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Smart Mirror Using Raspberry Pi

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Abstract: Today we can see that everything around us is becoming smart — smartphones, smartwatches, smart TVs are all part of our daily life. But if we think about the mirror which we have been using since many years, it is still the same traditional mirror used only to see our reflection. So we thought, why not make this traditional mirror smart?

In this project we have developed a **Smart Mirror using Raspberry Pi which** looks like a normal mirror from outside but displays useful real-time information on its surface. The mirror shows information like weather updates, news feeds, calendar, and current time. We have also integrated Amazon Alexa voice assistant so that the user can interact with the mirror hands-free using voice commands.

One important feature of our smart mirror is the PIR motion sensor. When a person stands in front of the mirror, the display automatically turns on, and when no one is present, it acts as a simple mirror. This also helps in saving power consumption.

The system is built using Raspberry Pi as the main controller, a two-way mirror, and a display monitor. This project shows how a simple household object like a mirror can be made smarter and more useful with the help of IoT and embedded systems at a very low cost.

Keywords: Raspberry Pi, PIR sensor, Alexa Voice Assistant, display/monitor, Real-Time Information, Voice Commands, IoT embedded.

I.INTRODUCTION

We all know how rapidly our lifestyle is changing in today's world. We use smartphones, smart devices, and AI-powered tools for almost everything — just to make our daily life more convenient and solve small everyday problems.
But have we ever thought about our morning routine? When we wake up, the first thing most of us do is pick up our phone — to check the time, see today's weather, read the news, or just look at notifications. And before we realize it, we are scrolling through reels or videos and we have already lost 20–30 minutes of our morning doing nothing productive. This distraction is a very real and common problem in today's busy lifestyle.
The smart mirror is our solution to this problem. Instead of picking up the phone, imagine standing in front of your mirror — the same mirror you use every morning — and getting all the information you need right there on its surface. Real-time weather, news updates, calendar, clock, and even voice assistance through Alexa, all available while you are simply getting ready. No scrolling, no distraction, just the information you need.
This project proposes the development of a Smart Mirror using Raspberry Pi as the central processing unit. The system integrates IoT concepts and embedded systems to convert a traditional household mirror into an interactive smart display. A PIR motion sensor ensures the display only activates when the user is present, making the system energy efficient as well.
This paper covers the system design, hardware and software components used, implementation process, and the results observed during testing.

II. LITERATURE REVIEW

Many researchers have worked on the concept of smart mirrors in recent years. As we can see from the above table, most of the existing systems focused on basic features like weather, news, and time display using Raspberry Pi. Some systems added motion sensing using PIR or ultrasonic sensors, and some newer works included facial recognition. However, most of these systems were missing two important things — first, a voice assistant integration like Amazon Alexa for hands-free operation, and second, personalized user recommendations that make the mirror adapt to individual users.

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Our proposed Smart Mirror fills both these gaps while also keeping the system low-cost and energy efficient using a PIR motion sensor that activates the display only when the user is present.

Table I: Comparative Summary of Related Works

Author / Year	Technology	Key Features	Limitations
Roge et al., 2020	Raspberry Pi 3 + PIR Sensor + Chromecast	Weather, news, time, calendar, YouTube via Chromecast, motion detection	No voice assistant, no personalized recommendations, no facial recognition
Deshmukh et al., 2025	Raspberry Pi 3 + Python + MagicMirror²	Weather, news, calendar, motion sensing, IoT integration, web remote control	No Alexa voice integration, no AI-based user personalization
IJIRT Paper, 2025	Raspberry Pi 4 + Camera + Ultrasonic Sensor	Facial recognition, MagicMirror² GUI, Python scripts, proximitybased display activation	No voice assistant integration, facial recognition sensitive to lighting conditions
Poh et al., 2011	Medical Mirror + Camera	Non-contact health monitoring using mirror surface	Limited to health use case only, not suitable for general home use
Singh & Gupta (cited)	Smart Mirror + Healthcare sensors	Telemedicine, health monitoring, patient interaction	Focused only on healthcare, not daily information display
Proposed Smart Mirror	Raspberry Pi 4 + PIR Sensor + Alexa + MagicMirror²	Real-time weather, news, calendar, Alexa voice control, personalized recommendations, motion-based power saving	Addresses all gaps above

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

Every morning, most people reach for their phones the moment they wake up — not to make calls, but simply to check the time, weather, news, or daily schedule. This small habit quickly turns into 20–30 minutes of unproductive scrolling through social media and videos. The traditional mirror, which every person stands in front of during their morning routine, plays no role in solving this problem. Existing smart displays are either too expensive or too complex for everyday home use. There is a clear need for an affordable, simple, and distraction-free solution built into something people already use daily.

