DESIGN AND CONSTRUCTION OF A SMART MIRROR

BY

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A PROJECT SUBMITED TO THE DEPARTMENT OF MECHATRONICS ENGINEERING, FEDERAL UNIVERSITY OYE EKITI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN MECHATRONICS ENGINEERING

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This project work titled SMART MIRROR by FASAKIN TAIWO ASAOLU, meets the requirements for the award of Bachelor of Engineering (B.Eng.) degree in Mechatronics Engineering Department, Federal University Oye-Ekiti.

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EXTERNAL EXAMINER	**DATE**

DEDICATION

This report is dedicated to the ruler of the universe the custodian of great wisdom and the giver of knowledge Almighty God, for his love, guidance and blessing through my stay at the university, to my parents who made my academic succession a reality through their financial support.

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ABSTRACT

This project describes the **DESIGN AND CONSTRUCTION OF SMART MIRROR** that represents an unobtrusive interface for the ambient home environment. The mirror provides a natural means of interaction through which the resident can control the household smart appliances and access personalized services. The smart mirrors functionalities have been demonstrated by developing easily extendable home automation system facilitates the integration of household appliances and various customized information services. Intelligent mirror, which continues the work today will take its place in the future technology, provides both mirror and computer aided information services to its user.

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CHAPTER ONE

1.0 INTRODUCTION

The world around is constantly changing. Interactive computing, with wirelessly connected device that are being used in various day to day activities, are changing and improving the standard of the quality life. Based on interactive computing and communication technologies, many devices/ products are now emerging and with this multimedia intelligence it is providing comfortable, secure and convenient personal services and making a lot of users comfortable. We have smart cities, smart phones, smart cars, and more. This fast way of life requires the developments of home automation projects. The smart homes which automatically close or open windows based on weather conditions outside.

This project presents the design and construction of a smart mirror using raspberry pi. A smart mirror is capable to displaying time, date, weather, news feeds, email notification and cloud. The many benefits of using a smart mirror it make life easier as need to look at phones every time we need to check time, weather is also reduced. The smart mirror helps in developed smart house with embedded artificial intelligence finding application in industries. We look at the mirror daily and internet with it psychologically to find out how we look and how our attire is. The interactive mirror is develop with proper embedded intelligence for offering feature such as weather of city, latest updates of news and headlines and local time corresponding to location.

1.1 THEORY

The vision of Ambient Artificial Intelligence (AmI) has brought a new twist to the decade old research and industry initiatives in realizing Smart Environments. The AmI vision, as proposed by the European Consortium, promotes a standard where humans are surrounded by

intelligent and natural interfaces offered by the interconnected heterogeneous computing devices embedded into everyday objects. The environment thus created is capable of recognizing and responding to the actions and presence of individuals. Therefore, Aml can be seen as the driving force toward a more user-friendly and user-empowered smart environment for providing effective support to human interactions. The AmI aware smart environments and surrounding, whether it is the home environment or the distributed environment, uses a variety of smart technologies. These technologies integrate sensing, processing, reasoning, and networking capabilities in addition to heterogeneous applications, services and digital contents. With all of these rich technologies involved, AmI faces challenges on how to integrate them with the everyday objects. Often unremarkably, in order to provide computing intelligence in the surrounding environment. The application of AmI in the home environment may provide quality, convenience, efficiency, security, and safety to its residents. AmI for assisted living, especially for the elderly and the people with disabilities has already received much attention. Besides, the areas of home automation, communication and socialization, rest, refreshment, entertainment and sports, working, and learning at home will be influenced by the innovations of Aml. Therefore, the design of smart artifacts for the ambient homes should not be only technology-driven; it should also consider other aspects of home environment with a view to providing comfort and convenience to people living in the environment. Our work is geared towards this direction and is focused on the design and development of a smart mirror interfaces for the ambient home environment. In this project we make the following contribution. We proposed and developed a functional prototype of the smart mirror using off the-shelf technologies that provide personalized data feeds such as weather, time, and reminder. The mirror can be used as a traditional mirror that essentially provides a sense of natural interaction with the surrounding

environment and also we provide an easily extendable framework for integrating web services such as YouTube videos, interactive maps and checking a full week's weather with the mirror interface The Artificially Intelligent Smart Mirror is designed to perform several functionalities that can be explained, it will mimic a natural mirror interface through a flat LED monitor used for the mirror display. A one-way mirror is used in front of the LED monitor thereby mimicking the function of a regular mirror. For personalized information services the users will be able to obtain minute updates of latest news and public headlines, weather reports as well as get reports of our interests.

1.2 BACKGROUND

This research is based on IoT using Raspberry pi technology. The background study was conducted to identify existing similar systems in order to get a better result. Raspberry technology has been used in many advanced applications with advanced results. This review mainly covers the methodology followed in the background study, including the advantages and disadvantages of the system. One is about a smart mirror which is an interactive system which possesses limited features such as displaying the date, time, and current weather condition and outside temperature and news feeds. However, it can simply display the information which is available on the Internet and cannot connect with the smart phones using an Android application. This smart mirror lacks many features and people cannot send notifications to the mirror, which is its main disadvantage which has not been resolved until now. The existing research which is about an Environment Monitoring System can remotely monitor environmental parameters such as temperature, humidity, amount of CO2 in air and many more in a given environment at any scale using sensors such as DHT11 Digital Humidity and Temperature Sensor, ADIS16220 Digital Vibration Sensor and LPG Gas Sensor - MQ-6. Raspberry-pi used as the main board and

sensors will collect all the real-time data from this environment and this real-time data will be fetched by the web server and displayed. This system can monitor most of the parameters in the environment and it is capable of many other practical uses including monitoring of temperature and humidity in a house, outbuilding, greenhouse, or even a museum. Mendrela et al. present a Patient Monitoring System which can be used to wirelessly monitor patients. The physiological parameters such as temperature, blood pressure, ECG and level of saline are measured through WSN (Wireless Sensor Nodes) using sensors such as Temperature sensor- LM 35, Blood pressure sensor, Level Detector, ECG electrodes and RF modules. This will improve the normal life of patient by reducing the risk of infection and severe conditions when the doctor or nurse is not nearby. But the major problem of this system is the difficulty to monitor symptoms that are not externally visible such as depression and mental disorders. V. Ramya et al discussed a secure and energy efficient Wireless Industrial Automation system which is based on Raspberry pi technology. It controls industrial devices, manages power utilities and also monitors the employee activities. These are all done through Wi-Fi network with help of server PC. This server PC is password protected and it can be opened only by the authorized person. They have been mainly focused on reducing the power consumption and to alert the people about the critical situations in the industry. This system prevents more accidents and provides more security and privacy to the organizations like industry, education and hospitals. This is a system using Raspberry pi on children tracker application is for children safety protection. This system for guidance the user to detect the coordinate of their children. In system development part, this communication process is started from the system able detect the children coordinate and send it to the user web server. Raspberry Pi is the main controller of this system. Over all the system is user friendly and it allows to track the child anytime anywhere in any weather condition. Home

automation is one of big area of Internet of Things (IoT) gives huge benefits and also give little bit disadvantages. PIR sensor, Temperature sensor , Smoke or gas detector sensor, Heater and water level sensor all sensors together create proper understanding about how manage the system. Smita et al. presents the application of IoT for Smart Home Automation system which includes a Raspberry Pi as a processing unit for data which is extracted from various sub-systems like, Temperature sensing system, Automatic light system, Cooling system, and Gas detection system, Water level sensing system, Motion detection system and Lights on and off system. With low cost raspberry pi module implement the intelligent processes through ARM1176JZFS processor and connected decisions and monitoring through the internet. Accessing interconnected devices using internet through TCP/IP concept is most secured and efficiency way. It may depend on measuring sensors data, controlling home appliance, monitoring live status of devices and etc.

1.3 PROBLEM STATEMENT

In today's complicated world, efficient parenting becomes more important, and parents and guardians must educate and bring up their children in a technologically advanced environment. Children need the guidance of their parents more than ever. Yet, in today's busy world, where both parents are normally employed, or in the case of single parents, this is quite challenging. However, this problem could be overcome through a revolutionary device called the Raspbian smart Mirror that can be implement using Raspberry pi technology, which will be the subject of our research based on IoT. This reduces the time available for them to communicate with their children and to make sure that they are safe. It will also enable teenagers to make responsible at their work. This will be especially useful in the case of differently disabled children, since they would require more adult supervision and attention from their parents. The

main focus is to save the time of working parents, enable efficient parenting and make day to do life easier and faster which is an integral part of home automation as well. Raspbian Magic Mirror is a smart mirror which will possess the ability to display advance details and connect with the user's smart phone by using an Android application.

1.4 AIMS AND OBJECTIVES

The aim of the project is to design and implement a smart mirror using an lcd display and a microcomputer (Raspberry pi) while the objectives are to:

I. Describe and explain the fabrication and design of the smart mirror using a lcd display and a microcomputer (Raspberry pi), and

II. Develop a mirror that can serve not just the purpose of a mirror, but can also give information such as news feeds, weather forecast, email notifications and can also serve as an advertisement tool.

