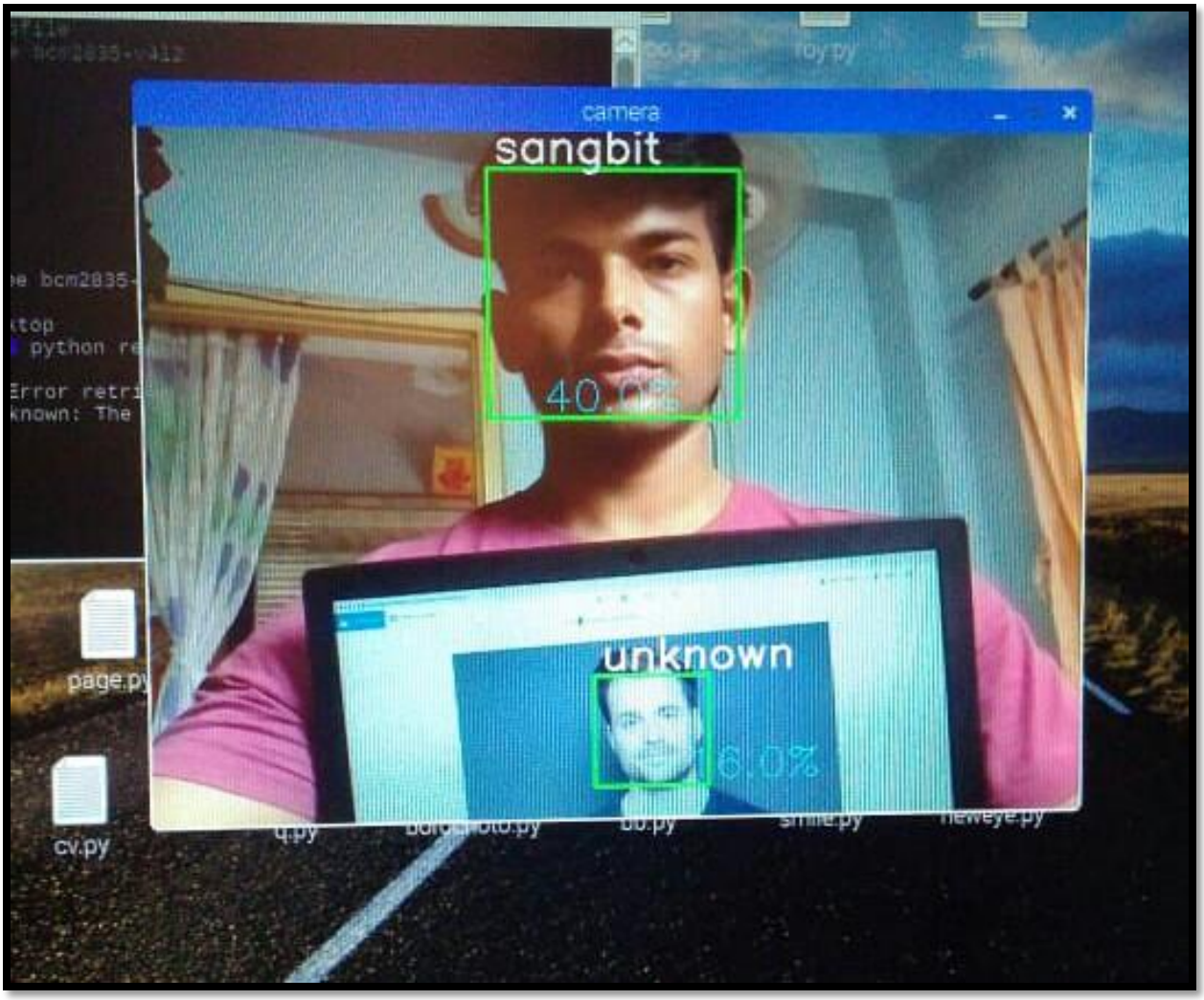


Figure 20(b): Outcome of the face recognization process

In the above figure one can see that one face is being recognized as it is stored in the database and another face is not properly recognized and is showing “Unknown “from here one can conclude that if the face is not stored in the database previously then the face won’t be recognized and will show unknown

In this proposed scheme it has been already decided to introduce a smart door lock system where a miniature door will be used. The door will be driven by a DC motor which will be driven by a relay. the Pi camera is attached to the camera slot and the DC motor and Relay is attached to the GPIO pins of the Raspberry Pi. As it is a two channel relay so it is connected to the LED and the DC motor which helps in driving the DC motor .Here the DC motor drives a miniature door

which is being used for a door locking system for surveillance purposes. The door only opens after a successful recognization process, when the face is stored previously in the database and that image has got the access to open the door then it will work otherwise it won't open.

