

IoT based Smart Mirror with Facial Recognition using Raspberry Pi

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Abstract— In recent years the advancement of technologies of information and communication have helped to improve the quality of people's lives. The paradigm of internet of things presents innovative solutions that are changing the style of life of the people. Because of this proposes the implementation of a smart mirror as part of a system of home automation, with which we intend to optimize the time of people as they prepare to start their day. This device is constructed from a reflective glass, LCD monitor, a Raspberry Pi, a camera and a platform IoT oriented cloud computing, where the information is obtained to show in the mirror, through the consumption of web services. The information is customizable thanks to a mobile application, which in turn allows the user photos to access the mirror, using authentication with facial recognition and user information to predict the news to show according to your profile. In addition, as part of the idea of providing the user a personalized experience, the Smart Mirror incorporates a news recommendation algorithm, implemented using a predictive model, which uses the algorithm.

Keywords—*Internet of Things, Smart Mirror, Raspberry Pi, Facial Recognition, Cloud Computing, Home Automation*

I. INTRODUCTION

The development of IoT and embedded computing has made daily-use items into intelligent and networked gadgets able to perform many tasks. One of the inventions that have been introduced is the Smart Mirror, which serves as an innovative gadget that provides the functionality of mirrors and displays digital information. The use of IoT technology with facial recognition capabilities in Smart Mirrors has revolutionized smart homes' technology by introducing personalization automation and more exciting features. It can be described as two-way mirror with a computer display integrated behind the reflective glass. Once switched on the digital screen starts displaying information such as weather, time

and date, notifications, events, news updates, and health information. In its inactive state, the device looks like an ordinary mirror, making it simple aesthetically while incorporating many features. The use of IoT technology allows the gadget to access the internet and interact with cloud services and other gadgets. Through this, people can receive timely updates, synchronize their data, and automate some of their tasks.

It allows connection to smartphones, smart assistants, wearables, and any other smart devices at home via WiFi or Bluetooth. Thus, it acts as the main center of information exchange every day. The facial recognition feature is among the most innovative capabilities provided by this particular Smart Mirror device. It brings a higher level of personalization and security. By means of advanced image recognition and machine learning techniques like OpenCV, mirror can recognize individual users and provide unique content according to their identity. For example, if a person stands near the smart mirror, then it will recognize his face and present him with unique information like a schedule, reminders, fitness achievements, or news categories that suit this user's interests best.

II. LITERATURE REVIEW

Gayanga Kuruppu et al. [1] proposed a smart mirror system capable of delivering personalized content based on facial emotion recognition. The system uses a camera to capture facial expressions and applies emotion recognition algorithms to identify the user's emotional state. Based on detected emotions such as happiness, sadness, or neutrality, the mirror displays customized information like motivational quotes, news, or music suggestions. This work highlights the importance of emotion-aware systems in enhancing user experience and personalization. However, the system mainly focuses on emotion recognition and does not deeply address multi-user authentication or scalability.

I. C. A. Garcia et al. [2] presented a smart mirror that integrates facial recognition for user authentication along with a personalized news recommendation algorithm. The mirror identifies users through facial recognition and then displays tailored news content based on their preferences. This work emphasizes secure authentication and content customization, making the system suitable for multi-user environments. The limitation of this approach lies in its dependency on stable internet connectivity and limited exploration of emotional context while delivering content.

S. P. S. Sirinayake et al. [3] developed an IoT-based intelligent assistant mirror using Raspberry Pi aimed at improving daily routines and smart living. The mirror displays real-time information such as weather updates, calendar schedules, reminders, and news feeds. The system demonstrates effective integration of IoT services and smart home concepts. Although the mirror enhances daily productivity, it lacks advanced personalization features such as facial emotion recognition or adaptive content delivery.

P. B. Thevarcad et al. [4] proposed a personalized day-to-day IoT-based smart mirror using facial recognition technology. The system recognizes individual users and displays personalized information such as schedules, reminders, and notifications. This work highlights the use of facial recognition to support multi-user environments and improve data privacy. However, emotional intelligence and behavior-based personalization are not deeply explored in this study.

