

Design and Development of an Intelligent Raspberry Pi- Based Smart Mirror Using IOT

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Abstract - This project presents the design and development of an intelligent Raspberry Pi-based smart mirror prototype that combines computer vision and IoT features to enhance user interaction. The system uses a Raspberry Pi as the main controller, integrated with a 7-inch HDMI display and a USB camera. The camera captures facial images through computer vision techniques to detect the user's face and analyse face shape. Based on the detected face shape, the smart mirror suggests suitable hairstyles, providing personalized grooming assistance. In addition to appearance-based recommendations, the mirror displays real-time local information such as news updates, temperature, and humidity for a customized location. The user interface is presented seamlessly on the mirror display, offering an interactive and modern experience. This prototype demonstrates the potential of smart mirror technology as a personalized, user-friendly solution for daily information access and personal care applications.

Key Words: Smart Mirror, Raspberry Pi , Internet of Things (IoT) , Computer Vision , Face Detection , Face Shape Analysis, Personalized Recommendations, Hair style Suggestion System

1.INTRODUCTION

Advancements in embedded systems, computer vision, and Internet of Things (IoT) technologies have enabled the development of interactive smart devices that enhance everyday experiences. Smart mirrors represent one such innovation, combining digital information display with personalized user interaction in a seamless and intuitive manner. This project proposes the design and development of an intelligent smart mirror system built around the Raspberry Pi, integrated with a 7-inch HDMI display and a USB camera. The system employs computer vision techniques to detect and analyze the

user's face shape, enabling personalized hairstyle recommendations. In addition to grooming assistance, the mirror provides real-time updates such as news, temperature, and humidity for a selected location. By blending information access with personalized suggestions, the prototype demonstrates how smart mirror technology can transform routine daily interactions into an engaging and intelligent experience.

2. LITERATURE SURVEY

According to Eben Upton and G. Halfacree [1] and Simon Monk [2], smart mirror systems based on embedded platforms such as the Raspberry Pi integrate a two-way mirror with a display panel to provide real-time information including weather updates, calendar events, and news feeds. These studies emphasize low-cost hardware design and energy efficiency for smart home applications. However, most early prototypes focus primarily on information display rather than interactive personalization. They lack advanced user recognition features, which limits their ability to provide customized services. Therefore, integrating intelligent vision based modules is necessary to enhance system capability. According to Adrian Kaehler and Gary Bradski [3], facial detection and recognition techniques using the OpenCV framework are widely applied in surveillance, authentication, and human-computer interaction systems. These approaches utilize algorithms such as Haar cascades for detecting facial features efficiently. Furthermore, Ian Goodfellow, Yoshua Bengio, and Aaron Courville [4] explain that deep learning-based CNN models improve accuracy in face detection and feature extraction. However, most studies focus on identity recognition rather than facial shape analysis, and implementing such models on embedded platforms introduces computational challenges. Hence, lightweight and optimized models are required for real-time performance.

3. EXISTING SYSTEM

Existing smart mirror systems are primarily developed using embedded platforms such as the Raspberry Pi and basic IoT technologies. These systems typically consist of a two-way mirror, a display screen, and a processing unit that presents real-time information like date, time, weather updates, and news feeds. Most existing implementations function as information display systems, where data is fetched from the internet using APIs and shown on the mirror interface. Some systems also support additional features such as voice commands, gesture control, or smartphone integration to improve user interaction. In IoT-based smart mirrors, the system is connected to the internet through Wi-Fi to continuously update real-time data such as temperature, humidity, and online notifications. These mirrors are designed to make daily routines more efficient by allowing users to access essential information while using a mirror. A few advanced systems include basic facial recognition or motion detection for security purposes, such as identifying users or detecting intruders. However, these features are often limited in accuracy and reliability due to hardware constraints and lack of optimized algorithms.

4. PROPOSED SYSTEM

The proposed system focuses on the design and development of an intelligent smart mirror using the Raspberry Pi integrated with Internet of Things (IoT) technology and computer vision techniques. The system consists of a two-way mirror, an LCD/LED display panel, and the processing unit, where the display is placed behind the mirror to show digital information while still allowing reflection. In this design, the Raspberry Pi acts as the central controller that manages all hardware and software operations. The system retrieves real-time data such as weather updates, time, news, and calendar events using IoT-based APIs through an internet connection. This information is processed and displayed on the mirror interface in a user-friendly format. To enhance intelligence and interactivity, the proposed system incorporates a camera module for facial detection and recognition using OpenCV. This allows the system to identify users and provide personalized information based on individual preferences. Additionally, machine learning techniques can be integrated to analyze facial features and suggest recommendations such as grooming tips or accessories. The system is also designed to support user interaction through touchless methods such as voice commands or

gesture recognition, improving usability and convenience. Local processing is emphasized to reduce dependency on cloud services, thereby improving response time and ensuring better data security and privacy. Overall, the proposed system design aims to overcome the limitations of existing systems by providing an intelligent, interactive, and personalized smart mirror solution. It combines IoT, embedded systems, and machine learning to deliver enhanced performance and a better user experience in smart home environments.

5. RESULTS

This captured data is processed by a microcontroller or a single-board computer such as a Raspberry Pi, which acts as the core processing unit of the system. The working principle is based on computer vision and image processing techniques, where the camera continuously monitors the user's face.