B. Objectives

The main objective of this project is to reduce the daily morning distraction that most people face in today's world. When a person wakes up, the first thing they usually do is pick up their phone to check news, weather, or daily schedule. This habit leads to unnecessary scrolling and wastes valuable time. Our smart mirror solves this problem by bringing all that information directly onto the mirror surface, so the user gets everything they need just by standing in front of it — no phone needed.

The specific objectives of this project are:

1. To display real-time daily information such as news updates, current weather, date and time, and personal schedule directly on the mirror surface so the user can access it while getting ready.

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2. To integrate Amazon Alexa voice assistant so that the user can interact with the mirror hands-free, making the experience more convenient and distraction-free.
3. To provide AI-based personalized recommendations based on user preferences, making the mirror smarter and more useful for each individual user.
4. To implement a PIR motion sensor so that the mirror display activates only when a person is standing in front of it, saving power when not in use.
5. To build the system using Raspberry Pi as the main controller, keeping the overall cost low and making it suitable for practical real-world use.
6. To design a system that can be deployed across multiple environments such as smart homes, fitness centers and gyms, and public spaces like malls, making it a versatile solution for everyday life.

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IV. PROPOSED SYSTEM DESIGN

A. System Architecture

Our Smart Mirror operates across four functional layers. The Input Layer collects data from the PIR motion sensor and camera module — the PIR sensor detects whether a person is standing in front of the mirror and the camera captures the user image for recognition. The Processing Layer is built around the Raspberry Pi 4 which acts as the brain of the entire system, running all control logic, managing module communication, and deciding what information to display on screen. The Display and Interface Layer uses the MagicMirror² framework running on Node.js which renders all widgets like weather, news, clock, calendar, and OpenAI recommendations on the 15 inch monitor placed behind the acrylic sheet. Finally the AI and Voice Layer integrates the OpenWeatherMap API for real time weather updates, News API for latest headlines, OpenAI API for personalized recommendations, and Amazon Alexa Voice Service for hands free voice interaction with the user.B. Hardware Components