Prof. Dr. Ashwini Barbadekar et al. [5] focused on the design and implementation of a cost-effective smart mirror using Raspberry Pi. The primary objective of this research is to develop an affordable smart mirror system suitable for household applications. The mirror displays essential information such as time, weather, and news while maintaining low hardware costs. Although the system is economical and practical, it offers limited intelligence and lacks advanced features such as facial recognition, emotion detection, and personalized recommendations.

III. PROPOSED SYSTEM

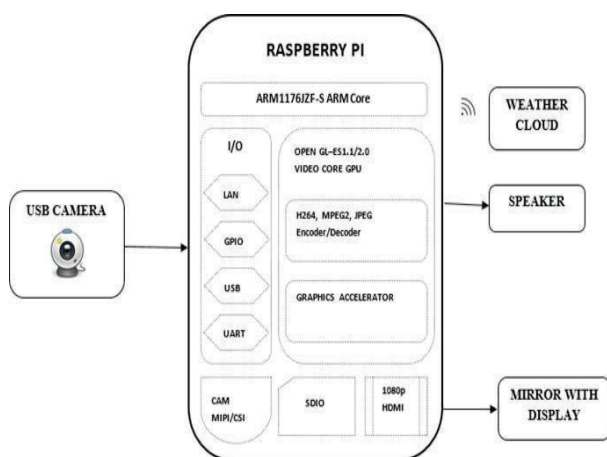


Fig 1. Proposed System

The fig.1 represents the proposed system of IoT-based Smart Mirror with Facial Recognition using Raspberry Pi,

where the Raspberry Pi functions as the central processing and control unit. A USB camera continuously captures real-time video of the user, which is processed by the ARM-based processor using OpenCV algorithms for face detection and recognition. The integrated GPU and hardware accelerators support efficient image processing and smooth graphical rendering, while the encoded visual output is displayed on the mirror through an HDMI interface.

The system connects to cloud services via a network interface to retrieve real-time weather information and other contextual data, which are overlaid on the mirror display. Audio notifications can be delivered through an external speaker, and additional interfaces such as GPIO, USB, UART, and SDIO allow easy integration of IoT devices and peripherals. The architecture demonstrates a compact, scalable, and efficient integration of computer vision, multimedia processing, and IoT services suitable for smart home applications.

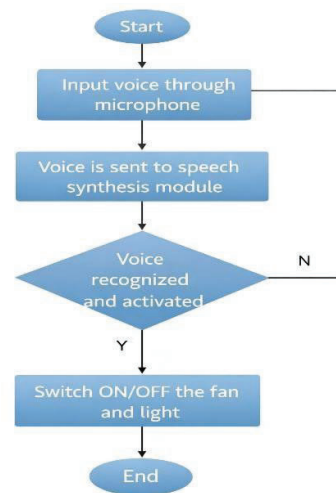


Fig 2. Flowchart for Home Automation

The fig.2 illustrates the working procedure of the voice-controlled IoT module. The first step is to set up the system. After that, the user gives a voice command through a microphone that is connected to the Raspberry Pi. The voice input that was recorded is sent to the speech processing module, where it is analysed and turned into a command that can be understood.

Next, the system uses voice recognition to see if the command spoken matches the control instructions that were set up ahead of time. The system goes back to listening for valid input if it doesn't recognise the voice command. When the system recognises and activates the right control action, it does what it needs to do, like turning the fan or light on or off through the IoT control interface. Finally, the command is run, and the process ends. This flowchart shows a simple and hands-free way for users to interact, which makes it easier for them.

It also displays the headlines of the news or weather forecast. It looks like a regular mirror but it has screen inside. Transmitted data managed in a centralized data base. A flat monitor is used for the displaying the information. Smart Mirror contains several information. It is a simple webpage that contains an embedded browser in it.

IV. HARDWARE REQUIREMENTS

The following are the hardware components represented in fig.3, used in IoT based Smart Mirror with Facial Recognition using Raspberry Pi.

A. Raspberry Pi

The core computing element that controls the operations of the entire smart mirror system. Its functionality includes image acquisition, facial detection, facial recognition and general operation control of the system. Real-time image streams obtained from the camera module are transferred to the Raspberry Pi and processed by its advanced computer vision techniques and algorithms. It controls the display of personalized information based on the obtained facial recognition results. Moreover, the Raspberry Pi is responsible for managing sensor data inputs using its GPIO interface and connecting to the Internet using its built-in Wi-Fi capabilities for obtaining the real-time data. It becomes possible to develop IoT-based functionalities of the smart mirror.

