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**EE 337 Principles of Engineering Design II**

**Final Project Report**

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**Smart Mirror Project**

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# Abstract:

This project report documents the development and implementation of a Smart Mirror, designed to enhance daily routines with an interactive and user-friendly interface. The Smart Mirror integrates a Raspberry Pi, various sensors, and custom software modules to deliver a range of functionalities including real-time weather updates, news feeds, personal greetings, calendar integration, and voice-controlled music streaming via Spotify. A significant innovation introduced in this project is the custom integration of a PIR motion sensor to optimize energy consumption, turning the display on or off based on user presence. Additionally, the integration of a mini microphone facilitates voice commands, further enhancing user interaction through Google Assistant. The project faced several challenges, notably in hardware integration and software stability, which were overcome through iterative testing and component modifications. The outcomes of the project not only demonstrate the technical feasibility of integrating complex systems into everyday household items but also suggest pathways for future enhancements such as health monitoring and expanded smart home connectivity. This report aims to detail the engineering processes involved, highlight the learning outcomes, and discuss potential future improvements for the Smart Mirror.

### INTRODUCTION

### BACKGROUND

The Smart Mirror project represents an innovative intersection of technology and daily life, designed to enhance personal efficiency and interactivity in home environments. The concept of a Smart Mirror is built on the foundation of a traditional mirror, augmented with advanced technologies such as displays, sensors, and real-time data processing capabilities. This project specifically integrates a Raspberry Pi, various sensors including a PIR motion sensor, a mini microphone, and custom software modules to create an interactive and intelligent system that responds to user presence and commands.

* Purpose and Scope

The primary objective of this project is to develop a multifunctional Smart Mirror that not only serves the conventional purpose of a mirror but also offers customizable digital functionalities such as displaying weather updates, news headlines, calendar events, and streaming music. The scope of the project encompasses hardware assembly, software development, and the integration of third-party services like Spotify and Google Assistant for an enhanced interactive experience.

* Technological Context

The development of smart home devices has been accelerating, driven by advancements in IoT (Internet of Things) technologies and a growing consumer interest in home automation products. Smart mirrors are a relatively recent innovation within this domain, embodying the convergence of AI, sensor technology, and user-centric design. This project leverages the open-source Magic Mirror² platform, which provides a basis for the integration and customization of various modules.

* User Interaction Design

Recognizing the importance of user interaction, this project focuses on intuitive design and voice command functionality to facilitate ease of use and accessibility. The integration of a mini microphone allows the mirror to receive and process voice commands, enabling hands-free operation which is crucial for applications in environments such as bathrooms or dressing areas.

* Energy Efficiency

A key aspect of the design is energy conservation, addressed through the use of a PIR motion sensor that detects user presence. This sensor allows the system to remain in a low-power state when not in use, activating the display only when motion is detected, thereby optimizing power consumption.

* Challenges and Innovations

Throughout the development of the Smart Mirror, the project team faced multiple challenges, including hardware integration issues, software stability, and the seamless interaction of different modules. These challenges were met with innovative solutions such as custom wiring configurations for the speakers and advanced error handling in software to improve system reliability and user experience.

* Relevance to the Field

The Smart Mirror project is not only a testament to the capabilities of current technology but also serves as a prototype for future developments in the area of smart home devices. It provides valuable insights into the practical challenges of integrating various technologies into a single cohesive unit and sets the stage for further research and development in enhancing the functionality and scope of such devices.

**Stakeholders and Their Needs**

1. **End Users (Homeowners and Renters)**
   * **Needs**:
     + Accessibility to real-time information (weather, news, calendar) seamlessly integrated into daily routines.
     + Energy-efficient devices that help reduce electricity bills.
     + Intuitive and hands-free interaction to enhance convenience and accessibility.
     + Aesthetically pleasing technology that complements home decor.
2. **Developers and Technical Team**
   * **Needs**:
     + Clear requirements and feedback for developing and refining functionalities.
     + Tools and resources for effective development, testing, and deployment of the software and hardware components.
     + Documentation and support for maintaining and upgrading the system.
3. **Project Sponsors and Investors**
   * **Needs**:
     + Assurance that the project meets market needs and has potential for commercial success.
     + Regular updates and reports on project progress and milestones.
     + Return on investment through the successful deployment and market acceptance of the Smart Mirror.
4. **Manufacturers and Suppliers**
   * **Needs**:
     + Specifications and standards required for components like mirrors, Raspberry Pi units, sensors, and other hardware.
     + Timely orders and payments for the supplied components.
     + Long-term partnerships for future projects and developments.
5. **Regulatory Bodies**
   * **Needs**:
     + Compliance with safety and privacy regulations in the development and deployment of the Smart Mirror.
     + Proper management of data to protect user privacy and adhere to data protection laws.
6. **Environmental and Energy Conservation Groups**
   * **Needs**:
     + Incorporation of sustainable and energy-efficient practices in the design and operation of the Smart Mirror.
     + Reduction of electronic waste through durable design and the use of recyclable materials.