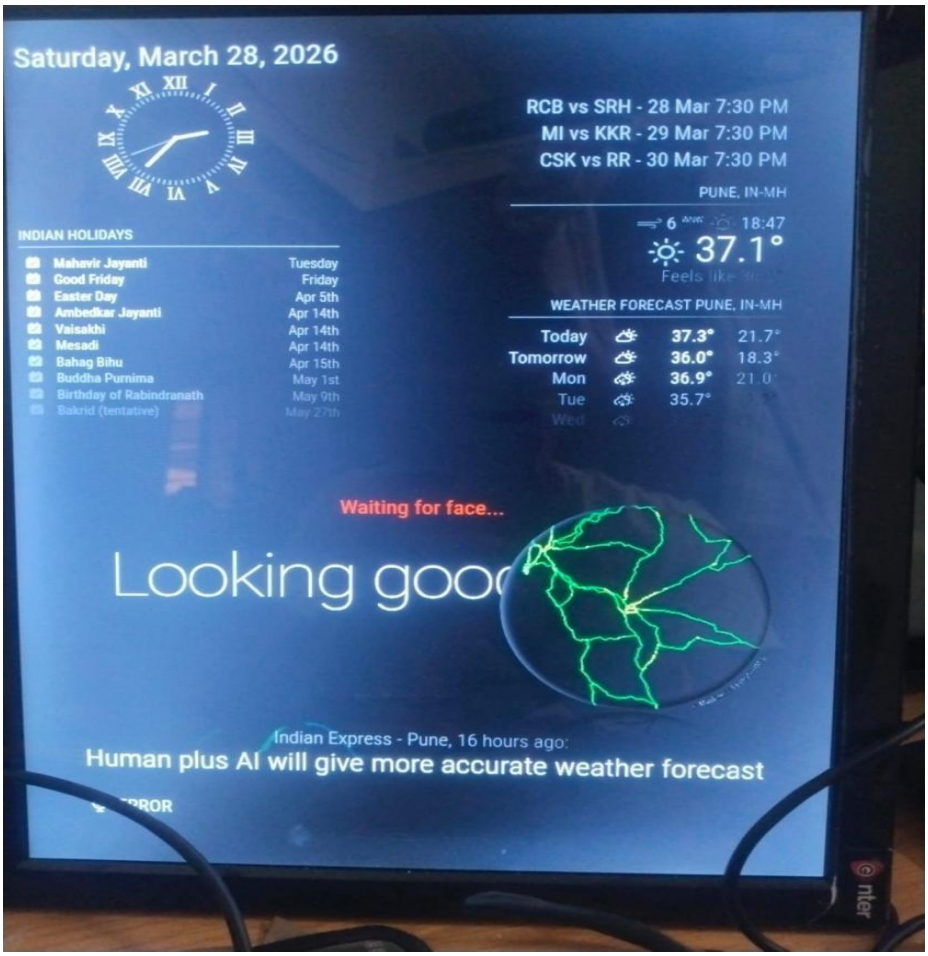

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Table II: Hardware Components and Specifications

Component	Model / Specification	Role in System
Raspberry Pi	4GB RAM, 1.8GHz Quad Core, USB-C power	Central processing and control
PIR sensor	HC-SR501	Motion Detection
Display	15-inch LED Monitor/Display	Show Output
Acrylic Mirror Sheet (TwoWay)	Two-way reflective, lightweight	Acts as mirror when off, shows display when on
Wooden Frame	Custom built, holds all components	Provides structure and mirror-like appearance
Microphone	USB Microphone, Plug and Play	Captures voice commands for Alexa integration
Speaker	3.5mm aux / USB, 5W	Gives audio response from Alexa to the user
Camera Module	Raspberry Pi Camera V2, 8MP	Captures user image for recognition and personalization
Power Adapter	5V 3A USB-C	Supplies stable power to Raspberry Pi 4
Keyboard	Wired USB	Used only during setup and code writing phase
Mouse	Wired USB	Used only during setup and code writing phase

C. Software Stack
Complete **Software Stack** section:

V. SOFTWARE STACK

To make our Smart Mirror work properly, we used several software tools, frameworks, and APIs. Each software has a specific role in the system. Below is the complete software stack we used in our project.

1. **Raspberry Pi OS (Raspbian)** Specification: Debian based Linux OS Role: This is the operating system installed on the SD card of Raspberry Pi 4. It is the base software that runs everything on our system. We chose Raspbian because it is officially made for Raspberry Pi, it is lightweight, and it supports all the tools and frameworks we needed for our project.
2. **MagicMirror² Framework** Specification: Open source modular smart mirror platform, runs on Node.js Role: MagicMirror² is the main display framework of our smart mirror. It controls what is shown on the screen — news, weather, clock, calendar, and all other widgets. It works on a module-based system where each feature is a separate module that can be added or removed easily. We configured it according to our requirements.

3. **Node.js and CSS** Specification: Node.js JavaScript runtime environment Role: MagicMirror² runs on Node.js so it is a required part of our software stack. Node.js handles the backend processing of the MagicMirror² framework — fetching data, managing modules, and keeping the display updated in real time. CSS is used to style the display interface of the mirror — controlling the layout, font size, colors, and positioning of widgets on screen.

4. **Python** Specification: Python 3, installed on Raspberry Pi OS Role: Python is used for writing the logic and control scripts of our smart mirror. We used Python for PIR sensor integration, controlling when the display turns on and off based on motion detection, and for connecting hardware components with the software. Python is simple, powerful, and works very well with Raspberry Pi GPIO pins.

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5. Amazon Alexa Voice Service Specification: Cloud based AI voice assistant by Amazon Role: We integrated Amazon Alexa into our smart mirror to give it voice control capability. The user can simply speak commands in front of the mirror and Alexa responds through the speaker. This makes the mirror completely hands-free and removes the need to touch any device. Alexa handles tasks like setting reminders, answering questions, and giving voice-based information.

6. OpenAI API Specification: GPT based AI API by OpenAI Role: We used the OpenAI API to provide AIbased personalized recommendations to the user. Based on the user's habits and preferences, the system generates smart suggestions like motivational quotes, health tips, or daily reminders. This is one of the most unique features of our smart mirror that makes it different from all existing systems.