Fig 1: Emotion is Neutral and Hairstyle is Classic

The image represents a prototype of an intelligent smart mirror system developed using embedded computing and Internet of Things concepts. The system integrates a reflective two-way mirror with a display unit placed behind it, allowing digital information to be superimposed on the mirror surface while still maintaining its reflective property. A compact camera module is mounted at the top of the frame to capture real-time facial images of the user standing in front of the mirror. This captured data is processed by a microcontroller or a single-board computer such as a Raspberry Pi, which acts as the core processing unit of the system. The working principle is based on computer vision and image processing techniques, where the camera continuously monitors the user's face. The system uses 29 facial recognition and emotion detection algorithms to analyze the user's expressions and classify them into predefined emotional states such as neutral, happy, or sad. Based on this analysis, the system displays relevant information on the mirror interface, such as the detected emotion and suggested hairstyle, enhancing user interaction and personalization.



Fig 2: Emotion is Surprise and Hairstyle is Under cut

The image illustrates the functional operation of an intelligent smart mirror system that combines embedded hardware with real-time image processing and IoT-based data display. The system is built using a two-way reflective mirror with a display panel positioned behind it, enabling digital information to appear on the mirror surface without obstructing the user's reflection. A camera module mounted on the frame captures live video input of the user, which is continuously processed by a central computing unit such as a Raspberry Pi. The system operates by detecting and tracking the user's face using computer vision algorithms. A bounding box is visible around the detected face, indicating that facial detection is actively being performed. Once the face is detected, the system applies emotion recognition techniques using machine learning models trained on facial expression datasets. The detected emotion in this instance is displayed as "surprise," demonstrating the system's ability to interpret facial features such as eye movement, mouth shape, and overall expression patterns.

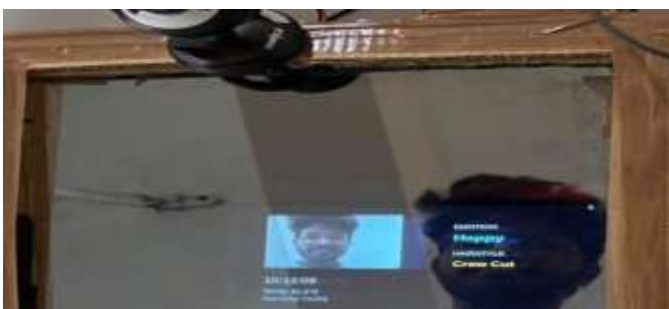


Fig 3: Emotion is Happy and Hairstyle is Crew Cut

The image represents the real-time operation of an intelligent smart mirror system that integrates a two-way mirror, embedded processing, and computer vision to provide interactive user feedback. The mirror surface allows reflection while simultaneously displaying digital information generated by a display unit placed behind it. A camera module mounted on the side of the frame captures the user's face continuously, enabling the system to perform facial detection and analysis. The

system employs image processing and machine learning techniques to identify facial features and classify the user's emotional state. The detected face is processed using trained models that analyze facial landmarks such as the eyes, eyebrows, and mouth to determine expressions. In this instance, the system recognizes the emotion as "happy," indicating that the algorithm successfully interprets the user's facial cues in real time. Based on the identified emotion, the system generates personalized recommendations, such as suggesting a suitable hairstyle. The displayed suggestion, such as "crew cut," demonstrates the integration of decision-making logic.

6. CONCLUSION

The proposed Raspberry Pi-based smart mirror prototype demonstrates an innovative integration of embedded systems, computer vision, and IoT technologies to create an interactive and personalized user experience. By utilizing the Raspberry Pi as the core controller, the system efficiently manages real-time facial detection and face shape analysis through a USB camera. Based on this analysis, the mirror provides customized hairstyle recommendations, enhancing personal grooming assistance. Additionally, the integration of real-time information such as news, temperature, and humidity makes the system both informative and practical for daily use. The seamless display interface ensures smooth interaction without disrupting the natural mirror functionality. Overall, the prototype highlights the potential of smart mirror technology as a user-friendly, intelligent solution for personalized lifestyle and smart home applications.

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Fig 4 : Emotion is Angry and Hairstyle is Crew Cut

The image demonstrates the real-time functioning of an intelligent smart mirror system that integrates a two-way mirror with embedded computing, computer vision, and IoT-based sensing. The mirror allows simultaneous reflection and display by placing a digital screen behind a semi-transparent reflective surface. A camera module mounted on the frame continuously captures the user's facial image, which is processed by a central unit such as a Raspberry Pi to enable interactive features. The system utilizes face detection algorithms to locate the user's face, as indicated by the highlighted bounding box around the facial region. Once the face is detected, advanced image processing and machine learning models analyze facial landmarks and expression patterns to determine the emotional state of the user. In this instance, the system identifies the emotion as "fear," showing its capability to distinguish subtle variations in facial expressions through trained classification models. Based on the detected emotion, the system provides personalized recommendations, such as suggesting an appropriate hairstyle like "undercut." This demonstrates the integration of artificial intelligence with decision-making logic to enhance user interaction by delivering context-aware suggestions. The system thus functions not only as a reflective surface but also as an intelligent assistant capable of interpreting user behavior.

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