IoT-Enabled Raspberry Pi-Based Intelligent Mirror: A Personalized Digital Companion

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Abstract: The paper introduces an innovative intelligent mirror system that leverages a Raspberry Pi-based processor with advanced technologies like Internet of Things (IoT), and AI. The conceptual system is designed to replace the traditional notice boards in schools, colleges, offices, and public spaces. It incorporates Google Assistant Software, allowing the users to receive real-time news updates, and notifications, and engage with an innovative intelligent mirror using user interactions. The mirror employs specialized glass and a sleek back frame to ensure the system's functionality as both a mirroring surface and an interactive screen. Python programming is utilized to control the entire system. Furthermore, the mirror system facilitates extended video and ebook consumption without causing eye strain, offering a convenient, comfortable user experience, and potentially reducing children's reliance on mobile phones.

Keywords: Artificial intelligence, internet of things, intelligent mirror, raspberry Pi 3B+

1. Introduction

The Internet of Things (IoT) transforms our daily routine by integrating devices and enabling real-time communication. The term Internet of Things (IoT) is defined as "Technologies, systems, and design principles related to the emerging wave of Internet-connected things that are based on the physical environment" [1]. In Today's modern era, people seek a fulfilling life, and advanced technologies have the potential to meet their daily needs. Everyone desires seamless connectivity and effortless access to information. Through the Internet, anyone can quickly stay informed and up to date with global events. IoT refers to a network of interconnected devices and objects that communicate and exchange information through internet connectivity. The enormous growth of IoT which expands various applications, includes converting traditional homes into smart homes. The Smart home refers to the network that interconnects various digital devices, enabling them to interact with each other via the internet. The primary function of an intelligent mirror is to display weather, date & time, calendar, and notifications can be displayed on the mirror while you are grooming yourself in front of the mirror. The other important of this project by provide customizable information on the display. The system can display widgets and provide social media interaction that appeals to most users. The world of technology is improving day by day but no technology can be invented to help the intelligent mirror using IoT & AI. Using the controller, the existing system displays weather information, current time, and the user's location on the mirror. The major drawback of the existing system is its security measures, anyone can easily control it through voice commands which leads to system malfunction [2]. The potential drawback of the intelligent mirror is its continuous search for

nearby Bluetooth devices, which can lead to increased power consumption. For users without mobile phones, the intelligent mirror's features may be unavailable or restricted. [3]. The smart mirror's primary drawback is its reliance on face recognition techniques for user authentication. The lighting conditions or changes in a user's appearance lead to potential access issues [4]. The rest of this article consists of the following sections. Section 2 discusses the Literature review of Smart Mirror and its limitations. Section 3 proposes the framework and its components of the proposed system. The working principle, testing procedure, and results are explained in Sections 4, 5, and 6, respectively. Conclusions and future work are drawn in Sections 7 and 8 respectively.

2. Literature Review

The functionality of a traditional mirror is combined with interactive displays, Artificial Intelligence, and internet connectivity. The works in this field are [1–10]. Sridhar *et al.* [1] implemented a two-way smart mirror that merges digital features and displays the time, weather, and calendar events. It consists of various components such as Raspberry Pi, a two-way mirror, and different temperature sensors, transforming the traditional mirror into a smart mirror. Karthick *et al.* [2] presented a two-way smart mirror that provides real-time information and also supports voice control features. Merish *et al.* [3] indicated the two-way smart mirror with Raspberry Pi which integrates various technologies to improve user interaction and convenience. SPSS Sirinayake *et al.* [4] designed an intelligent two-way mirror that incorporates Artificial Intelligence and Internet of Things technology. The mirror provides weather reports, COVID-19 reports, News, and health monitoring. Karthick *et al*. [5] developed a Two-way mirror with home automation capabilities. It provides real-time information such as time, weather, and news. The system can able to control the home appliances via voice commands. Rani *et al.* [6] discussed a futuristic mirror with Artificial Intelligence capabilities that can adapt to its environment. It offers various features like weather updates, news, and campus notices. The Device which includes Raspberry Pi and sensors to make daily life activities more efficient. Divyashree *et al.* [7] reported a smart mirror as a personal digital assistant. The mirror provides real-time information, live weather updates, local time, and also healthier lifestyle tips. Johri *et al.* [8] implemented a time-saving smart mirror that integrates the traditional mirror with advanced technology to provide essential information at a glance. Muneer *et al.* [9] designed a smart fitness mirror to monitor their health and fitness. The device includes various sensors to measure weight, height, and body composition using bio-electrical impedance analysis. Khale *et al.* [10] proposed a smart mirror that uses Raspberry Pi and displays in formation like weather, time, and news updates. Users can also access Gmail and other social media platforms.