1.5 SIGNIFICANCE OF STUDY

The smart mirror has the significance of helping humans for time management which has been a major problem in our world today, ability to see oneself in the mirror and get other information on the mirror, reducing the time spent on phones while trying to dress up and giving real time information while dressing up.

CHAPTER TWO

2.0 LITERATURE REVIEW

Conducting the literature review is done prior to undertaking the project. This will critically provide as much information as needed on the technology available and methodologies used by other research counterparts around the world on the topic. This chapter provides the summary of literature reviews on topics related to the smart mirror or a mirror that has capabilities to do more than the basic traditional mirror.

Vaibav Khanna *et al.*, (2017) designed the Smart Mirror implemented as a personalized digital device equipped with peripherals such as Raspberry Pi, microphone, speakers, LED Monitor covered with a sheet of reflective one way mirror provides one of the most basic common amenities such as weather of the city, latest updates of news and headlines and local time corresponding to the location. Using speech processing techniques the Smart Mirror therefore interacts with the user through verbal commands, functions and listens to the user's question and responds them adequately. Below is the block diagram of the design (Fig 2.1)

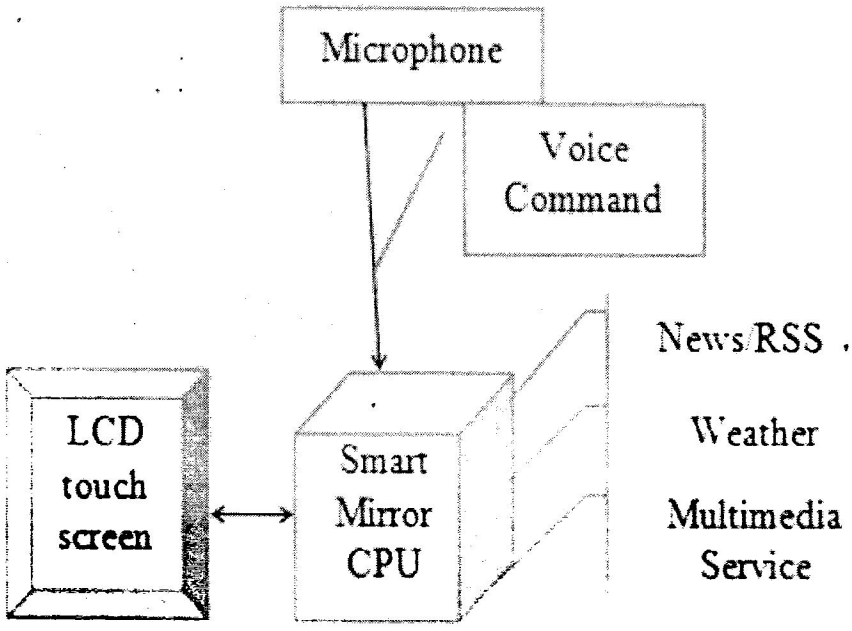


Fig 2.1 Design block diagram

Tien Le *et al.*, (2016) designed a "Smart Mirror" consisting of an electronic display along with a one-way mirror for the informational display. They used a camera to track movement and provide facial recognition with the use of an embedded computer. Users can create their customized display through a smartphone interface. Some informational displays contain information aggregated from third party APIs, such as social media feeds, news feeds, and weather updates.

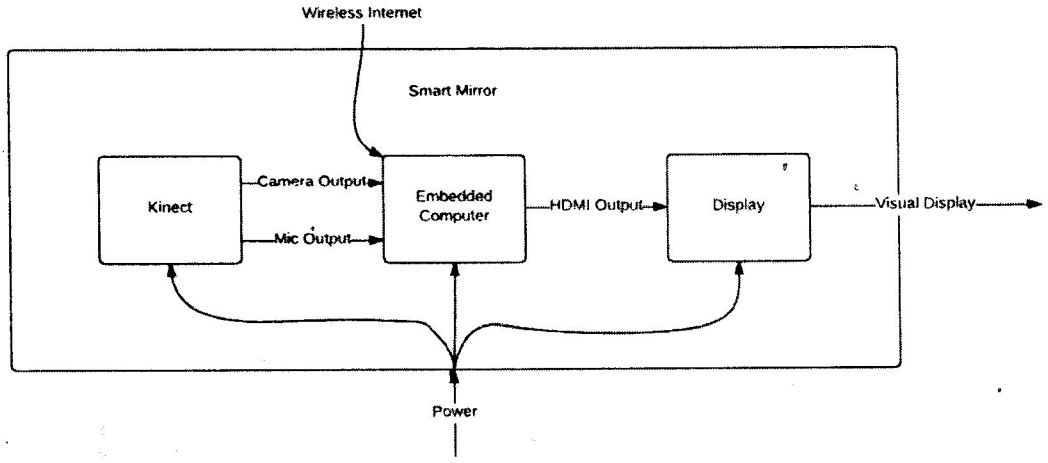


Fig 2.2 Working flow chart

Jane Jose *et at.*, (2017) designed a smart mirror with the ability to display date and time, outside temperature, reminders, to-do lists and the current weather condition. These features of the mirror were scraped from the internet and implemented using the raspberry pi board. The pi board was programmed the raspbian operating system which is part of linux. They integrated the GrovePi which helps add multiple modules to the pre-existent Pi Board. The availability of more modules allows the addition of more sensors in the case of this architecture

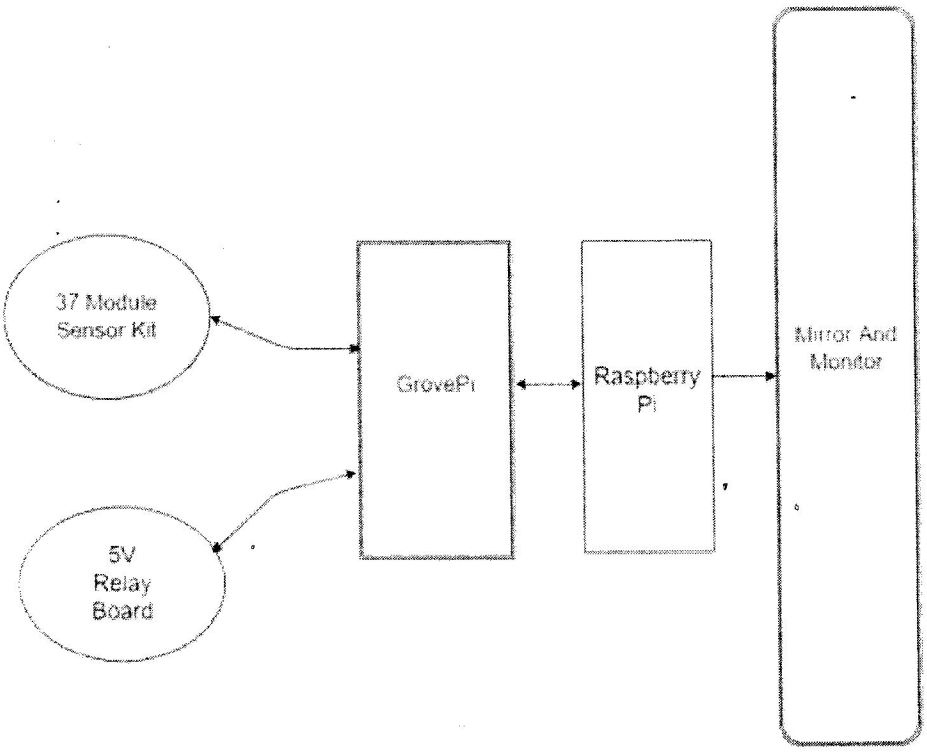


Fig 2.3 Design flow chart

R. M. B. N. Siripala *et al.*, (2017) designed a smart mirror that helps parent monitor their children while they are away, it can also be used to plan a routine table for the teenage children to help with their assignments and house hold chores. At the hardware implementation, the physical mirror body is designed with the Two-way mirror, LED Monitor and the Raspberry Pi Circuit. Coding the program is done at the software implementation where it again classified as frond end programming and back end programming. Database is also implemented and integrated to the same system.

Software Platforms and Languages:

- Application Running on Raspberry Pi: Electron Framework which is used JavaScript, HTML5 and Node JS
- Mobile Application: Android Framework using Java Language
- Web Application: Angular JS
- Database: MongoDB that is using Non-Structured query language.

The mobile application allows the parent to communicate with the mirror and child while away.