B. Two-way Mirror

The primary surface that provides the functionality of interacting with the smart mirror system. Two-way mirrors allow the user to use his smart mirror either as an ordinary mirror or as an information screen. The information presented on the display goes through the mirror to provide the user with easily visible information without distorting his reflection. In comparison with traditional glass mirrors, acrylic mirrors are lighter, more durable and easier to assemble; thus, they are ideal for smart homes.

C. LCD or Monitor Display

Installed behind the acrylic glass and displays content generated by the system. The information shown by LCD display may include time, date, weather, environmental sensors, and personalized messages based on successful facial recognition. The Raspberry Pi controls and connects to the display using HDMI ports in order to maintain high-quality images. Content displayed on the screen needs to be adjusted for readability through the mirror surface in various light conditions through adjusting brightness and resolution settings accordingly.

D. Pi Cam

The small and easy-to-carry camera model Pi camera is connected to the Raspberry Pi using the MIPI camera serial interface protocol. It can be utilized for picture processing, machine learning, and surveillance purposes. Pi camera plays the role of recognizing the user's face to allow access to the device only to authorized users. In our case, we need to connect the 5-megapixel Pi camera to the Raspberry Pi to enable face recognition functions of the smart mirror. The first model of Pi camera was produced with 5 megapixels in 2013. The second version 8-megapixel Camera Module v2 appeared in 2016.

E. Micro SD card

It stores the Raspberry Pi operating system, face recognition algorithms, face dataset of the users, sensor data logs, and the configuration files of the system. The use of SD card in this case is very helpful because it enables the booting of the system easily and any updates or modification of the software becomes possible with it. Storage space should be sufficient so as to enable smooth operations in the process of image processing.

F. Sensors

Some sensors are used in the smart mirror system. The PIR sensor is used to detect the presence of a person in front of the smart mirror and enables it to operate when there is some motion detected. This helps to conserve energy. The temperature sensor is used to measure the ambient temperature and displays the results in real-time on the mirror interface. Humidity sensor measures humidity levels. This helps the smart mirror to be able to give some comfort information to the user.

G. HDMI cable

This cable connects the Raspberry Pi to the display monitor.

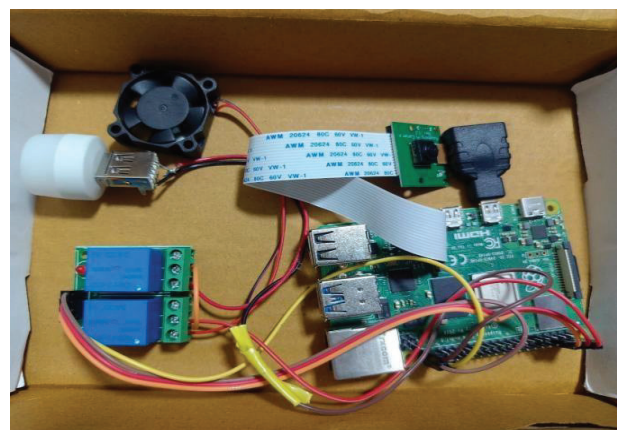


Fig 3. Hardware Components

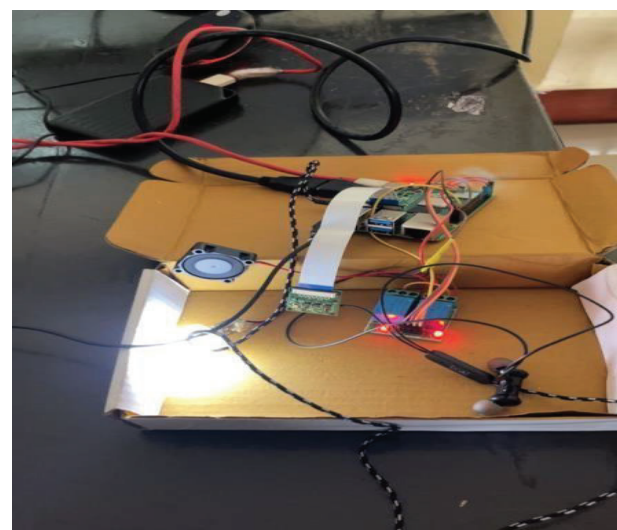


Fig 4. Hardware Connections

V. SOFTWARE REQUIREMENTS

The fig. 5 represents the main operating system in charge of the management of hardware resources, execution of application processes, and facilitation of network communication, Raspberry Pi OS will provide the stable Linux environment necessary for the execution of facial recognition algorithms, interaction with the sensors, and controlling the display. The key application of the proposed design will be created using the Visual Studio Code (VS Code) IDE, which provides efficient debugging options, management of code, and compatibility with various Python libraries used in the project.