3. Proposed Prototype

The proposed IoT intelligent mirror system includes a Rasp berry Pi 3 Model B+, a high-quality one-way mirror, an LED monitor, a speaker, a microphone, and a web application to provide a user-friendly and interactive interface. Users can control the IoT mirror access information through voice commands receiving audio feedback. The proposed system displays a wide range of information such as news updates, weather forecasts, and personal notifications. It allows users to watch videos and read eBooks for extended periods without causing eye strain. Additionally, Python programming and Google Assistant SDK are also utilized for effective voice recognition and command processing. The Intelligent mirror is designed not only for home use but also for public spaces, schools, colleges, and offices to streamline daily routines, notices, circulars, quotes, and advertisements. The system offers several practical implications such as enhanced user experience, improved information accessibility, versatility in applications, cost-effectiveness energy efficiency, customization potential, and community engagement. The block diagram of an IoT intelligent

mirror is shown in Fig. 1. Each block is discussed in detail in the following section.

4. Framework and Functionality

An IoT Intelligent Mirror system incorporates a range of hardware and software components to obtain its desired functionality. Here key components are listed below

4.1. Hardware Components

The proposed system is composed of several key hardware components that work together to create a functional and interactive device. Here are the main hardware components involved:

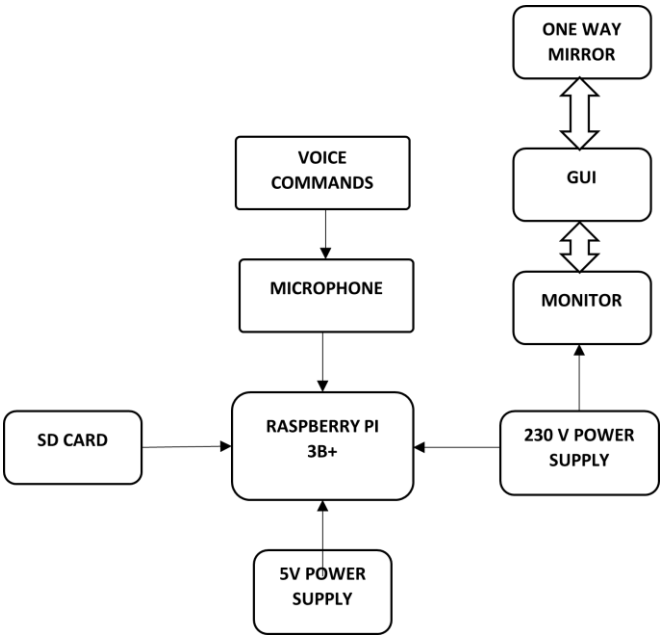

Fig. 1. Block of proposed system.

4.1.1 Raspberry Pi 3 model B+

Raspberry Pi 3 Model B + is the third generation Raspberry Pi offering additional improvements over its predecessor Model B. It plays a crucial role in an IoT Intelligent mirror to display personalized information such as current times, weather updates, news feeds, email notifications, schedules, and media content. It operates with Raspbian -OS, a Debian-based operating system, that supports various programming languages for code development. This is a Single-board computer that is responsible for processing commands and managing the display of information.

4.1.2 One-way mirror

One-way Mirror is a special type of glass that is coated with a thin layer of metallic material, typically silver or aluminum. This coating makes one reflective side and transparent on the other. The reflective side is positioned towards the user and the transparent side is placed behind the display device, enabling the digital content to be visible through the mirror.

4.1.3 LED monitor

LED Monitor is a specialized display device that uses Light light-emitting diode as its back-light source. In the Proposed system, the LED Monitor and Raspberry Pi are connected using an HDMI cable. This connection allows the Raspberry Pi to transmit visual information to an IoT Intelligent mirror. Through this

monitor, users can view personalized data such as date, time, calendar events, etc.,

4.1.4 Microphone

In the Proposed system, the Microphone plays a crucial role in enabling voice-based interaction with the device. It is connected to Raspberry Pi modules via a USB port to provide speech inputs to the IoT mirror.

4.1.5 Speaker

The Speaker is used to provide audio feedback and response from the system. It can be used to play music, deliver news updates, and voice-based responses to user queries.

4.1.6 Ultrasonic proximity sensor

The Ultrasonic proximity sensor is a device that measures the distance of an object using sound waves. This sensor is connected to the system via the Arduino UNO platform. It can detect when a user is standing in front of the mirror, activating the mirror's functions.

4.2. Software Components

An IoT intelligent mirror system relies on various software components to function effectively and provide a seamless user experience. Here are the key software components involved.

4.2.1. Python programming

The Python programming language is used to develop and control the IoT mirror. Its simplicity and versatility make Python a suitable choice for this project. It allows for easy integration with the hardware components.

4.2.2. Google assistant software development kit

Google Assistant SDK is used to enable voice recognition and command processing. Users can interact with an IoT mirror using voice commands through Google Assistant SDK, which makes the mirror user-friendly.

4.2.3. Machine learning algorithms

Implementing machine learning algorithms makes the smart mirror a more intelligent and adaptable device, providing a more personalized and engaging user experience.