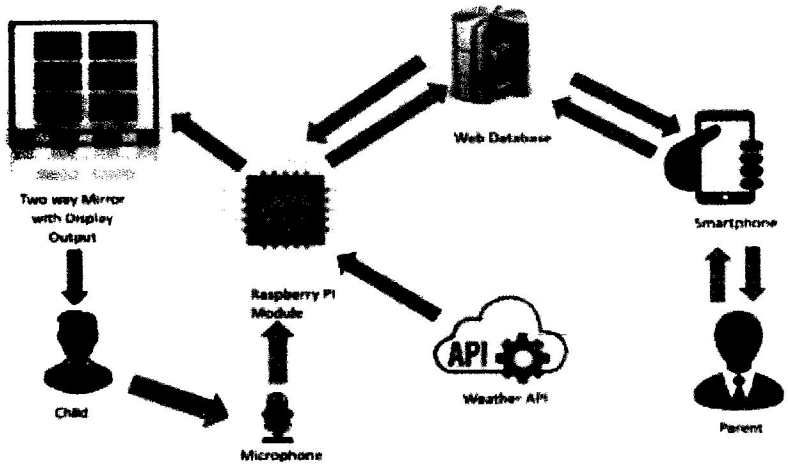


Fig 2.4 API connections

Aswin O *et al.*, (2018) proposed a smart mirror that can be integrated into the daily bathroom routine, which uses the raspberry pi 3 computer and frame work that retrieves it data from the web via Wi-Fi connectivity. Through the facial recognition and speech recognition model, the smart mirror recognises/ identifies the user

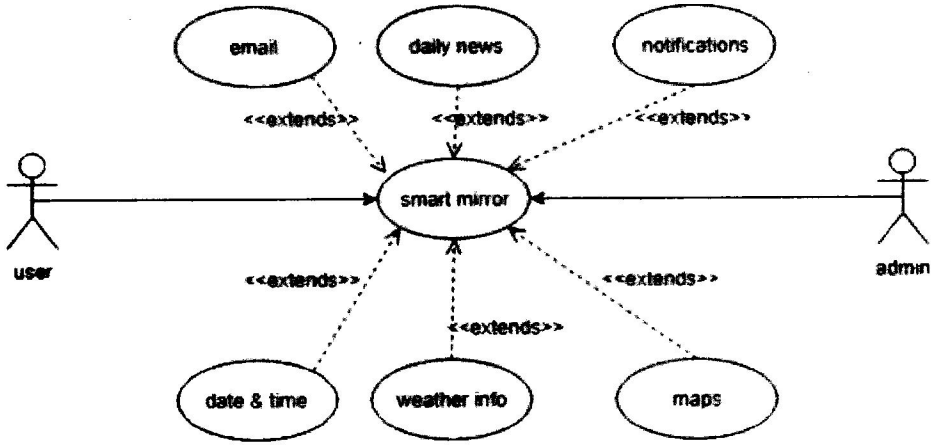


Fig 2.5 Data processing block diagram

Georgiy Brussenskiy *et al.*, (2014) proposed a smart mirror that has the necessary applications and features needed for time efficiency focused device. First, there is the easy on and off. The mirror automatically recognizes that there is a user present and turns on the screen hidden behind the two-way mirror. A suit of six applications are presented on the 32" high-definition screen surrounded by a framed encasing that contains speakers and a webcam. These apps include weather, Twitter, news, to-do list, calendar, and music. The smart mirror application is run from a central computer with Windows 8.1 which features a multi-core CPU, solid-state memory, and wireless connectivity. The application can be interacted with by use of the Leap Motion controller. This controller allows for touch-free control of the smart mirror by use of finger swipes, taps, and circles. There is also the option to use voice control to play music, post a tweet, or add a task to the to-do list. Finally, the mirror monitors its own temperature and humidity levels so that if the bathroom becomes potentially harmful to the computer's hardware, it can execute preventive measures and shut the system down.

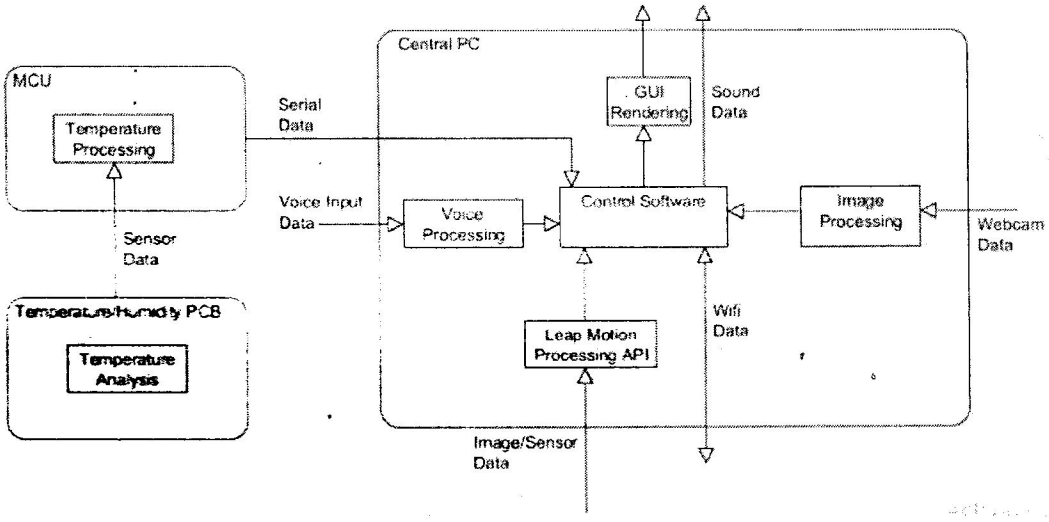


Fig 2.6 Process flow and data exchange

Abhishek Pathak *et al.*,(2018) designed a futuristic smart mirror with artificial intelligence using the raspberry pi the system has the ability to recognize face and provide details of the same, incorporates the theory of artificial intelligence. They created a smart system for users where it detects face using OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. This software is mostly used for image processing and video analysis. With the help of this programming the computer processes and ultimately understands images and videos. The mirror will recognize user's face and it will be processed using Raspberry Pi and display user's feeds. User's image will be stored in database.

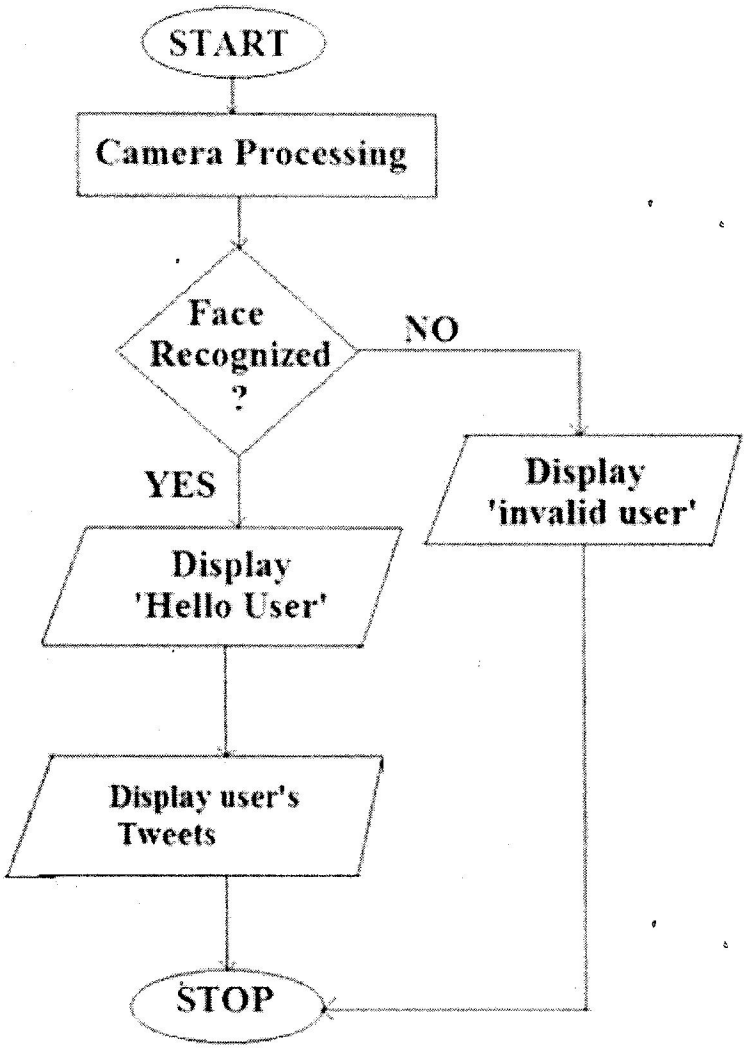


Fig 2.7 Flow chart

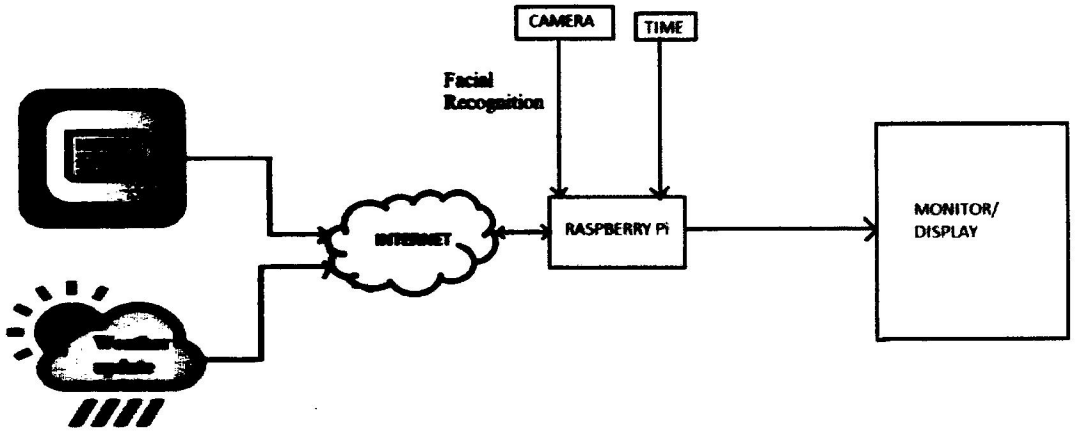


Fig 2.8 Modules API connections

Vivek.V *et al.*, (2018) proposed a design for a smart mirror for disabled/physically challenged. The **various technologies used** in the proposed smart mirror are Artificial Intelligence, Deep learning, **Cloud. Artificial intelligence** has extended its intelligent conclusion retrieval is being achieved **using Machine learning.** It derives the conclusion based upon the collected data. Machine **learning is latest technology** of making the machine to learn the data and to bring the conclusion **by making itself a decision.** Deep learning is the growing technique of determining the **conclusion with high accuracy.** Deep learning is a kind of machine learning in which ML learns **without being explicitly programming.** Once the program is implemented it should react based **on real time data in variable** environment.