CONCLUSION AND FUTURE WORKS

Home Automation is the most trending technology currently. This form of technology includes a lot of prospects from a lot of topics or subject assembled together. Home automation here has almost brought a evolutionary change in handling or operating home appliances and equipments and made it easy and convenient to use home appliances. A lot of home appliances can be controlled through home automation such as lights, fans, TV, air conditioners, fridge etc. Home automation helps us in operating this appliances from far away. In this proposed scheme an effort has been made to build a home automation system with the main virtue of Face Recognization. Face Recognization here has been done with the help of a Raspberry Pi camera which was used to take pictures of the faces and store it in the database where. The whole recognizarion has been done on Open CV which is a library function in Python language and is an open source. OpenCV is an open source 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 liked to use the Haar classifier, LBPH (Lower Binary Pattern histogram) face recognizer. Face recognization is ought to be successful if the matching index after recognization is more than 45%. In figure20 we are seeing the output of the Face Recognization. Firstly taking the pictures and storing it in the database then during the recognization process the outcome shows the name of the identity if it is stored in the database and it also shows the matching index which is previously mentioned that if it is 45% or more then it is successful otherwise not. Here clearly it is not the case as the matching index is showing 29.0%. In figure 20(a) one can see that the output of the face recognization and the person is identified properly. The matching index here is 44% which is almost 45% (the desired matching index) so we can say here that it is approximately successful. And in another picture one other face has been added where the image of the face was not stored previously so as a result it is showing unknown. In this proposed scheme a door lock system is also going to be used which will help in making the security part more strong. The door will be driven by a DC motor which will be connected to a relay. To better the Face recognition performance, there are miscellaneous things that can be improved here, some of them being fairly easy to go with. For example, you could add color processing, edge detection, etc. Today, one of the fields that utilizes facial recognition the most is security. Facial recognition is an extremely viable apparatus that can help law masters perceive offenders and programming organizations are

utilizing the innovation to enable clients to get to their innovation. This innovation can be additionally created to be utilized in different roads, for example, ATMs, getting to secret documents, or other touchy materials. This can make other safety efforts, for example, passwords and keys old. Another way that trend-setters are hoping to execute facial acknowledgment is inside trams and other transportation outlets. They are hoping to use this innovation to utilize faces as charge cards to pay for your transportation expense. Rather than setting off to a stall to purchase a ticket for an admission, the face acknowledgment would take your face, run it through a framework, and charge the record that you've recently made. This could conceivably streamline the procedure and advance the stream of traffic definitely.

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1 Introduction

The Raspberry Pi Compute Module 3+ (CM3+) is a range of DDR2-SODIMM-mechanically-compatible System on Modules (SoMs) containing processor, memory, eMMC Flash (on non-Lite variants) and supporting power circuitry. These modules allow a designer to leverage the Raspberry Pi hardware and software stack in their own custom systems and form factors. In addition these modules have extra IO interfaces over and above what is available on the Raspberry Pi model A/B boards, opening up more options for the designer.

The CM3+ contains a BCM2837B0 processor (as used on the Raspberry Pi 3B+), 1Gbyte LPDDR2 RAM and eMMC Flash. The CM3+ is currently available in 4 variants, CM3+/8GB, CM3+/16GB, CM3+/32GB and CM3+ Lite, which have 8, 16 and 32 Gigabytes of eMMC Flash, or no eMMC Flash, respectively.

The CM3+ Lite product is the same as CM3+ except the eMMC Flash is not fitted, and the SD/eMMC interface pins are available for the user to connect their own SD/eMMC device.

Note that the CM3+ is electrically identical and, with the exception of higher CPU z-height, physically identical to the legacy CM3 products.

CM3+ modules require a software/firmware image dated November 2018 or newer to function correctly.

2 Features

2.1 Hardware

Low cost

Low power

High availability

High reliability

– Tested over millions of Raspberry Pis Produced to date

– Module IO pins have 15 micro-inch hard gold plating over 2.5 micron Nickel

2.2 Peripherals

48x GPIO

2x I2C

2x SPI

2x UART

2x SD/SDIO

1x HDMI 1.3a

1x USB2 HOST/OTG

1x DPI (Parallel RGB Display)

1x NAND interface (SMI)

1x 4-lane CSI Camera Interface (up to 1Gbps per lane)

1x 2-lane CSI Camera Interface (up to 1Gbps per lane)

1x 4-lane DSI Display Interface (up to 1Gbps per lane)

1x 2-lane DSI Display Interface (up to 1Gbps per lane)