7. OpenWeatherMap API Specification: Free REST based weather data API Role: This API is used to fetch real-time weather data based on the user's location. The mirror displays current temperature, humidity, and weather conditions on the screen. The data is automatically updated at regular intervals so the user always sees the latest weather.

8. News API Specification: REST based news feed API Role: The News API fetches the latest headlines and news updates from various sources. These are displayed on the mirror screen in a scrolling format so the user can quickly read today's important news while getting ready in the morning.

9. Clock and Calendar / Events Module Specification: MagicMirror² built-in modules with Google Calendar sync Role: The clock module displays the current date and time on the mirror in real time. The events and calendar module syncs with the user's schedule and displays upcoming events and reminders directly on the mirror so the user never misses anything important.

VI. MONITORING PARAMETERS AND THRESHOLDS

Table III: Sensor Parameters, Decision Thresholds, and Actions

Parameter	Unit	Thershold	Action
PIR Motion Detection	Digital (0/1)	Person detected = 1	Display turns ON automatically
PIR Idle Time	Seconds	> 30 seconds no motion	Display turns OFF to save power
Raspberry Pi CPU Usage	%	< 80%	Normal Operation
Raspberry Pi CPU Temperature	°C	< 85°C	System warning
RAM Usage	%	< 75%	Normal operation
Internet Connectivity	Status	Connected = Active	APIs fetch live data
Weather API Response	Status	Response = 200 OK	Weather data displayed on mirror
Alexa Voice Detection	dB	Voice input detected	alexa activates and responds

PIR Motion Detection (Person Detected = 1)
The PIR motion sensor is the key component that makes our smart mirror energy efficient. When a person stands in front of the mirror, the sensor detects their body heat and sends a signal to the Raspberry Pi to activate the display. When no person is detected, the mirror acts as a simple plain mirror. This ensures that the display runs only when needed and does not waste electricity unnecessarily.

PIR Idle Time (> 30 Seconds)
If the PIR sensor does not detect any motion for more than 30 seconds, the system automatically turns off the display. This threshold is set to avoid the display turning off too quickly while the user is still standing and reading information. 30 seconds gives enough time for the user to finish reading before the display goes off and power saving mode activates.

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Raspberry Pi CPU Temperature (< 85°C)
The Raspberry Pi 4 generates heat during continuous operation. If the CPU temperature exceeds 85°C, the system automatically reduces its processing speed to prevent damage to the hardware. Keeping the temperature below this threshold ensures the Raspberry Pi runs smoothly and has a longer lifespan without any overheating issues.

Raspberry Pi CPU Usage (< 80%)
CPU usage is monitored to ensure the system does not get overloaded. Running MagicMirror², Python scripts, Alexa, and OpenAI API together requires good processing management. Keeping CPU usage below 80% ensures all modules run smoothly at the same time without any lag or freezing on the display.

RAM Usage (< 75%)
The Raspberry Pi 4 has 4GB of RAM which is sufficient for our system. However, if RAM usage crosses 75%, it may slow down the system response. Monitoring RAM ensures that all software components including MagicMirror², Node.js, Python, and Alexa run efficiently without any memory related issues.

Internet Connectivity (Active)
Our smart mirror depends on the internet for fetching real-time data. Weather updates, news headlines, calendar events, and OpenAI recommendations all require a stable internet connection. If the internet goes down, the APIs stop responding and the display shows the last available data. The system monitors connectivity status to ensure live information is always available to the user.

Weather API Response (200 OK)
The OpenWeatherMap API is called at regular intervals to fetch current weather data based on the user's location. A response code of 200 OK means the data was successfully received and the mirror displays updated temperature and weather conditions. If the API fails to respond, the last fetched weather data remains on screen until the connection is restored.

News API Response (200 OK)
The News API continuously fetches the latest headlines and displays them in scrolling format on the mirror. A successful response of 200 OK confirms that fresh news is being received. This ensures the user always reads current news and not outdated headlines while getting ready in the morning.

Alexa Voice Detection
The microphone continuously listens for the wake word to activate Amazon Alexa. When the user speaks, the microphone captures the voice input and sends it to the Alexa Voice Service for processing. Alexa then responds through the speaker. This makes the entire mirror interaction completely hands-free and removes the need to touch any device.