Fig 5. Raspberry Pi OS

OpenCV is the library used to develop the functionalities of facial recognition and image processing, and it involves the face recognition and detection libraries developed using the OpenCV. This library captures the live video frames from the camera module and then recognizes the facial features before authenticating the user. OpenCV makes it possible for real-time recognition with reliability at various light levels. The internet is an essential software component since it helps connect the system to the IoT services, get real-time weather information, and communicate with cloud-based servers.

The connectivity of the network plays an important role in the functioning of the IoT in the smart mirror application. The Raspberry Pi establishes a connection to the internet via either a wired or wireless network. With reliable network connectivity, the smart mirror will have constant access to various internet-based resources. Network connectivity ensures the synchronization of the smart mirror application with external applications for the purpose of dynamic data delivery. The application utilizes IoT communication protocols for data exchange among smart mirror applications and cloud services as well as user interfaces.

There are various means of users' interaction within the framework of the developed smart mirror system. First of all, there is a web interface that will be able to show the personalized content like current time, date, weather updates, sensors' data, and notifications to the user. Moreover, this web interface will be placed behind the two-way acrylic mirror to provide high visibility and interaction opportunities.

Another user interaction possibility is mobile app interface based on Telegram bot for remote control and alerts. Telegram bot allows sending various messages like notifications or alerts about particular issues or events and helps to increase system usability. The display unit will act as visual user interface that will show users' interaction and all the processed data in real-time. Such combination of software requirement, connectivity options, and interface helps to achieve high effectiveness of real-time facial recognition, IoT services, and personalized content usage. The selected software and communication methods make the implementation of such integration quite simple and reliable.

VI. RESULT AND ANALYSIS

This section discusses the experimental results obtained from the implementation of the proposed IoT-based Smart Mirror with Facial Recognition using Raspberry Pi. The analysis focuses on system functionality, facial recognition performance, hardware reliability, IoT-based appliance control, and overall system effectiveness. The results are validated using real-time observations as shown in the experimental setup and output images.



Fig 6. Snapshot of working Smart Mirror

The fig.6 illustrates the smart mirror successfully displays real-time information such as current time, date, location, and weather conditions along with a live video feed of the user. The system continuously captures video frames using a Raspberry Pi camera module and processes them using OpenCV-based facial detection and recognition algorithms. Experimental observation shows that the facial detection process works efficiently under indoor lighting conditions with minimal latency. The face detection and recognition pipeline, implemented using OpenCV libraries, was able to recognize registered users within a fraction of a second. This confirms the suitability of Raspberry Pi for lightweight

computer vision applications in smart home environments. The overlay of real-time information on the mirror validates the system's usability as a daily assistant, helping users access essential information while performing routine activities.

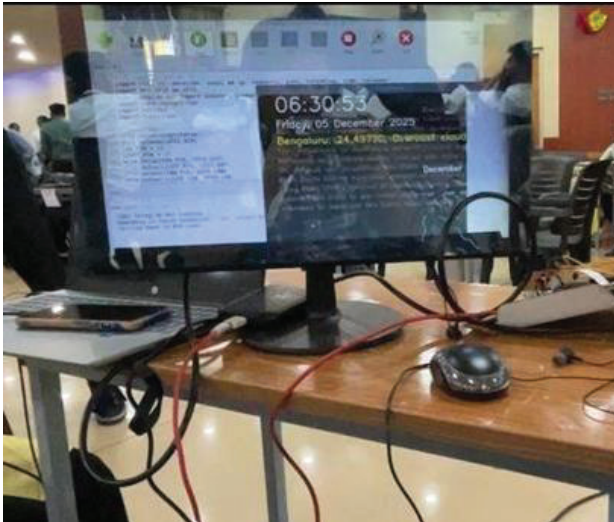


Fig 7. Final output

The fig.7 represents the complete hardware setup, including the Raspberry Pi, monitor, power supply, camera module, and necessary interconnecting wires. The hardware components were integrated successfully without any compatibility issues.