Daniel Bonnerer *et al.*, (2016) designed and developed a mirror that has a user identification **module, interactive games** for the user and Activities tracking. It enhanced with the emotion **detection. Here it is not implemented** for any security features.

Husni Ruslai et al., (2017) developed a smart mirror for a smart life, the smart mirror is **developed based on three** objectives namely to:

1. **Design a prototype Smart** Mirror using Raspberry PI
2. **Develop a voice recognition** system to facilitate the implementation of Smart Mirror, and
3. **Carry out the testing** process on Raspberry PI for usability evaluation to users.

But the security and home safety is not being implemented, the authors focused on developing smart mirror for smart life where bring a Human Technology interface and to meet the functional requirements. There are predefined available commands to enhance the user to use those commands to use smart mirror efficiently.

Muhammad Mu'izzudeen Yusri *et* al., (2017) proposed a smart mirror called the "Wize mirror", in this design a touch less data acquisition is achieved using Vision camera and Multispectral camera for emotional analysis. The Wize Mirror features an advanced sensing framework for unobtrusive acquisition of videos, images, and 3D scans of individuals standing in front of the mirror. Multispectral cameras are used for analysis the skin tissues and microcirculation. In the main objective is to promote a healthy lifestyle using smart mirror.

Yasmina Andreu A. *et al.*, (2016) proposed a Wize mirror that uses multisensory cardio-metabolic risk monitoring system. In this paper, mirror is built as a result of the FP7 funded SEMEOTICONS (Semeiotic Oriented Technology for Individuals Cardio metabolic risk self-assessment and Self-monitoring). In this, user can self-monitor their well-being status over time and to improve their lifestyle using latest technology.

Young Bag Moon *et al.,* (2015) proposed a smart mirror to monitor the elder at the home, it collect the data like pulse, emotion, Blood pressure of them and collect those data in EC system, This system then process the data with the threshold limit set in the EC system, When a threshold limit exceed, and alert messages with the critical value of forwarded to the elder care taker via SMS.

Piyush Maheshwari *et al.*, (2017) developed a smart mirror that is a reflective interface, which displays the news feed, calendar, reminder features to the user. Author also proposed it with a face recognition system that identifies the user, here no other features are being proposed.

Chidambaram Sethukkarasi *et al.*, (2012) proposed an interactive mirror with Home aware, it consist of many interactive features like Load cell, RFID, webcam. The load cell is used to weigh the user and get his BMI, RFID is used to detect the garments worn by the user, and webcam is to perform the face recognition. Here no home automation and security features are being proposed.

TABLE 1.0 Previous works and there limitations.

S/N	TITLE OF PROJECT	OUTPUT	LIMITATIONS
1	Smart Mirror implemented as a personalised digital device	Provides one of the most basic common amenities such as weather of the city, latest updates of news and headlines and local time corresponding to the location.	No security features
2	Smart Mirror	Uses a camera to track movement and provide facial recognition with the use of an embedded computer. Users can create their customized display through a smartphone interface. Displays information aggregated from third party APIs, such as social media feeds, news feeds, and weather updates.	None
3	Home Automated Smart Mirror as an Internet of Things (IoT) Implementation	Smart mirror has the Home automated system with home application control	No security features and no social media
4	Smart mirror that helps parent monitor their children	Used to plan a routine table for the teenage children to help with their assignments and house hold chores. The mobile application allows the parent to communicate with the mirror and child while away.	No security features and no social media

5	Smart mirror for the bathroom	Through the facial recognition and speech recognition model, the smart mirror recognises/ identifies the user	
6	Smart mirror for time	There is the easy on and off. The mirror automatically recognizes that there is a user present and turns on the screen hidden behind the two-way mirror. The Leap Motion controller allows for touch-free control of the smart mirror by use of finger swipes, taps, and circles. There is also the option to use voice control to play music, post a tweet, or add a task to the to-do list. The mirror monitors its own temperature and humidity levels	
7	A futuristic smart mirror with artificial intelligence	A smart system for users where it detects face using OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. The mirror will recognize user's face and it will be processed using Raspberry Pi and display user's feeds. User's image will be stored in database.	No social media features
8	A smart mirror for disabled/physically	The mirror is based on artificial	No security features, no

	challenged	intelligence, deep learning. Deep learning is a kind of machine learning in which ML learns without being explicitly programming. Once the program is implemented it should react based on real time data in variable environment.	social media features
9	FitMirror: A Smart Mirror For Positive Affect in Everyday User Morning Routines	Smart mirror has user identification, Interactive games, activities tracking, Emotion detection	No security and emergency features
10	Smart mirror for smart life	Effective Voice user interface and interact using available commands, Home control system is implemented.	Security feature and Home safety is not being implemented. No social media activities
11	A smart mirror to promote a healthy lifestyle	Reduce the socio-economic burden of chronic and widespread diseases, such as cardiovascular and metabolic diseases.	Security feature and Home safety is not being implemented, No voice user interface.
12	Wize Mirror - a smart, multisensory cardio metabolic risk monitoring system	Translate the semeiotic code of the human face into computational descriptors and measures, automatically extracted from videos, multispectral images	No social media activities. No Home control system.
13	Smart Mirror Health Management Services based on IoT Platform	Monitor the parent health (Pulse, Blood pressure, etc.), uses Elder care system which collects the data and notify their care taker via SMS to their Android phone.	No security provided to elder who are alone in the home, No entertainment

			features, Emergency call facilities not available
14.	Smart Mirror: A Reflective Interface to Maximize Productivity	Smart mirror for displaying the news feeds, Calendar, weather and it has face recognition using webcam	No security features and No Home control system.
15	Design and Development of Interactive Mirror for Aware Home	Smart mirror with face recognition, load sensors for measuring user's weight, Radio-frequency identification (RFID) reader and RFID tags for identifying the garment worn by the user	No security features and No Home control system.

CHAPTER THREE

3.0 METHODOLOGY

3.0.1 Materials selection and design

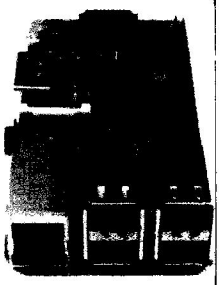
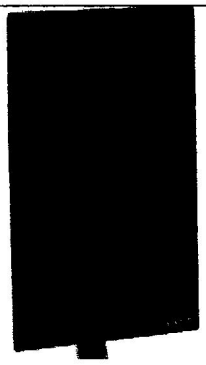
The materials used for the construction of the smart mirror frame/exterior are wood and see through glass (Two way mirror), this materials were used to construct the frame and screen of the mirror.

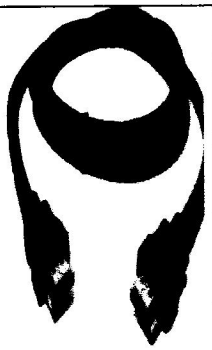
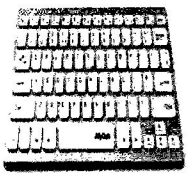
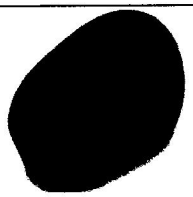
Wood is a porous and fibrous structural tissue found in the stems and roots of trees and other woody plants. It is an organic material, a natural composite of cellulose fibers that are strong in tension and embedded in a matrix of lignin that resists compression. Perhaps one of the biggest advantages of using wood is that it is a natural resource, making it readily available and economically feasible. It is remarkably strong in relation to its weight, and it provides good insulation from the cold. Wood is highly machinable, and can be fabricated into all kinds of shapes and sizes to fit practically any construction need. Wood is also the perfect example of an environmentally sustainable product; it is biodegradable and renewable, and carries the lowest carbon footprint of any comparable building material.

Also known as two-way mirror, a see through mirror is glass that is reflective on one side and clear on the other, giving the appearance of a mirror to those who see the reflection but allowing people on the clear side to see through, as if at a window. Two-way mirrored glass is made the same way traditional mirrors are made, with a thin coating of metal behind the glass; however, two-way mirrored glass only has half the amount of metal backing that traditional mirrors do. One coat of metal causes most of the light to reflect back toward the source but does prevent some of it from passing through, which allows occupants on the other side to see through. The metal coating does, however, darken what can be seen from the non-reflective side, giving the impression of looking through a tinted window.