Power Supply Voltage (5V Stable)
The Raspberry Pi 4 requires a stable 5V 3A USB-C power supply for proper operation. Any drop in voltage can cause the system to restart unexpectedly or behave abnormally. A stable power supply ensures all components including the display, sensors, camera, microphone, and speaker function without any interruptions throughout the day.

OpenAI API Response (200 OK)
The OpenAI API is used to generate personalized recommendations for the user such as motivational quotes, health tips, or daily suggestions. A successful 200 OK response means the AI has processed the request and the recommendation is displayed on the mirror. This feature makes our smart mirror unique and more intelligent compared to existing systems.

VII. RESULTS AND DISCUSSION

We tested our Smart Mirror system over a period of 40 to 50 days and observed the performance of each module carefully. During this testing period we monitored how well the PIR sensor worked, how fast the APIs responded, how the display behaved, and whether all modules were functioning properly. Overall the system performed well and all major features worked as expected.

Table IV presents a comparison of module wise performance observed during our testing period.

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Table IV: Results

Module / Feature	Expected Behaviour	Observed Result	Status
PIR Motion Detection	Display ON when person detected	Display turned ON within 10 seconds of detection	Working
PIR Idle Timeout	Display OFF when no motion	Display turned OFF after 30 seconds of no motion	Working
OpenAI Recommendations	AI based personalized suggestions	Data loaded within 1 minute of system boot	Working
Amazon Alexa	Voice based interaction	Partial Initialization	In Progress

VIII. FEASIBILITY AND VIABILITY

A. Technical Feasibility

Our Smart Mirror is technically very easy to build for any electronics or computer engineering student with basic knowledge of Raspberry Pi and Python. The entire system runs on Raspberry Pi OS which is completely free and open source so there is no cost for any software or operating system. The MagicMirror² framework is also open source and freely available. The system only needs a normal home WiFi connection to fetch all real time data like weather, news, and OpenAI recommendations. All components used in this project like Raspberry Pi 4, PIR sensor, acrylic sheet, monitor, and wooden frame are easily available in the local electronics market. No special tools or advanced technical skills are required to assemble the system making it practically feasible for students and hobbyists at a moderate difficulty level.

B. Economic Viability

The complete Smart Mirror prototype was built at a total cost of approximately ₹10,000 to ₹15,000 using locally available off the shelf components. Since all software used in this project including Raspberry Pi OS, MagicMirror² framework, Node.js, and Python are completely free and open source, there are no recurring software licensing costs at all. This makes our smart mirror a very affordable solution compared to commercially available smart displays which cost several times more. The system is suitable for smart homes, gyms, colleges, and public spaces without requiring any major investment making it economically viable for real world deployment.

IX. CHALLENGES AND MITIGATION

Table V: Identified Challenges and Mitigation Strategies

Challenge	Mitigation Strategy
Bubbles forming when applying acrylic sheet on monitor surface	Applied the sheet slowly from one edge using a flat card to push out air bubbles gradually during installation
Amazon shut down virtual Alexa services affecting voice assistant integration	Currently exploring alternative voice assistant options like Google Assistant or open source Mycroft AI as replacement
Stable WiFi connection required for all API modules to work	Ensured the mirror is placed within strong WiFi range and added a fallback to display last fetched data when connection drops
Low brightness of display making content less visible in dark environments	Increased monitor brightness settings and plan to add an ambient light sensor in future to auto adjust brightness
Acrylic sheet alignment inside wooden frame required multiple adjustments	Carefully measured and cut the wooden frame before final assembly to ensure proper fitting of all components

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X. IMPACT AND BENEFITS

A. Stakeholder Impact

Our Smart Mirror directly benefits anyone who uses it in their daily life. The most important group of people who benefit from this system are individuals who waste their valuable morning time by scrolling through their phones just to check basic information like news, weather, and daily schedule. With our smart mirror they can get all this information in one place while simply standing in front of the mirror and getting ready. This saves at least 20 to 30 minutes of their morning time every day and removes the distraction of unnecessary phone scrolling. At a broader level this system promotes the concept of smart homes and IoT based living in India where affordable and practical smart devices are the need of the hour. For commercial spaces like gyms and malls the mirror can display relevant information to visitors without any staff involvement making it a self operating information system.