5. System Testing

Ensuring functionality and performance, the testing phase of the IoT Intelligent Mirror System ensures that every component operates seamlessly. Testing can be done in various aspects, including input validation, dynamic information display, voice command functionality, Machine Learning algorithms integration, and overall system testing. The IoT Intelligent mirror system is demonstrated to handle various data types, including positive numbers, negative numbers, and special numbers while evaluating accuracy. The dynamic information display worked effectively, providing real-time updates based on user commands, and transforming the mirror into an intelligent notice board. The voice command functionality powered by the Google Assistant SDK was tested for accuracy. The Integration of a Machine Learning algorithm allowed the system to improve its performance. The Raspberry Pi was successfully incorporated, serving as the core component and facilitating communication with the mirror system. Overall, the system met the design specifications and user requirements. The system testing process is outlined in Table 1.

Table 1. The System Testing Process

S. No	Test Case	Description	Results
1	Validation of input data	Estimates the mirror's capability to accurately process diverse data types.	Mirror rigorously checks inputs to avoid errors.
2	Dynamic Information Display	Ensures the system's responsiveness to user interactions and web data.	Mirror displays real-time information and acts as a dynamic notice board.
3	Voice command functionality	To evaluate the voice command functionality, utilizing Google's Assistant Voice Commands.	Mirror responds to Google Assistant commands.
4	Machine Learning Integration	Analyses the performance of Machine Learning algorithms concerning user interactions	Mirror successfully incorporates Machine Learning algorithms.
5	Memory Card Installation	Confirms the memory card is properly inserted to enable software setup	Software setup successfully enabled.
6	Raspberry Pi Integration	Verifies the integration of Raspberry Pi	Raspberry Pi interacts effectively with mirror.
7	Overall System Testing	Examines the system's overall functionality and performance.	Mirror functions and performance as expected.

6. Experimental Results

The Python Programming and Machine Learning algorithms were implemented and tested through simulations. The system displays the date, time, temperature, weather conditions, atmospheric pressure, humidity levels, sunrise, and sunset times, and news updates on the LED screen, activated by Google Assistant SDK commands as illustrated in Fig. 2. The construction of the intelligent mirror system is depicted in Fig. 3.

Fig. 2. Intelligent mirror shows date, time, and weather.

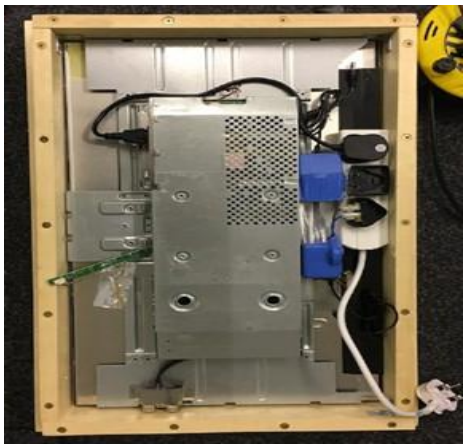

Fig. 3. Construction of IoT intelligent mirror.

7. Comparative Analysis

This paper enhances smart mirror systems by integrating IoT, AI, and Machine Learning for dynamic functionality and secure interaction. It addresses key limitations in prior works, such as weak security, limited connectivity, and static displays, while expanding use cases to public and professional settings. The proposed system emphasizes advanced customization, user- centric design, and future-ready adaptability. These advancements in Table 2 underscore the paper's focus on delivering a secure, efficient, and versatile smart mirror system.

Table 2. Comparative Evolution of Our Research Findings with Previous Research

S.No	Aspect	Previous Work	This Paper
1	Technology	Primarily uses Raspberry Pi and simple information display.	Integrates IoT, AI, and Machine Learning for enhanced interactivity.
2	User Interaction	Voice commands (simple interaction) but lacks security.	Voice control with more advanced AI, incorporating security features.
3	Security	Limited security, vulnerable to unauthorized access.	Focus on secure voice control and interaction to address security risks.
4	Connectivity	Reliant on Bluetooth, which can drain the battery and limit functionality.	Utilizes more reliable, energy-efficient connections (likely Wi-Fi or Ethernet) to avoid issues with Bluetooth dependency.
5	Voice Assistant	Some systems use voice assistants like Google Assistant but with limited customization and flexibility.	Integration of voice assistant (Google Assistant or SDK) with more advanced features.
6	Display Type	Typically, a one-way mirror with basic information (time, weather).	Enhanced user interface with dynamic content (news, calendar, notifications) and voice integration.
7	Security Measures	No robust security for voice commands.	Added security mechanisms for voice interaction to prevent unauthorized control.
8	Development Tools	Primarily uses Python and simple GUI frameworks.	Python with advanced frameworks (Tkinter, other SDKs) for developing a sophisticated user interface.

8. Conclusions

The intelligent mirror system, with the integration of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) algorithms utilizes a Raspberry Pi which delivers various services including real-time weather information, time, date, atmospheric updates, and sunrise and sunset times. Additionally, users can watch videos and read eBooks for extended periods without experiencing eye strain. The system's innovative integration of existing technologies, coupled with its efficiency in saving time and power. Not only it is designed for home use but it can be implemented in public spaces, schools, colleges, and offices for making announcements, circulating information, and displaying advertisements.

9. Future Work

The system's future work could focus on enhancing its functionality and user experience. This might involve incorporating additional interaction methods and strengthening security measures.

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