3.0.2 System components and description

System components of the smart mirror

S/N	System components	Qty	Image	Description	Reasons for use
1	Raspberry Pi 3B	1		The Raspberry Pi device looks like a motherboard, with the mounted chips and ports exposed, but it has all the components you need to connect input, output, and storage devices and start computing.	Serves as the processor of the system, coordinating all inputs, outputs and connection to the internet.
2	AOC lcd monitor	1		A 19 inches lcd screen with VGA input , it is an output device that displays information in pictorial form.	To display ouputs of the system and serves the puropose of interfacing with the user.
3	8GB Micro SD card	1		A small chip, encased with a rectangular plastic.	To store the operating system of the mirror.
4	Standard type A HDMI cable	1		HDMI (High-Definition Multimedia Interface) is a proprietary audio/video interface for transmitting	Serves as an audio/video interface for transmitting uncompressed video data and compressed or uncompressed

				uncompressed video data and compressed or uncompressed digital audio data from an HDMI-compliant source device, such as a display controller, to a compatible computer monitor, video projector, digital television, or digital audio device	digital audio data from the raspberry pi to the monitor.
5	HDMI to VGA adapter	1		An auadio visual interface and adapter for inter-connections from a HDMI male port to a VGA male port.	It connects the HDMI cable from the raspberry pi to the monitor VGA port.
6	2.4 Ghz wireless keyboard	1		A keyboard is a typewriter-style device which uses an arrangement of buttons or keys to act as mechanical levers or electronic switches.	Its a device used to input data manually into the system.
7	2.4 Ghz wireless mouse	1		A computer mouse is a hand-held pointing device that detects two-dimensional motion relative to a surface.	It is used to navigate and communicate with the system.

3.0.3 Component Overview

The Raspberry Pi is essentially a wireless Internet capable system-on-a-chip (SoC) with 1 GB RAM, connection ports, a Micro SD card slot, camera and display interfaces and an audio/video jack. A Raspberry Pi is a credit card-sized computer originally designed for education, inspired by the 1981 BBC Micro. The Raspberry Pi is slower than a modern laptop or desktop but is still a complete Linux computer and can provide all the expected abilities that implies, at a low-power consumption level. The Raspberry Pi is open hardware, with the exception of the primary chip on the Raspberry Pi, the Broadcomm SoC (System on a Chip), which runs many of the main components of the board–CPU, graphics, memory, the USB controller, etc. Many of the projects made with a Raspberry Pi are open and well-documented as well and are things you can build and modify.

The Raspberry Pi was designed for the Linux operating system, and many Linux distributions now have a version optimized for the Raspberry Pi. Two of the most popular options are Raspbian, which is based on the Debian operating system, and Pidora, which is based on the Fedora operating system. For beginners, either of these two work well; which one you choose to use is a matter of personal preference. A good practice might be to go with the one which most closely resembles an operating system you're familiar with, in either a desktop or server environment. If you would like to experiment with multiple Linux distributions and aren't sure which one you want, or you just want an easier experience in case something goes wrong, try NOOBS, which stands for New Out Of Box Software. When you first boot from the SD card, you will be given a menu with multiple distributions (including Raspbian and Pidora) to choose from. If you decide to try a different one, or if something goes wrong with your system, you simply hold the Shift key at boot to return to this menu and start over.

There are, of course, lots of other choices. OpenELEC and RaspBMC are both operating system distributions based on Linux that are targeted towards using the Raspberry Pi as a media center. There are also non-Linux systems, like RISC OS, which run on the Pi. Some enthusiasts have even used the Raspberry Pi to learn about operating systems by designing their own.

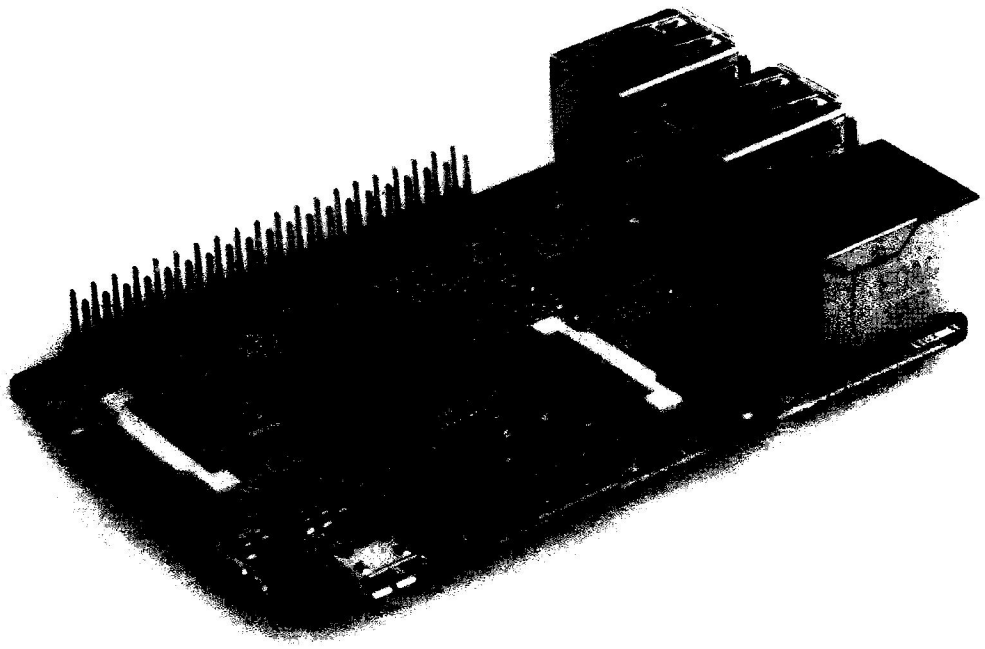
Here are the various components on the Raspberry Pi board:

- BCM43438 wireless LAN and Bluetooth Low Energy (BLE) on board
- Quad Core 1.2GHz Broadcom BCM2837 64bit CPU -- This is a Broadcom BCM2835 System on a Chip (SoC) that's made up of an ARM central processing unit (CPU) and a Videocore 4 graphics processing unit (GPU). The CPU handles all the computations that make a computer work (taking input, doing calculations and producing output), and the GPU handles graphics output.
- 40-pin extended GPIO -- These are exposed general-purpose input/output connection points that will allow the real hardware hobbyists the opportunity to tinker.
- RCA -- An RCA jack allows connection of analog TVs and other similar output devices.
- Audio out -- This is a standard 3.55-millimeter jack for connection of audio output devices such as headphones or speakers. There is no audio in.
- LEDs -- Light-emitting diodes, for all of your indicator light needs.
- 4 USB 2 ports -- This is a common connection port for peripheral devices of all types (including your mouse and keyboard). You can use a USB hub to expand the number of ports or plug your mouse into your keyboard if it has its own USB port.
- HDMI -- This connector allows you to hook up a high-definition television or other compatible device using an HDMI cable.
- Power -- This is a 5v Micro USB power connector into which you can plug your compatible power supply.
- SD cardslot -- This is a full-sized SD card slot. An SD card with an operating system (OS) installed is required for booting the device. They are available for purchase from the manufacturers, but you can also download an OS and save it to the card yourself if you have a Linux machine and the wherewithal.
- 100 Base Ethernet -- This connector allows for wired network access and is only available on the Model B.
- 4 Pole stereo output and composite video port.
- CSI camera port for connecting a Raspberry Pi camera.
- DSI display port for connecting a Raspberry Pi touchscreen display.

The Raspberry Pi measures roughly 3.4 inches by 2.1 inches (8.6 centimeters by 5.3 centimeters), but it is pretty powerful for such a small device. This was made possible by the

ready availability of inexpensive and tiny processors for mobile devices, which need to pack a decent amount of processing and multimedia capability into a small shell with the ability to stay relatively cool and not suck power too quickly. A chip with ARM architecture was picked for this reason (a processor architecture commonly used for mobile phones and similar devices). The chip has 256 MB of RAM, runs at 700 MHz and includes a 1080p-capable GPU. Like many of the earliest home computers, the device comes without peripherals or internal storage space, and the user will have to attach input, output and storage peripherals. At a minimum, you'll need a television or monitor for output, a keyboard (and possibly a mouse) for input, an SD card on which to house the OS and store data, a power supply and any necessary cables. You can add an external hard drive for additional storage, but the SD card will still be necessary, as the OS will boot from SD by default. The Raspberry Pi's programmability and simplicity make it very like the computers of yore that spawned so many programmers and system hobbyists. But unlike those computers, this device can be used for Web surfing. The Internet will make finding things you can do with the device much easier than back in the day.

Fig 2.0 Raspberry Pi model 3B



A computer monitor is an output device that displays information in pictorial form. A monitor usually comprises the display device, circuitry, casing, and power supply. The display device in modern monitors is typically a thin film transistor liquid crystal display (TFT-LCD) with LED backlighting having replaced cold-cathode fluorescent lamp (CCFL) backlighting. A liquid crystal display (LCD) monitor is a computer monitor or display that uses LCD technology to show clear images, and is found mostly in laptop computers and flat panel monitors. This technology has replaced the traditional cathode ray tube (CRT) monitors, which were the previous standard and once were considered to have better picture quality than early LCD variants. With the introduction of better LCD technology and its continuous improvement, LCD is now the clear leader over CRT, in terms of color and picture quality, not to mention capabilities for large resolutions. Also, LCD monitors may be made much more cheaply than CRT monitors. Liquid crystal display technology works by blocking light. Specifically, an LCD is made of two pieces of polarized glass (also called substrate) that contain a liquid crystal material between them. A backlight creates light that passes through the first substrate. At the same time, electrical currents cause the liquid crystal molecules to align to allow varying levels of light to pass through to the second substrate and create the colors and images that you see.