2.3 Software

ARMv8 Instruction Set

Mature and stable Linux software stack

– Latest Linux Kernel support

– Many drivers upstreamed

– Stable and well supported userland

– Full availability of GPU functions using standard APIs

3 Block Diagram

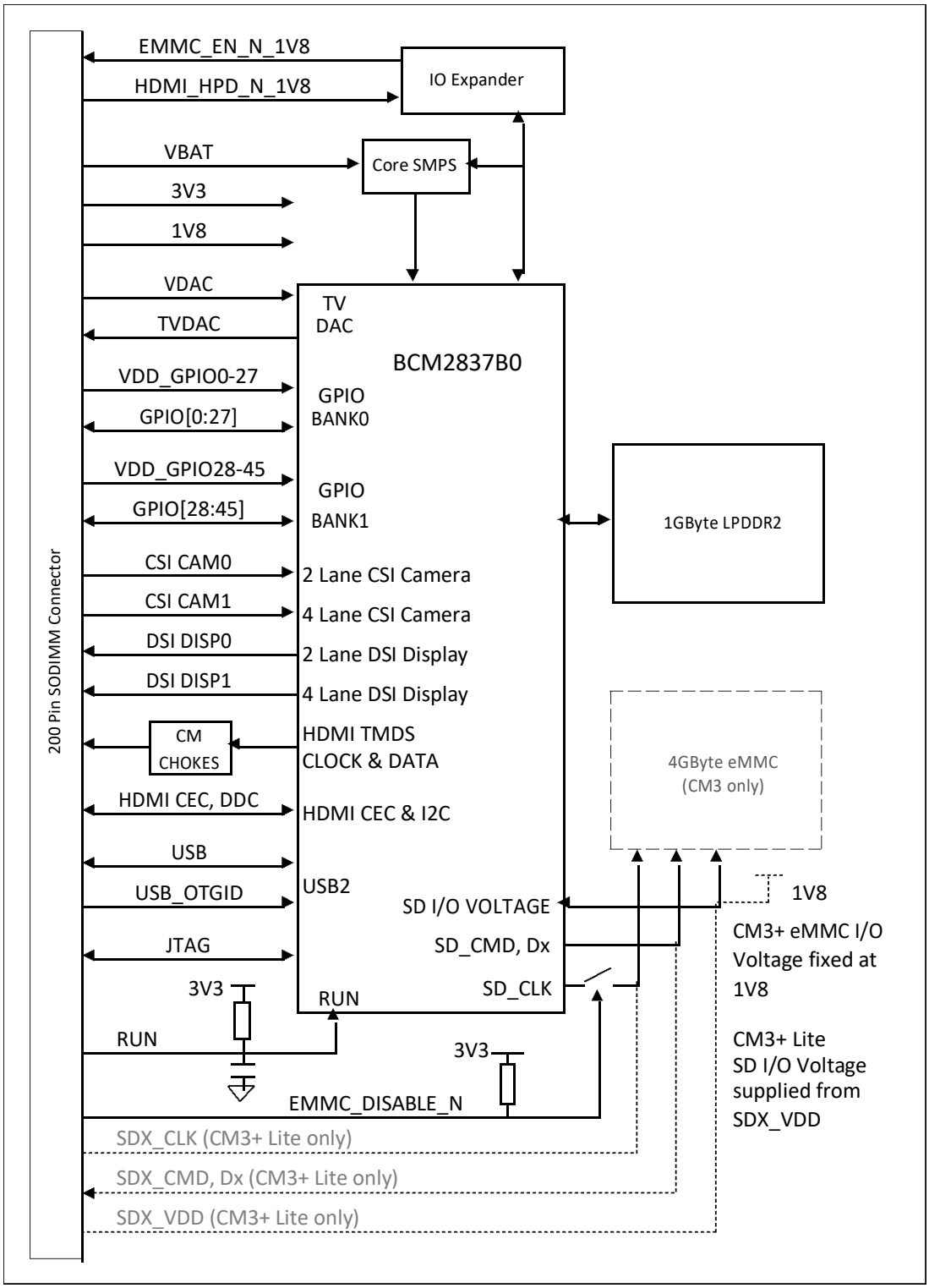

Figure 1: CM3+ Block Diagram

4 Mechanical Specification

The CM3+ modules conform to JEDEC MO-224 mechanical specification for 200 pin DDR2 (1.8V) SODIMM modules and therefore should work with the many DDR2 SODIMM sockets available on the market. (Please note that the pinout of the Compute Module is not the same as a DDR2 SODIMM module; they are not electrically compatible.)

The SODIMM form factor was chosen as a way to provide the 200 pin connections using a standard, readily available and low cost connector compatible with low cost PCB manufacture.

The maximum component height on the underside of the Compute Module is 1.2mm.

The maximum component height on the top side of the Compute Module is 2.5mm.

The Compute Module PCB thickness is 1.0mm +/- 0.1mm.

Note that the location and arrangement of components on the Compute Module may change slightly over time due to revisions for cost and manufacturing considerations; however, maximum component heights and PCB thickness will be kept as specified.

Figure 2 gives the CM3+ mechanical dimensions.