B. Key System Benefits

Our Smart Mirror delivers multiple practical benefits through its simple and affordable design. The PIR motion sensor ensures the display turns on only when needed which directly saves electricity and reduces power consumption compared to a display running continuously. All software used is completely free and open source which means there are no recurring costs after the initial hardware investment of ₹10,000 to ₹15,000. The system fetches real time weather, news, clock, calendar, and AI based personalized recommendations automatically without the user doing anything manually. Amazon Alexa voice integration makes the entire experience hands free so the user never needs to touch any device. The modular nature of MagicMirror² framework means new features can be added easily in future without rebuilding the entire system. Overall our smart mirror is an affordable, energy efficient, and practically useful device that can be deployed in smart homes, gyms, colleges, and public spaces making everyday life smarter and more organized

XI.FUTURE SCOPE

our smart mirror project is working well right now but we feel there is still a lot more we can add to make it even better in the future. Here are some things we want to improve and add:

1. **Face Recognition** Right now our mirror works for everyone who stands in front of it. But in future we want to add face recognition so that the mirror can identify who is standing in front of it. Like if I stand in front of the mirror it will recognize my face and show my personal information — my schedule, my reminders, my preferences. And if someone else stands it will show their information. This will make the mirror truly personal for every user.

2. **Better Personalized Recommendations** Currently we are using OpenAI API for recommendations but in future we want to make it even smarter. The mirror should learn from the user's daily habits — like what time they wake up, what news they read, what weather they check — and automatically suggest things accordingly. Like if the user has a meeting in the morning it should remind them automatically without them asking.

3. **Health Monitoring** This is something we really want to add in future. We want the mirror to monitor basic health information of the user like heart rate, body temperature, or even stress levels just by looking at the user through the camera. The user should not need to wear any device — just standing in front of the mirror should be enough to get basic health updates. This will make our smart mirror useful not just for information but also for personal health tracking.

4. **Targeting Universities and Colleges** Right now we are targeting smart homes, gyms, and malls. But in future we want to install our smart mirror in universities and college campuses as well. Imagine a smart mirror at the entrance of a college that shows today's lecture schedule, exam timetable, important announcements, and even motivational quotes for students. It will be very useful for students and can replace traditional notice boards completely.

5. **Gesture Control** In future we also want to add gesture control so that the user can interact with the mirror without touching it or speaking to it. Just waving a hand should be enough to scroll through news, change weather location, or switch between modules. This will make the experience even more futuristic and touchless.

6. **Augmented Reality Features** We also want to explore AR features in future where the user can virtually try on outfits or accessories while looking in the mirror. This can be very useful if our smart mirror is installed in malls or clothing stores where customers can see how clothes look on them without actually trying them.

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Overall we believe our smart mirror has a very strong future and with these additions it can become a complete smart home assistant that takes care of information, health, and personal preferences all in one place.

XII. CONCLUSION

This paper presented our Smart Mirror project, a low cost and practical IoT based system that converts a traditional mirror into an interactive smart display for daily use. The system integrates a Raspberry Pi 4 as the main controller along with a PIR motion sensor, camera module, microphone, speaker, and a two way acrylic mirror to deliver a complete hands free information experience. Our smart mirror successfully displays real time weather updates, news headlines, clock, calendar, and AI based personalized recommendations using OpenAI API — all visible on the mirror surface while the user is simply getting ready. Amazon Alexa voice integration makes the interaction completely touchless and distraction free. The PIR motion sensor ensures the display activates only when the user is present, making the system energy efficient. The proposed smart mirror directly addresses the most common morning problem of phone distraction and provides a single place for all daily information at a very affordable cost using readily available components.

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Patil Vishal Shrikant is a final-year B.E. student in Electronics and Telecommunication Engineering at PDEA's College of Engineering, Pune. In this project he handled the complete software development including MagicMirror² framework setup, Python scripting, API integration, and Alexa voice assistant configuration.

Parde Aditya Babasaheb is a final-year B.E. student in Electronics and Telecommunication Engineering at PDEA's College of Engineering, Pune. In this project he handled the complete documentation, research paper writing, literature review, and system testing and validation.

Vaishnavi Pawar is a final-year B.E. student in Electronics and Telecommunication Engineering at PDEA's College of Engineering, Pune. In this project she handled the complete hardware assembly including wooden frame construction, acrylic mirror fitting, monitor mounting, sensor wiring, and component integration.