Older monitors used a cathode ray tube (CRT). Monitors are connected to the computer via VGA, Digital Visual Interface (DVI), HDMI, Display Port, Thunderbolt, low-voltage differential signaling (LVDS) or other proprietary connectors and signals. Originally, computer monitors were used for data processing while television receivers were used for entertainment. From the 1980s onwards, computers (and their monitors) have been used for both data processing and entertainment, while televisions have implemented some computer functionality. The common aspect ratio of televisions, and computer monitors, has changed from 4:3 to 16:10, to 16:9.

Modern computer monitors are easily interchangeable with conventional television sets. However, as computer monitors do not necessarily include components such as a television tuner and speakers, it may not be possible to use a computer monitor as a television without external components. A desktop monitor is typically provided with a stand from the manufacturer which lifts the monitor up to a more ergonomic viewing height. The stand may be attached to the monitor using a proprietary method or may use, or be adaptable to, a Video Electronics Standards Association, VESA, standard mount. Using a VESA standard mount allows the

monitor to be used with an after-market stand once the original stand is removed. Stands may be fixed or offer a variety of features such as height adjustment, horizontal swivel, and landscape or portrait screen orientation. There are multiple technologies that have been used to implement liquid crystal displays (LCD). Throughout the 1990s, the primary use of LCD technology as computer monitors was in laptops where the lower power consumption, lighter weight, and smaller physical size of LCD's justified the higher price versus a CRT. Commonly, the same laptop would be offered with an assortment of display options at increasing price points: (active or passive) monochrome, passive color, or active matrix color (TFT). As volume and manufacturing capability have improved, the monochrome and passive color technologies were dropped from most product lines. TFT-LCD is a variant of LCD which is now the dominant technology used for computer monitors.

Most modern monitors will switch to a power-saving mode if no video-input signal is received. This allows modern operating systems to turn off a monitor after a specified period of inactivity. This also extends the monitor's service life. Some monitors will also switch themselves off after a time period on standby. Most modern systems provide a method of screen dimming after periods of inactivity or when the battery is in use. This extends battery life and reduces wear. Many monitors have other accessories (or connections for them) integrated. This places standard ports within easy reach and eliminates the need for another separate hub, camera, microphone, or set of speakers. These monitors have advanced microprocessors which contain codec information, Windows Interface drivers and other small software which help in proper functioning of these functions. Some displays, especially newer LCD monitors, replace the traditional anti-glare matte finish with a glossy one. This increases color saturation and sharpness but reflections from lights and windows are very visible. Anti-reflective coatings are sometimes applied to help reduce reflections, although this only mitigates the effect. The resolution for computer monitors has increased over time. From 320x200 during the early 1980s, to 1024x768 during the late 1990s. Since 2009, the most commonly sold resolution for computer monitors is 1920x1080. Before 2013 top-end consumer LCD monitors were limited to 2560x1600 at 30 in (76 cm), excluding Apple products and CRT monitors. Apple introduced 2880x1800 with Retina MacBook Pro at 15.4 in (39 cm) on June 12, 2012, and introduced a 5120x2880 Retina iMac at 27 in (69 cm) on October 16, 2014. By 2015 most major display manufacturers had released

3840x2160 resolution displays. Newer monitors are able to display a different image for each eye, often with the help of special glasses, giving the perception of depth. An auto stereoscopic screen can generate 3D images without headgear.

Fig 3.1 LCD monitor

SMART MIRROR BLOCK DIAGRAM AND ANALYSIS

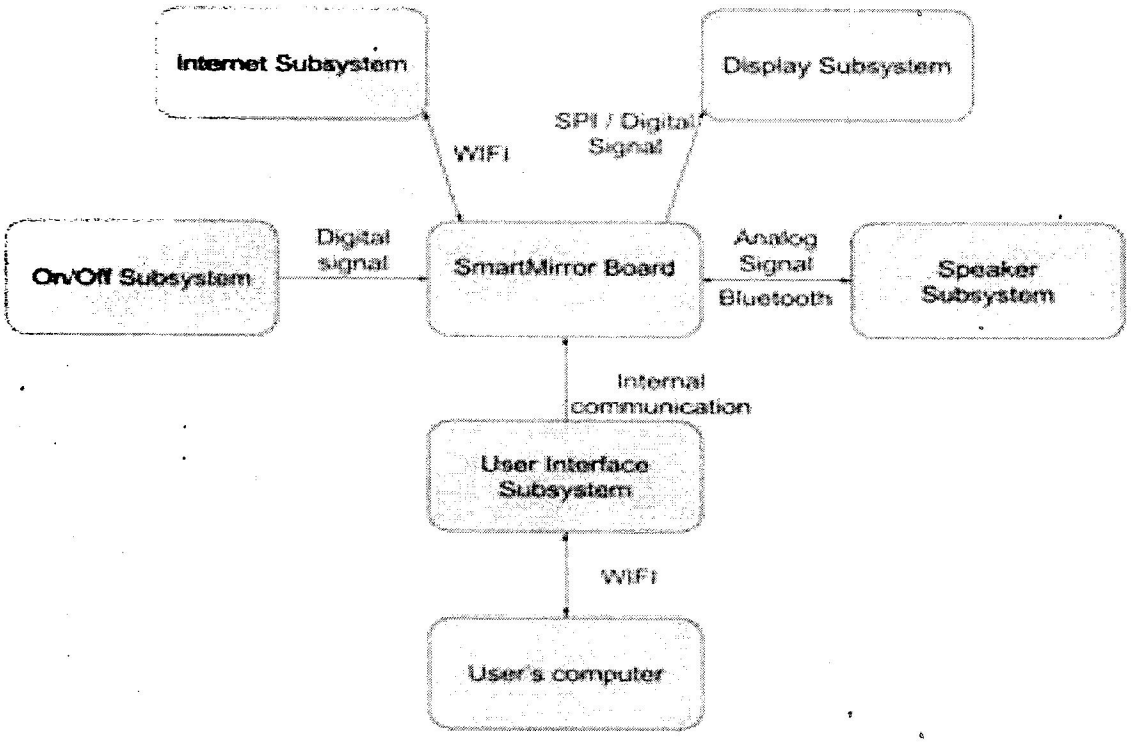


Fig 3.2 A block diagram of the smart mirror

3.0.4 CODING

The programming languages used are Python and node javascript.

Python is a general-purpose language, which means it can be used to build just about anything, which will be made easy with the right tools/libraries. Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales. In July 2018, Van Rossum stepped down as the leader in the language community after 30 years.

Python features a dynamic type system and automatic memory management. It supports multiple programming paradigms, including object-oriented, imperative, functional and procedural, and has a large and comprehensive standard library. Python interpreters are available for many operating systems. CPython, the reference implementation of Python, is open source software and has a community-based development model, as do nearly all of Python's other implementations. Python and CPython are managed by the non-profit Python Software Foundation. Python is a multi-paradigm programming language. Object-oriented programming and structured programming are fully supported, and many of its features support functional programming and aspect-oriented programming. Many other paradigms are supported via extensions, including design by contract and logic programming. Python uses dynamic typing, and a combination of reference counting and a cycle-detecting garbage collector for memory management. It also features dynamic name resolution, which binds method and variable names during program execution. Rather than having all of its functionality built into its core, Python was designed to be highly extensible. This compact modularity has made it particularly popular as a means of adding programmable interfaces to existing applications. It has simple easy-to-use syntax, making it the perfect language for someone trying to learn computer programming for the first time. Python has a very simple and elegant syntax. It's much easier to read and write Python programs compared to other languages like: C++, Java, C#. Python makes programming fun and allows you to focus on the solution rather than syntax. You can freely use and distribute Python, even for commercial use. Not only can you use and distribute software written in it, you can even make changes to the Python's source code. You can move Python programs from one

platform to another, and run it without any changes. It runs seamlessly on almost all platforms including Windows, Mac OS X and Linux. Python has a number of standard libraries which makes life of a programmer much easier since you don't have to write all the code yourself. For example: Need to connect MySQL database on a Web server? You can use MySQLdb library using import MySQLdb. Standard libraries in Python are well tested and used by hundreds of people. So you can be sure that it won't break your application. Everything in Python is an object. Object oriented programming (OOP) helps you solve a complex problem intuitively. With OOP, you are able to divide these complex problems into smaller sets by creating objects. You don't need to define the type of a variable in Python. Also, it's not necessary to add semicolon at the end of the statement. Python allows you to write programs having greater functionality with fewer lines of code.

Node.js is a JavaScript runtime built on Chrome's V8 JavaScript engine. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. npm is a Node.js package of open source library which is largest in the world. It's an asynchronous event driven JavaScript runtime, which is designed to build scalable network applications. It can handle many concurrent connections at a time, where when connection request are made concurrently for each connection a callback is fired .If there is no task to be performed Node will go to sleep. Node.js is an open-source, cross-platform JavaScript run-time environment for executing JavaScript code server-side. Historically, JavaScript was used primarily for client-side scripting, in which scripts written in JavaScript are embedded in a webpage's HTML, to be run client-side by a JavaScript engine in the user's web browser.