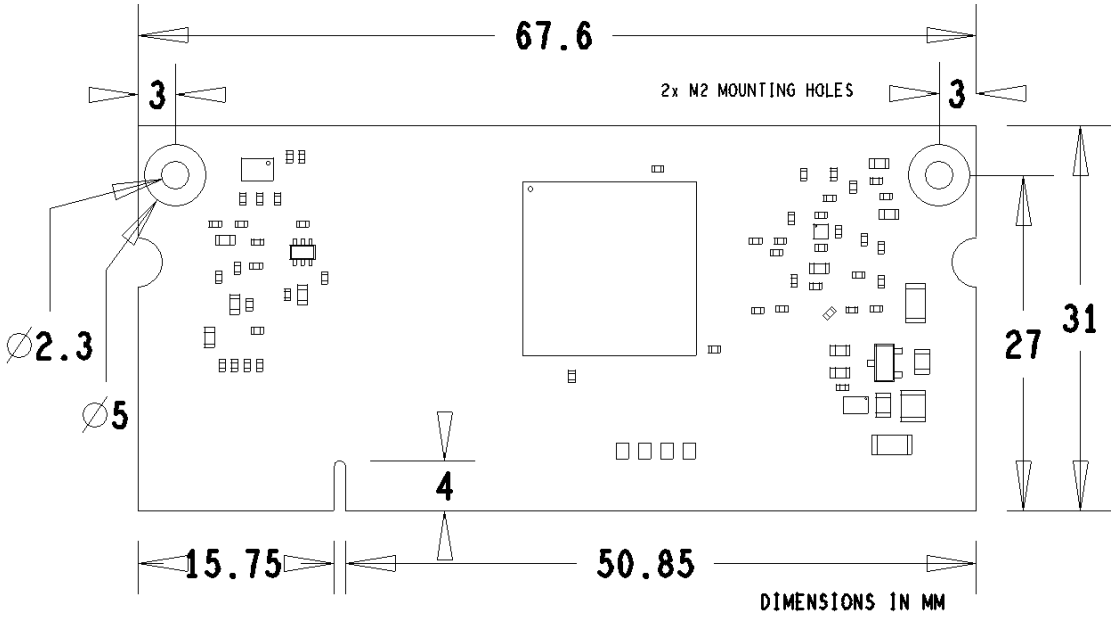

Figure 2: CM3+ Mechanical Dimensions

5 Pin Assignments

CM3+	CM3+ Lite	PIN	PIN	CM3+	CM3+ Lite
GND		1	2	EMMC_DISABLE_N	
GPIO0		3	4	NC	SDX_VDD
GPIO1		5	6	NC	SDX_VDD
GND		7	8	GND	
GPIO2		9	10	NC	SDX_CLK
GPIO3		11	12	NC	SDX_CMD
GND		13	14	GND	
GPIO4		15	16	NC	SDX_D0
GPIO5		17	18	NC	SDX_D1
GND		19	20	GND	
GPIO6		21	22	NC	SDX_D2
GPIO7		23	24	NC	SDX_D3
GND		25	26	GND	
GPIO8		27	28	GPIO28	
GPIO9		29	30	GPIO29	
GND		31	32	GND	
GPIO10		33	34	GPIO30	
GPIO11		35	36	GPIO31	
GND		37	38	GND	
GPIO0-27_VDD		39	40	GPIO0-27_VDD	
		KEY			
GPIO28-45_VDD		41	42	GPIO28-45_VDD	
GND		43	44	GND	
GPIO12		45	46	GPIO32	
GPIO13		47	48	GPIO33	
GND		49	50	GND	
GPIO14		51	52	GPIO34	
GPIO15		53	54	GPIO35	
GND		55	56	GND	
GPIO16		57	58	GPIO36	
GPIO17		59	60	GPIO37	
GND		61	62	GND	
GPIO18		63	64	GPIO38	
GPIO19		65	66	GPIO39	
GND		67	68	GND	
GPIO20		69	70	GPIO40	
GPIO21		71	72	GPIO41	
GND		73	74	GND	
GPIO22		75	76	GPIO42	
GPIO23		77	78	GPIO43	
GND		79	80	GND	
GPIO24		81	82	GPIO44	
GPIO25		83	84	GPIO45	
GND		85	86	GND	
GPIO26		87	88	HDMI_HPD_N_1V8	
GPIO27		89	90	EMMC_EN_N_1V8	
GND		91	92	GND	
DSI0_DN1		93	94	DSI1_DP0	
DSI0_DP1		95	96	DSI1_DN0	
GND		97	98	GND	
DSI0_DN0		99	100	DSI1_CP	
DSI0_DP0		101	102	DSI1_CN	
GND		103	104	GND	
DSI0_CN		105	106	DSI1_DP3	
DSI0_CP		107	108	DSI1_DN3	
GND		109	110	GND	
HDMI_CLK_N		111	112	DSI1_DP2	
HDMI_CLK_P		113	114	DSI1_DN2	
GND		115	116	GND	
HDMI_D0_N		117	118	DSI1_DP1	
HDMI_D0_P		119	120	DSI1_DN1	
GND		121	122	GND	
HDMI_D1_N		123	124	NC	
HDMI_D1_P		125	126	NC	
GND		127	128	NC	
HDMI_D2_N		129	130	NC	
HDMI_D2_P		131	132	NC	
GND		133	134	GND	
CAM1_DP3		135	136	CAM0_DP0	
CAM1_DN3		137	138	CAM0_DN0	
GND		139	140	GND	
CAM1_DP2		141	142	CAM0_CP	
CAM1_DN2		143	144	CAM0_CN	
GND		145	146	GND	
CAM1_CP		147	148	CAM0_DP1	
CAM1_CN		149	150	CAM0_DN1	
GND		151	152	GND	
CAM1_DP1		153	154	NC	
CAM1_DN1		155	156	NC	
GND		157	158	NC	
CAM1_DP0		159	160	NC	
CAM1_DN0		161	162	NC	
GND		163	164	GND	
USB_DP		165	166	TVDAC	
USB_DM		167	168	USB_OTGID	
GND		169	170	GND	
HDMI_CEC		171	172	VC_TRST_N	
HDMI_SDA		173	174	VC_TDI	
HDMI_SCL		175	176	VC_TMS	
RUN		177	178	VC_TDO	
DD_CORE (DO NOT CONNECT		179	180	VC_TCK	
GND		181	182	GND	
1V8		183	184	1V8	
1V8		185	186	1V8	
GND		187	188	GND	
VDAC		189	190	VDAC	
3V3		191	192	3V3	
3V3		193	194	3V3	
GND		195	196	GND	
VBAT		197	198	VBAT	
VBAT		199	200	VBAT	

Table 2: Compute Module 3+ SODIMM Connector Pinout

Table 2 gives the Compute Module 3+ pinout and Table 3 gives the pin functions.