Raspberry Pi acts as the primary controller and processor. Various processes run simultaneously from this processor such as facial detection. HDMI cable helps to establish communication between the Raspberry Pi and display monitor with low latency to produce high-quality output images on the screen. The camera component operates from behind the mirror surface to capture video data for face detection and recognition. The circuit diagram above illustrates how the power flow works and peripherals connected. The USB and jump wires help to establish communication with external hardware components and IoT controller modules.

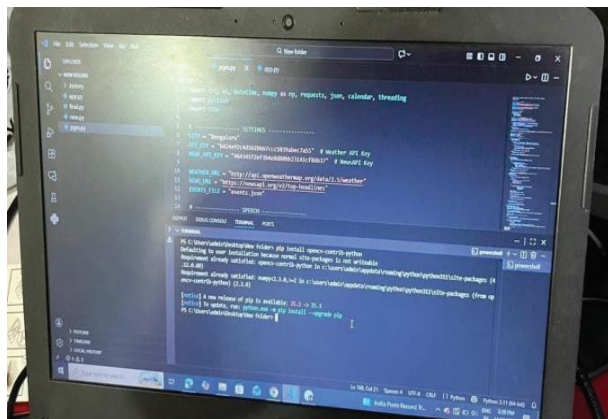


Fig 8. Command Prompt

The fig.8 illustrates the command prompt of software development and execution environment used for implementing the proposed IoT-based smart mirror system. The image features a Python application within an integrated development environment on a Raspberry Pi setup. This environment is crucial for managing facial recognition, data retrieval, and IoT services. The configuration parameters in the code include city location, weather API keys, news API keys, and file-based event handling.

These parameters allow for dynamic access to real-time weather data, news updates, and scheduled events, all displayed on the smart mirror interface. The successful installation and operation of OpenCV and its related Python libraries, as seen in the terminal output, confirm that the software environment is ready for computer vision tasks. The terminal output also shows that the system operates without conflicts, indicating solid software integration. Package installation logs verify that necessary libraries are installed correctly and are compatible with the current Python version. This confirms the reliability of the software stack and supports smooth facial recognition algorithms on the Raspberry Pi.



Fig 9. Telegram Notification

The IoT functionality of the smart mirror system is demonstrated in fig.9, which shows the Telegram bot interface used for controlling household appliances such as lights and fans. Users can send predefined commands through the Telegram application, and the system responds with confirmation messages indicating the execution status. The communication between the Telegram bot and the Raspberry Pi was found to be reliable, with minimal delay in command execution.

The appliances responded quickly to user commands, showing effective IoT integration. The use of Telegram offers a secure, easy-to-use, and platform-independent interface, removing the need for a dedicated mobile app. This highlights how well cloud-based messaging platforms can integrate with IoT systems for remote monitoring and control. The user can operate the devices anywhere through the internet, providing ease of use. According to the results of the experiment, the proposed IoT-based smart mirror system works effectively in facial recognition precision, information display in real time, and remote operation of the devices. This combination of computer vision and IoT technology develops an all-in-one smart mirror with enhanced ease of use and interactivity for the user.

VII. CONCLUSION

This paper presents a IoT-based Smart Mirror with Facial Recognition using Raspberry Pi, designed to provide an intelligent, interactive, and personalized user experience in smart home environments. The proposed system combines real-time facial recognition, information display, and IoT-based appliance control into a single embedded platform. By using OpenCV techniques and simple software design, the system recognizes authorized users and shows relevant information like time, weather updates, and personalized notifications directly on the mirror. Experimental results confirm that the system works reliably on a low-cost Raspberry Pi while maintaining real-time responsiveness.

The facial recognition module performed steadily under typical indoor lighting, and the IoT communication module allowed seamless control of household appliances through Telegram. The integration of hardware and software shows that the smart mirror system is feasible, scalable, and cost-effective for practical smart home uses.

VIII. REFERENCE

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