Node.js was first conceived in 2009 by Ryan Dahl and was developed and maintained by Ryan which then got sponsored and supported by Joyent. Dahl was not happy the way Apache Http server used to handle the lot of concurrent connections and the way code was being created which either blocked the entire process or implied multiple execution stacks in the case of simultaneous connections. This lead him to create a Node.js project which he went on to demonstrate at the inaugural European JSConf on November 8, 2009. He used Google's V8 JavaScript engine, an event loop, and a low-level I/O API in his project which won lon of hearts and standing ovation. In June 2011, Microsoft and Joyent implemented a native Windows version of Node.js. The first Node.js build supporting Windows was released in July 2011.In

January 2012, Dahl stepped aside, promoting coworker and npm creator Isaac Schlueter to manage the project.In December 2014, Fedor Indutny started io.js, a fork of Node.js. Due to the internal conflict over Joyent's governance, In February 2015, the intent to form a neutral Node.js Foundation was announced. By June 2015, the Node.js and io.js communities decided to work together under the Node.js Foundation.

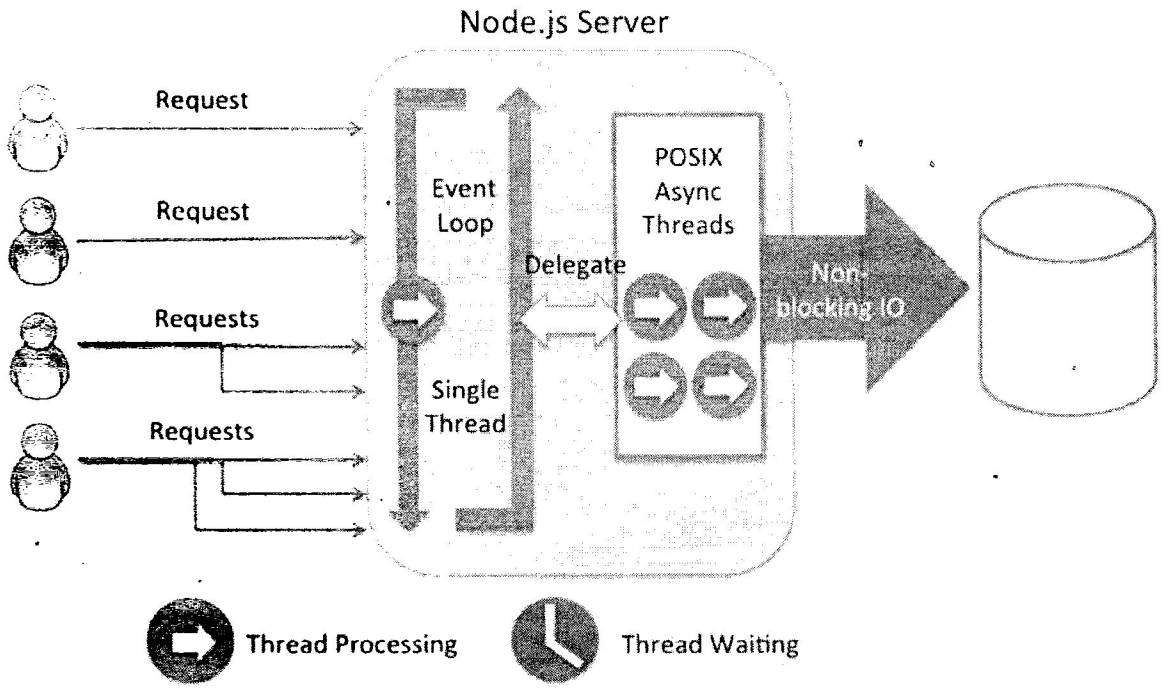


Fig 3.3 Server request processing

Some of the important features that make Node.js the first choice of software architects are:

- Asynchronous and Event Driven – All APIs of Node.js library are asynchronous, that is, non-blocking. It essentially means a Node.js based server never waits for an API to return data. The server moves to the next API after calling it and a notification mechanism of Events of Node.js helps the server to get a response from the previous API call.
- Very Fast – Being built on Google Chrome's V8 JavaScript Engine, Node.js library is very fast in code execution.
- Single Threaded but Highly Scalable – Node.js uses a single threaded model with event looping. Event mechanism helps the server to respond in a non-blocking way and makes

the server highly scalable as opposed to traditional servers which create limited threads to handle requests. Node.js uses a single threaded program and the same program can provide service to a much larger number of requests than traditional servers like Apache HTTP Server.

- No Buffering – Node.js applications never buffer any data. These applications simply output the data in chunks.
- License – Node.js is released under the MIT license

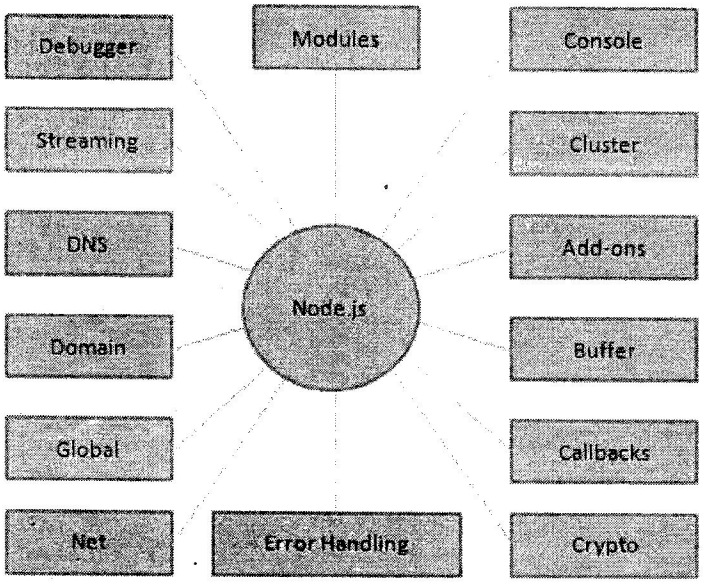


Fig 3.4 Concept of node.js

3.0.5 INSTALLATION PROCEDURE

The first step was to prepare the SD card by formatting it then we downloaded Raspbian OS jessie then we wrote the OS on the memory card. Now that we have the operating system on the card, we're ready to boot up the Raspberry Pi (rpi). We put the card into the slot on the bottom of the rpi, plug in the monitor cable and other peripherals, and then we turn the monitor on. After booting the raspberry Pi, we configured the environment to suit the smart mirror project, we expanded the file system, configured language, time zone, change locale, keyboard layout, Wifi country, configure SSH etc. We then configured the raspberry pi wireless so we could connect to

the internet then we updated the system removed unwanted programs. After the desired system configuration has been achieved, we then installed the smart mirror framework which has been preprogrammed on the smart mirror. The next thing we did was to rotate the screen vertically in the configuration file using the terminal. Screensaver and banking was disabled as well and after these, power saving feature was disabled for the wifi to enable the system to always stay connected. After all these necessary configurations, the next line of action was to create a valid configuration file for the smart mirror framework. The features of the smart mirror like weather, time, email, newsfeed, scheduler etc. Were developed separately as modules so we created and installed each module for each feature we want on the smart mirror. We installed the date and time module, weather, email, calendar, newsfeed, remote control feature, compliment module on the smart mirror and we configured their properties appropriately in the configuration file. These method enables us add new features to the smart mirror easily without tampering with the core smart mirror framework.

3.0.6 FRAME CONSTRUCTION

The box/frame houses all the components, including the microphone, and looks pretty.. Cutting the box we picked up a long piece of oak from Home Depot. I then cut all the wood to length, based on calculations. We used a handy jig to form a neat 90-degree angle and then used countersinks and screws to form the box. Because we are going to be attaching the frame from the bottom, we need to add a few supports. We cut a few pieces of thin pine and screwed them into place from the inside. The screws we used were sized so that we wouldn't pierce the side of the box. Now that the box is built, it's time to build the frame. We measured and cut the frame pieces and then used the compound miter saw to cut the ends into 45 degree angles. Clamping each piece together and then cutting with the miter saw ensures that the edges will be at a symmetrical 45 degree angle. We used a few pieces of scrap pine to do this, measuring the output and calibrating the saw as needed. I'm going to attach my framing from beneath so that the screws don't show, but first we need to get the frame nice and rigid. To do this, we glued it together, give it time to set, and then proceed to attach it from beneath. We laid down some newspaper, applied a small amount of wood glue to each corner, squared everything up with my speed square, and then used clamps to hold everything in place. Then, We waited a day for the

glue to cure. Before we glued the frame, we measured one last time to make sure that its inside dimensions are still correct (this can be a costly mistake both time-wise and material-wise!). We applied a small amount of glue to the lip of the box and then drove screws through the box supports to attach the frame from the underside. This way, the screws won't show from the outside but the frame will be securely attached to the box. The frame is ready for sanding! Again, We measured the box slightly too narrow so we won't be able to fit an interior support on one side of the frame. Thus, We used a little extra glue and clamps to hold it in place so that that particular side will remain tight. we used 220-grit sandpaper and power sander to sand all exterior surfaces of the frame and box. The wood we purchased was already finished nicely so we didn't need to go rougher than that. We removed the excess saw dust with a damp cloth. Using a foam brush, we applied a thin layer of wood paint. This will protect the wood. Then, we applied a second coat, waited another 4 hours, and then we added a third and final coat. The monitor and Raspberry Pi are definitely going to generate a little bit of heat so we drilled some 1/4" ventilation holes on the sides of the frame. Then the mirror was attached, then we cut a small slot at the bottom to run a power cord through.