Pin Name	DIR	Voltage Ref	PDN[a] State	If Unused	Description/Notes
RUN and Boot Control (see text for usage guide)					
RUN	I	3V3[b]	Pull High	Leave open	Has internal 10k pull up
EMMC_DISABLE_N	I	3V3[b]	Pull High	Leave open	Has internal 10k pull up
EMMC_EN_N 1V8	O	1V8	Pull High	Leave open	Has internal 2k2 pull up
GPIO					
GPIO[27:0]	I/O	GPIO0-27_VDD	Pull or Hi-Z[c]	Leave open	GPIO Bank 0
GPIO[45:28]	I/O	GPIO28-45_VDD	Pull or Hi-Z[c]	Leave open	GPIO Bank 1
Primary SD Interface[d;e]					
SDX_CLK	O	SDX_VDD	Pull High	Leave open	Primary SD interface CLK
SDX_CMD	I/O	SDX_VDD	Pull High	Leave open	Primary SD interface CMD
SDX_Dx	I/O	SDX_VDD	Pull High	Leave open	Primary SD interface DATA
USB Interface					
USB_Dx	I/O	-	Z	Leave open	Serial interface
USB_OTGID	I	3V3		Tie to GND	OTG pin detect
HDMI Interface					
HDMI_SCL	I/O	3V3[b]	Z[f]	Leave open	DDC Clock (5.5V tolerant)
HDMI_SDA	I/O	3V3[b]	Z[f]	Leave open	DDC Data (5.5V tolerant)
HDMI_CEC	I/O	3V3	Z	Leave open	CEC (has internal 27k pull up)
HDMI_CLKx	O	-	Z	Leave open	HDMI serial clock
HDMI_Dx	O	-	Z	Leave open	HDMI serial data
HDMI_HPD_N 1V8	I	1V8	Pull High	Leave open	HDMI hotplug detect
CAM0 (CSI0) 2-lane Interface					
CAM0_Cx	I	-	Z	Leave open	Serial clock
CAM0_Dx	I	-	Z	Leave open	Serial data
CAM1 (CSI1) 4-lane Interface					
CAM1_Cx	I	-	Z	Leave open	Serial clock
CAM1_Dx	I	-	Z	Leave open	Serial data
DSI0 (Display 0) 2-lane Interface					
DSI0_Cx	O	-	Z	Leave open	Serial clock
DSI0_Dx	O	-	Z	Leave open	Serial data
DSI1 (Display 1) 4-lane Interface					
DSI1_Cx	O	-	Z	Leave open	Serial clock
DSI1_Dx	O	-	Z	Leave open	Serial data
TV Out					
TVDAC	O	-	Z	Leave open	Composite video DAC output
JTAG Interface					
TMS	I	3V3	Z	Leave open	Has internal 50k pull up
TRST_N	I	3V3	Z	Leave open	Has internal 50k pull up
TCK	I	3V3	Z	Leave open	Has internal 50k pull up
TDI	I	3V3	Z	Leave open	Has internal 50k pull up
TDO	O	3V3	O	Leave open	Has internal 50k pull up

[a] The PDN column indicates power-down state (when RUN pin LOW) [b] Must be driven by an open-collector driver
[c] GPIO have software enabled pulls which keep state over power-down [d] Only available on Lite variants
[e] The CM will always try to boot from this interface first
[f] Requires external pull-up resistor to 5V as per HDMI spec

Table 3: Pin Functions

6 Electrical Specification

Caution! Stresses above those listed in Table 4 may cause permanent damage to the device. This is a stress rating only; functional operation of the device under these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Minimum	Maximum	Unit
VBAT	Core SMPS Supply	-0.5	6.0	V
3V3	3V3 Supply Voltage	-0.5	4.10	V
1V8	1V8 Supply Voltage	-0.5	2.10	V
VDAC	TV DAC Supply	-0.5	4.10	V
GPIO0-27_VDD	GPIO0-27 I/O Supply Voltage	-0.5	4.10	V
GPIO28-45_VDD	GPIO28-45 I/O Supply Voltage	-0.5	4.10	V
SDX_VDD	Primary SD/eMMC Supply Voltage	-0.5	4.10	V

Table 4: Absolute Maximum Ratings

DC Characteristics are defined in Table 5

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{IL}	Input low voltage[a]	VDD_IO = 1.8V	-	-	0.6	V
		VDD_IO = 2.7V	-	-	0.8	V
		VDD_IO = 3.3V	-	-	0.9	V
V_{IH}	Input high voltage[a]	VDD_IO = 1.8V	1.0	-	-	V
		VDD_IO = 2.7V	1.3	-	-	V
		VDD_IO = 3.3V	1.6	-	-	V
I_{IL}	Input leakage current	TA = +85 C	-	-	5	A
C_{IN}	Input capacitance	-	-	5	-	pF
V_{OL}	Output low voltage[b]	VDD_IO = 1.8V, IOL = -2mA	-	-	0.2	V
		VDD_IO = 2.7V, IOL = -2mA	-	-	0.15	V
		VDD_IO = 3.3V, IOL = -2mA	-	-	0.14	V
V_{OH}	Output high voltage[b]	VDD_IO = 1.8V, IOH = 2mA	1.6	-	-	V
		VDD_IO = 2.7V, IOH = 2mA	2.5	-	-	V
		VDD_IO = 3.3V, IOH = 2mA	3.0	-	-	V
I_{OL}	Output low current[c]	VDD_IO = 1.8V, VO = 0.4V	12	-	-	mA
		VDD_IO = 2.7V, VO = 0.4V	17	-	-	mA
		VDD_IO = 3.3V, VO = 0.4V	18	-	-	mA
I_{OH}	Output high current[c]	VDD_IO = 1.8V, VO = 1.4V	10	-	-	mA
		VDD_IO = 2.7V, VO = 2.3V	16	-	-	mA
		VDD_IO = 3.3V, VO = 2.3V	17	-	-	mA
R_{PU}	Pullup resistor	-	50	-	65	k
R_{PD}	Pulldown resistor	-	50	-	65	k

[a] Hysteresis enabled
[b] Default drive strength (8mA)
[c] Maximum drive strength (16mA)

Table 5: DC Characteristics

AC Characteristics are defined in Table 6 and Fig. 3.

Pin Name	Symbol	Parameter	Minimum	Typical	Maximum	Unit
Digital outputs	t_{rise}	10-90% rise time[a]	-	1.6	-	ns
Digital outputs	t_{fall}	90-10% fall time[a]	-	1.7	-	ns
GPCLK	t_{JOSC}	Oscillator-derived GPCLK cycle-cycle jitter (RMS)	-	-	20	ps
GPCLK	t_{JPLL}	PLL-derived GPCLK cycle-cycle jitter (RMS)	-	-	48	ps

[a] Default drive strength, CL = 5pF, VDD IOx = 3.3V

Table 6: Digital I/O Pin AC Characteristics

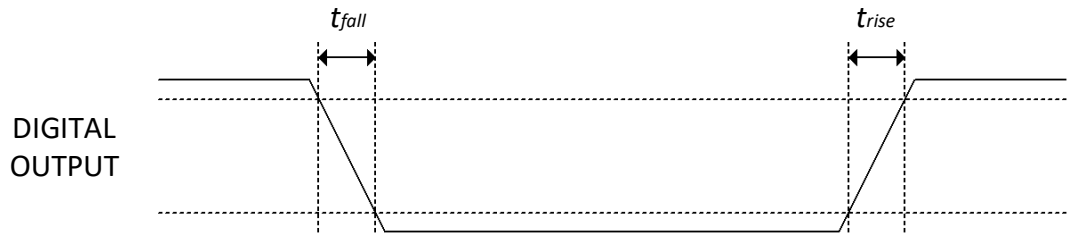

Figure 3: Digital IO Characteristics

7 Power Supplies

The Compute Module 3+ has six separate supplies that must be present and powered at all times; you cannot leave any of them unpowered, even if a specific interface or GPIO bank is unused. The six supplies are as follows:

1. VBAT is used to power the BCM2837 processor core. It feeds the SMPS that generates the chip core voltage.
2. 3V3 powers various BCM2837 PHYs, IO and the eMMC Flash.
3. 1V8 powers various BCM2837 PHYs, IO and SDRAM.
4. VDAC powers the composite (TV-out) DAC.
5. GPIO0-27 VREF powers the GPIO 0-27 IO bank.
6. GPIO28-45 VREF powers the GPIO 28-45 IO bank.

Supply	Descripion	Minimum	Typical	Maximum	Unit
VBAT	Core SMPS Supply	2.5	-	5.0 + 5%	V
3V3	3V3 Supply Voltage	3.3 - 5%	3.3	3.3 + 5%	V
1V8	1V8 Supply Voltage	1.8 - 5%	1.8	1.8 + 5%	V
VDAC	TV DAC Supply[a]	2.5 - 5%	2.8	3.3 + 5%	V
GPIO0-27_VDD	GPIO0-27 I/O Supply Voltage	1.8 - 5%	-	3.3 + 5%	V
GPIO28-45_VDD	GPIO28-45 I/O Supply Voltage	1.8 - 5%	-	3.3 + 5%	V
SDX_VDD	Primary SD/eMMC Supply Voltage	1.8 - 5%	-	3.3 + 5%	V

[a] Requires a clean 2.5-2.8V supply if TV DAC is used, else connect to 3V3

Table 7: Power Supply Operating Ranges

7.1 Supply Sequencing

Supplies should be staggered so that the highest voltage comes up first, then the remaining voltages in descending order. This is to avoid forward biasing internal (on-chip) diodes between supplies, and causing latch-up. Alternatively supplies can be synchronised to come up at exactly the same time as long as at no point a lower voltage supply rail voltage exceeds a higher voltage supply rail voltage.

7.2 Power Requirements

Exact power requirements will be heavily dependent upon the individual use case. If an on-chip subsys-tem is unused, it is usually in a low power state or completely turned off. For instance, if your application does not use 3D graphics then a large part of the core digital logic will never turn on and need power. This is also the case for camera and display interfaces, HDMI, USB interfaces, video encoders and decoders, and so on.

Powerchain design is critical for stable and reliable operation of the Compute Module 3+. We strongly recommend that designers spend time measuring and verifying power requirements for their particular use case and application, as well as paying careful attention to power supply sequencing and maximum supply voltage tolerance.

Table 8 specifies the recommended minimum power supply outputs required to power the Compute Module 3+.

Supply	Minimum Requirement	Unit
VBAT (CM1)	2000[a]	mW
VBAT (CM3,3L)	3500[a]	mW
3V3	250	mA
1V8	250	mA
VDAC	25	mA
GPIO0-27_VDD	50[b]	mA
GPIO28-45_VDD	50[b]	mA
SDX-VDD	50[b]	mA

[a] Recommended minimum. Actual power drawn is very dependent on use-case

[b] Each GPIO can supply up to 16mA, aggregate current per bank must not exceed 50mA Table 8: Mimimum Power Supply Requirements

8 Booting

The eMMC Flash device on CM3+ is directly connected to the primary BCM2837 SD/eMMC interface. These connections are not accessible on the module pins. On CM3+ Lite this SD interface is available on the SDX pins.

When initially powered on, or after the RUN pin has been held low and then released, the BCM2837 will try to access the primary SD/eMMC interface. It will then look for a file called bootcode.bin on the primary partition (which must be FAT) to start booting the system. If it cannot access the SD/eMMC device or the boot code cannot be found, it will fall back to waiting for boot code to be written to it over USB; in other words, its USB port is in slave mode waiting to accept boot code from a suitable host.

A USB boot tool is available on Github which allows a host PC running Linux to write the BCM2837 boot code over USB to the module. That boot code then runs and provides access to the SD/eMMC as a USB mass storage device, which can then be read and written using the host PC. Note that a Raspberry Pi can be used as the host machine. For those using Windows a precompiled and packeged tool is available. For more information see here.

The Compute Module has a pin called EMMC_DISABLE_N which when shorted to GND will disable the SD/eMMC interface (by physically disconnecting the SD_CMD pin), forcing BCM2837 to boot from USB. Note that when the eMMC is disabled in this way, it takes a couple of seconds from powering up for the processor to stop attempting to talk to the SD/eMMC device and fall back to booting from USB.