3.0.7 SMART MIRROR ASSEMBLY

The smart mirror assemble consists of the placement of the monitor, raspberry pi, speakers, and cables inside the frame. The steps to the assemble are as follows;

1. Place the monitor into the frame
2. The raspberry pi is placed behind the monitor at the lower part of the frame
3. Connect the HDMI cord to the HDMI to VGA adapter then to the monitor and raspberry pi
4. Put the power cable of the raspberry pi trough the hole made on the frame and connect it to the raspberry pi
5. Put the power cable of the monitor trough the hole made on the frame and connect it to the monitor

Fig 3.5 Diagram showing the assembly of the smart mirror

CHAPTER FOUR

4.0 RESULTS AND DISCUSION

The smart mirror was successfully developed using a raspberry pi 3B with a raspbian OS installed, the raspberry pi served as the processor of the smart mirror, a 19 inches LCD display for the smart mirror display. The frame was constructed using wood and an acrylic see through glass for the screen which acts as a mirror and a display screen, the frame was painted black and has a door at its back for access to the components inside.

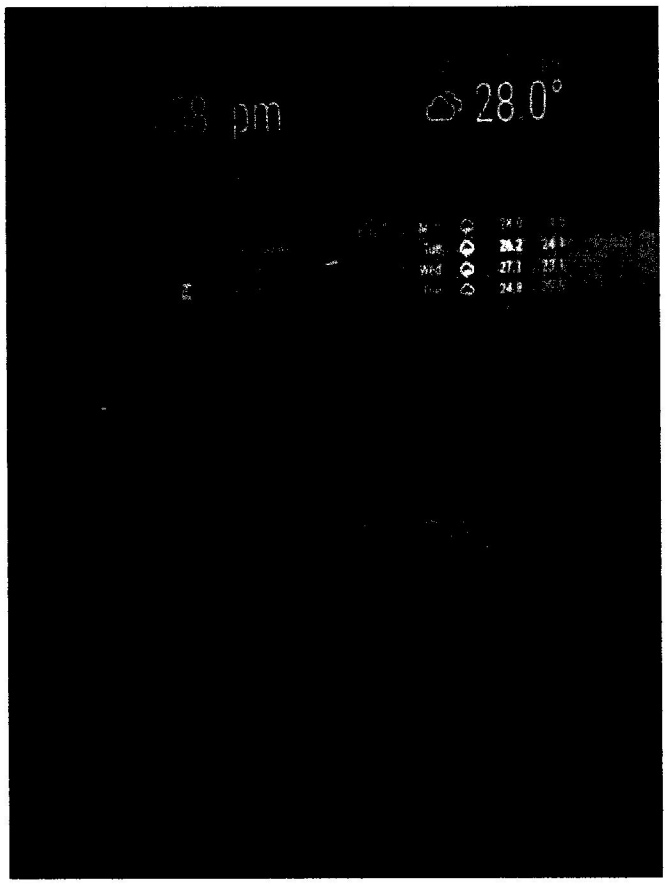


Fig 4.1 Picture of the Smart Mirror

4.1 CAPABILITIES OF THE SMART MIRROR

- Ability to display widgets.
- Functions as a mirror.
- The system looks aesthetically appealing.
- The system has a customizable U.I.
- The system has a means to store user accounts and preferences.
- The system has a separate means to begin usage.
- The system provides social media interaction that appeals to most users

4.2 APPLICATIONS OF THE SMART MIRROR

- Consumer and residential applications: Smart mirrors are used in residential applications such as the display of emails on the mirror, it could be used to get temperature of each rooms in the house displayed on the smart mirror, daily schedule, alarm and other notifications could be displayed on the smart mirror among many other uses.
- Heath care: The opportunity to apply smart mirror technology to healthcare to predict and to monitor aspects of health and disease is a natural but mostly underdeveloped idea. We envision that smart mirrors comprising a combination of intelligent hardware and software could identify subtle, yet clinically relevant changes in physique and appearance. Similarly, a smart mirror could record and evaluate body position and motion to identify posture and movement issues, as well as offer feedback for corrective actions. Successful development and implementation of smart mirrors for healthcare applications will require overcoming new challenges in engineering, machine learning, computer vision, and biomedical research.
- Retail and advertisement applications: In retail fashion, virtual mirrors could combine sensors, displays, and computer vision-equipped cameras to offer shoppers clothing

recommendations based on the data collected as well as fashion trends. The potential benefits of virtual mirrors in retail stores could include enhancement of brand experiences as well as an ease of sales associate workloads.

- Automotive sector: Highly functional mirrors can be tagged as smart mirrors, which are successfully being used in the automotive industry. Smart mirror technologies comprise of self-dimming capability, along with other features such as self-cleaning and self-repairing ability. the demand for smart mirrors has enhanced due to the rising focus on improved road safety drives. Also, with the incorporation of new electronic functionalities to the automotive mirrors, this market is expected to cross new milestones in the near future. The implementation of activated light sensors, and electro chromic self-dimming smart mirrors have surely improved road safety by increasing response times along with reducing driver fatigue. Digital smart mirrors are considerably gaining momentum due to various factors like comfort/convenience and design/style.

CHAPTER FIVE

5.0 CONCLUSION

We have been able to design a smart mirror that provides natural interaction between user and the ambient home services. The core of the mirror is based on a home automation system, which we developed to demonstrate the various functionalities provided by the mirror. These functionalities include access to personalized information services. Overall, the prototype provides an easily extendable framework that can be utilized to provide even more functionality to the user. The features of the mirror includes; calendar, date and time, email display, news feed from shara reporters, whether update, comments, smart devices as remote control.

5.1 RECOMENDATIONS

1. **Monitors of smaller thickness** should be used so as to make the entire mirror smaller.
2. **Wood of smaller thickness** should be used.
3. **A more appealing finishing** should be done to make the smart mirror more attractive.
4. **Motion sensors can be** integrated to the smart mirror to detect human presense so as to **save power when the** mirror is not needed.

5.2 REFERENCES

1. Vivek.V, Homan Rajan.G, Vijay.R, Surendar.S, R. Geetha. IOT Enabled Smart Mirror for Physically challenged. *International Journal of Innovative Research in Science,Engineering and Technology Vol. 7, Special Issue 2, March 2018*
2. Vaibhav. K, Yash. V , Dhruv. N, Preeti .P. Design and Develoment of Smart Mirror Using Raseberry Pi. *International Journal Of Electrical, Electronics And Data Communication Volume-5, Issue-1, Jan.-2017*
3. Joshua Roshan.D., Nidhi .S, Vaibhav. S, V. Suraj Reddy. Smart Mirror - A Home Automation system Implemented Using Ambient Artificial Intelligence. *International Journal of Innovative Research in Science,Engineering and Technology Vol. 6, Issue 7, July 2017*
4. Jane. J, Raghav.C, Jait. J, Mir Masood. A, Sonia Maria D'souza. Home Automated Smart Mirror as an Internet of Things (IoT) Implementation - Survey Paper. *International Journal of Advanced Research in Computer and Communication Engineering Vol. 6, Issue 2, February 2017*
5. R.M.B.N. Siripala, M. Nirosha, P.A.D.A. Jayaweera, N.D.A.S. Dananjaya, Ms. S.G.S. Fernando.
6. Raspbian Magic Mirror-A Smart Mirror to Monitor Children by Using Raspberry Pi Technology. *International Journal of Scientific and Research Publications, Volume 7, Issue 12, December 2017*
7. Aswin. O, Jerin. V, Deeksha. Y. B, Shruti. B Chichagandi . Smart Mirror Artificial Intelligence. *International Research Journal of Engineering and Technology (IRJET) Volume 5, Issue 4, April 2018*
8. Abhishek. P, Amitkumar. M, Rohit. S, Swapnil. B, Nirav. P. Smart Mirror using Raspberry Pi. *International Journal of Recent Trends in Engineering and Research.*
9. https://codeburst.io/all-about-node-js-you-wanted-to-know-25f3374e0be7
10. https://en.wikipedia.org/wiki/Python_(programming_language)
11. https://www.tutorialspoint.com/nodejs/nodejs_introduction.htm
12. https://www.programiz.com/python-programming
13. https://www.twowaymirrors.com/glass/
14. http://www.understandconstruction.com/wood.html
15. https://en.wikipedia.org/wiki/One-way_mirror
16. https://science.howstuffworks.com/question421.htm
17. https://www.explainthatstuff.com/wood.html
18. https://en.wikipedia.org/wiki/Raspberry_Pi

19 https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

20 https://whatis.techtarget.com/definition/Raspberry-Pi-35-computer

21 https://cie-group.com/how-to-av/videos-and-blogs/what-is-hdmi-high-definition-multimedia-interface