Note that once booted over USB, BCM2837 needs to re-enable the SD/eMMC device (by releasing EMMC_DISABLE_N) to allow access to it as mass storage. It expects to be able to do this by driving the EMMC_EN_N_1V8 pin LOW, which at boot is initially an input with a pull up to 1V8. If an end user wishes to add the ability to access the SD/eMMC over USB in their product, similar circuitry to that used on the Compute Module IO Board to enable/disable the USB boot and SD/eMMC must be used; that is, EMMC_DISABLE_N pulled low via MOSFET(s) and released again by MOSFET, with the gate controlled by EMMC_EN_N_1V8. Ensure you use MOSFETs suitable for switching at 1.8V (i.e. use a device with gate threshold voltage, Vt, suitable for 1.8V switching).

9 Peripherals

9.1 GPIO

BCM2837 has in total 54 GPIO lines in 3 separate voltage banks. All GPIO pins have at least two alternative functions within the SoC. When not used for the alternate peripheral function, each GPIO pin may be set as an input (optionally as an interrupt) or an output. The alternate functions are usually peripheral I/Os, and most peripherals appear twice to allow flexibility on the choice of I/O voltage.

GPIO bank2 is used on the module to connect to the eMMC device and for an on-board I2C bus (to talk to the core SMPS and control the special function pins). On CM3+ Lite most of bank2 is exposed to allow a user to connect their choice of SD card or eMMC device (if required).

Bank0 and 1 GPIOs are available for general use. GPIO0 to GPIO27 are bank0 and GPIO28-45 make up bank1. GPIO0-27 VDD is the power supply for bank0 and GPIO28-45 VDD is the power supply for bank1. SDX VDD is the supply for bank2 on CM3+ Lite. These supplies can be in the range 1.8V-3.3V (see Table 7) and are not optional; each bank must be powered, even when none of the GPIOs for that bank are used.

Note that the HDMI_HPD_N_1V8 and EMMC_EN_N_1V8 pins are 1.8V IO and are used for special functions (HDMI hot plug detect and boot control respectively). Please do not use these pins for any other purpose, as the software for the module will always expect these pins to have these special functions. If they are unused please leave them unconnected.

All GPIOs except GPIO28, 29, 44 and 45 have weak in-pad pull-ups or pull-downs enabled when the device is powered on. It is recommended to add off-chip pulls to GPIO28, 29, 44 and 45 to make sure they never float during power on and initial boot.

9.1.1 GPIO Alternate Functions

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
0	High	SDA0	SA5	PCLK	-	-	-
1	High	SCL0	SA4	DE	-	-	-
2	High	SDA1	SA3	LCD_VSYNC	-	-	-
3	High	SCL1	SA2	LCD_HSYNC	-	-	-
4	High	GPCLK0	SA1	DPI_D0	-	-	ARM_TDI
5	High	GPCLK1	SA0	DPI_D1	-	-	ARM_TDO
6	High	GPCLK2	SOE_N	DPI_D2	-	-	ARM_RTCK
7	High	SPI0_CE1_N	SWE_N	DPI_D3	-	-	-
8	High	SPI0_CE0_N	SD0	DPI_D4	-	-	-
9	Low	SPI0_MISO	SD1	DPI_D5	-	-	-
10	Low	SPI0_MOSI	SD2	DPI_D6	-	-	-
11	Low	SPI0_SCLK	SD3	DPI_D7	-	-	-
12	Low	PWM0	SD4	DPI_D8	-	-	ARM_TMS
13	Low	PWM1	SD5	DPI_D9	-	-	ARM_TCK
14	Low	TXD0	SD6	DPI_D10	-	-	TXD1
15	Low	RXD0	SD7	DPI_D11	-	-	RXD1
16	Low	FL0	SD8	DPI_D12	CTS0	SPI1_CE2_N	CTS1
17	Low	FL1	SD9	DPI_D13	RTS0	SPI1_CE1_N	RTS1
18	Low	PCM_CLK	SD10	DPI_D14	-	SPI1_CE0_N	PWM0
19	Low	PCM_FS	SD11	DPI_D15	-	SPI1_MISO	PWM1
20	Low	PCM_DIN	SD12	DPI_D16	-	SPI1_MOSI	GPCLK0
21	Low	PCM_DOUT	SD13	DPI_D17	-	SPI1_SCLK	GPCLK1
22	Low	SD0_CLK	SD14	DPI_D18	SD1_CLK	ARM_TRST	-
23	Low	SD0_CMD	SD15	DPI_D19	SD1_CMD	ARM_RTCK	-
24	Low	SD0_DAT0	SD16	DPI_D20	SD1_DAT0	ARM_TDO	-
25	Low	SD0_DAT1	SD17	DPI_D21	SD1_DAT1	ARM_TCK	-
26	Low	SD0_DAT2	TE0	DPI_D22	SD1_DAT2	ARM_TDI	-
27	Low	SD0_DAT3	TE1	DPI_D23	SD1_DAT3	ARM_TMS	-

Table 9: GPIO Bank0 Alternate Functions

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
28	None	SDA0	SA5	PCM_CLK	FL0	-	-
29	None	SCL0	SA4	PCM_FS	FL1	-	-
30	Low	TE0	SA3	PCM_DIN	CTS0	-	CTS1
31	Low	FL0	SA2	PCM_DOUT	RTS0	-	RTS1
32	Low	GPCLK0	SA1	RING_OCLK	TXD0	-	TXD1
33	Low	FL1	SA0	TE1	RXD0	-	RXD1
34	High	GPCLK0	SOE_N	TE2	SD1_CLK	-	-
35	High	SPI0_CE1_N	SWE_N	-	SD1_CMD	-	-
36	High	SPI0_CE0_N	SD0	TXD0	SD1_DAT0	-	-
37	Low	SPI0_MISO	SD1	RXD0	SD1_DAT1	-	-
38	Low	SPI0_MOSI	SD2	RTS0	SD1_DAT2	-	-
39	Low	SPI0_SCLK	SD3	CTS0	SD1_DAT3	-	-
40	Low	PWM0	SD4	-	SD1_DAT4	SPI2_MISO	TXD1
41	Low	PWM1	SD5	TE0	SD1_DAT5	SPI2_MOSI	RXD1
42	Low	GPCLK1	SD6	TE1	SD1_DAT6	SPI2_SCLK	RTS1
43	Low	GPCLK2	SD7	TE2	SD1_DAT7	SPI2_CE0_N	CTS1
44	None	GPCLK1	SDA0	SDA1	TE0	SPI2_CE1_N	-
45	None	PWM1	SCL0	SCL1	TE1	SPI2_CE2_N	-

Table 10: GPIO Bank1 Alternate Functions

Table 9 and Table 10 detail the default pin pull state and available alternate GPIO functions. Most of these alternate peripheral functions are described in detail in the Broadcom Peripherals Specification document and have Linux drivers available.

9.1.2 Secondary Memory Interface (SMI)

The SMI peripheral is an asynchronous NAND type bus supporting Intel mode80 type transfers at 8 or 16 bit widths and available in the ALT1 positions on GPIO banks 0 and 1 (see Table 9 and Table 10). It is not publicly documented in the Broadcom Peripherals Specification but a Linux driver is available in the Raspberry Pi Github Linux repository (bcm2835 smi.c in linux/drivers/misc).

9.1.3 Display Parallel Interface (DPI)

A standard parallel RGB (DPI) interface is available on bank 0 GPIOs. This up-to-24-bit parallel inter-face can support a secondary display. Again this interface is not documented in the Broadcom Peripher-als Specification but documentation can be found here.

9.1.4 SD/SDIO Interface

The BCM283x supports two SD card interfaces, SD0 and SD1.

The first (SD0) is a proprietary Broadcom controller that does not support SDIO and is the primary interface used to boot and talk to the eMMC or SDX x signals.

The second interface (SD1) is standards compliant and can interface to SD, SDIO and eMMC devices; for example on a Raspberry Pi 3 B+ it is used to talk to the on-board CYW43455 WiFi device in SDIO mode.

Both interfaces can support speeds up to 50MHz single ended (SD High Speed Mode).

9.2 CSI (MIPI Serial Camera)

Currently the CSI interface is not openly documented and only CSI camera sensors supported by the official Raspberry Pi firmware will work with this interface. Supported sensors are the OmniVision OV5647 and Sony IMX219.

It is recommended to attach other cameras via USB.

9.3 DSI (MIPI Serial Display)

Currently the DSI interface is not openly documented and only DSI displays supported by the official Raspberry Pi firmware will work with this interface.

Displays can also be added via the parallel DPI interface which is available as a GPIO alternate function - see Table 9 and Section 9.1.3

9.4 USB

The BCM2837 USB port is On-The-Go (OTG) capable. If using either as a fixed slave or fixed master, please tie the USB OTGID pin to ground.

The USB port (Pins USB DP and USB DM) must be routed as 90 ohm differential PCB traces.

Note that the port is capable of being used as a true OTG port however there is no official documentation. Some users have had success making this work.

9.5 HDMI

BCM283x supports HDMI V1.3a.

It is recommended that users follow a similar arrangement to the Compute Module IO Board circuitry for HDMI output.

The HDMI CK P/N (clock) and D0-D2 P/N (data) pins must each be routed as matched length 100 ohm differential PCB traces. It is also important to make sure that each differential pair is closely phase matched. Finally, keep HDMI traces well away from other noise sources and as short as possible.

Failure to observe these design rules is likely to result in EMC failure.

9.6 Composite (TV Out)

The TVDAC pin can be used to output composite video (PAL or NTSC). Please route this signal away from noise sources and use a 75 ohm PCB trace.

Note that the TV DAC is powered from the VDAC supply which must be a clean supply of 2.5-2.8V. It is recommended users generate this supply from 3V3 using a low noise LDO.

If the TVDAC output is not used VDAC can be connected to 3V3, but it must be powered even if the TV-out functionality is unused.

10 Thermals

The BCM2837 SoC employs DVFS (Dynamic Voltage and Frequency Scaling) on the core voltage. When the processor is idle (low CPU utilisation), it will reduce the core frequency and voltage to reduce current draw and heat output. When the core utilisation exceeds a certain threshold the core votlage is increased and the core frequency is boosted to the maximum working frerquency of 1.2GHz. The voltage and frequency are throttled back when the CPU load reduces back to an 'idle' level OR when the silicon temperature as mesured by the on-chip temperature sensor exceeds 80C (thermal throttling).

A designer must pay careful attention to the thermal design of products using the CM3+ so that performance is not artificially curtailed due to the processor thermal throttling, as the Quad ARM complex in the BCM2837 can generate significant heat output under load.

10.1 Temperature Range

The operating temperature range of the module is set by the lowest maximum and highest minimum of any of the components used.

The eMMC and LPDDR2 have the narrowest range, these are rated for -25 to +80 degrees Celsius. Therefore the nominal range for the CM3+ and CM3+ Lite is -25C to +80C.

However, this range is the maximum for the silicon die; therefore, users would have to take into account the heat generated when in use and make sure this does not cause the temperature to exceed 80 degrees Celsius.

11 Availability

Raspberry Pi guarantee availability of CM3+ and CM3+ Lite until at least January 2026.

12 Support

For support please see the hardware documentation section of the Raspberry Pi website and post ques-tions to the Raspberry Pi forum.