**Competing Solutions**

1. **Standard Smart Mirrors**
   * **Examples**: HiMirror, Capstone Connected.
   * **Features**: These mirrors typically offer features like LED lighting, weather updates, news feeds, and sometimes basic health tracking or skin analysis.
   * **Limitations**: Often limited in customization and integration capabilities, with a focus more on specific functionalities like beauty or fitness rather than holistic home integration.
2. **DIY Smart Mirror Kits**
   * **Examples**: Raspberry Pi-based kits available online.
   * **Features**: These kits provide the components and instructions for tech enthusiasts to build their own smart mirrors. They can be highly customizable.
   * **Limitations**: Requires a certain level of technical expertise to assemble and customize. Support and updates depend on the community or the individual’s ability to troubleshoot and modify.
3. **Integrated Smart Home Systems**
   * **Examples**: Systems incorporating Amazon Alexa or Google Home.
   * **Features**: These systems offer voice-controlled devices that can manage multiple aspects of home automation, including mirrors that can connect to the wider system.
   * **Limitations**: The smart mirror functionality may be just a part of a broader system and not as focused or specialized as a standalone smart mirror.
4. **High-End Customizable Smart Home Interfaces**
   * **Examples**: Savant, Crestron.
   * **Features**: High degree of customization and integration with luxury home automation systems. Can include mirrors as part of a larger suite of smart home technologies.
   * **Limitations**: Typically very high cost and often require professional installation and maintenance

### Problem

In the modern world, individuals face increasing demands on their time and attention, stemming from both professional obligations and personal commitments. Traditional methods of organizing and accessing information, while functional, often do not align with the rapid pace of daily life and the growing integration of technology in personal spaces. This disconnect presents a challenge in terms of efficiency and accessibility of information in the moments and locations where it is most needed.

**Specific Challenges Addressed by the Smart Mirror Project:**

1. **Information Accessibility**: In many homes, access to real-time information such as news, weather, and personal schedules is fragmented across multiple devices such as smartphones, computers, or separate home automation systems. There is a need for a centralized, easily accessible hub that integrates this information seamlessly into daily routines without the need for manual interaction with multiple devices.
2. **Energy Efficiency**: Many electronic devices and home automation systems continuously consume power, even when not in active use. This continuous operation leads to unnecessary energy consumption, contributing to higher energy costs and environmental impact.
3. **Interactivity and Engagement**: Traditional home devices offer limited interaction, requiring physical engagement such as pressing buttons or manual activation. As homes become smarter, there is a growing expectation for more intuitive and less obtrusive interaction, such as voice or motion control, enhancing the user experience without the need for physical contact.
4. **Aesthetic Integration**: Most technological devices designed for home use focus on functionality over form, often clashing with or disrupting the home decor. There is a need for devices that not only complement but enhance the aesthetic value of the living spaces they occupy.

### AIM AND OBJECTIVE

The primary aim of the Smart Mirror project is to create an innovative, interactive, and energy-efficient Smart Mirror that enhances the daily routines of users by integrating essential information and media services into a single, aesthetically pleasing unit. This project seeks to meld technology with everyday life in a way that is seamless, intuitive, and adds value to the user’s home environment.

**Objectives of the Project:**

To achieve this aim, the project has set forth several specific objectives:

1. **Enhanced Information Accessibility**:
   * **Objective**: To develop a centralized information system that displays real-time data such as weather, news, calendar events, and music options directly on the mirror’s interface.
   * **Approach**: Utilize the Magic Mirror² platform to integrate various modules that pull data from external APIs and display this information in a user-friendly format.
2. **Increased Energy Efficiency**:
   * **Objective**: To implement energy-saving features that minimize the power consumption of the Smart Mirror while maintaining high functionality.
   * **Approach**: Integrate a PIR motion sensor that detects user presence and controls the display’s power state—turning it off during periods of inactivity and on when motion is detected.
3. **Intuitive User Interaction**:
   * **Objective**: To enhance the interactivity of the mirror, allowing users to control functions through voice and motion without physical contact.
   * **Approach**: Incorporate a mini microphone for voice command functionality using Google Assistant and develop gesture recognition capabilities to further ease user interaction.
4. **Aesthetic Integration into Home Environments**:
   * **Objective**: To design the Smart Mirror not just as a functional device but as a piece of home decor that enhances the visual appeal of its surroundings.
   * **Approach**: Focus on sleek, minimalist design principles that complement modern interiors, and customize the interface to reflect the aesthetic preferences of the user.
5. **Modular and Scalable Design**:
   * **Objective**: To create a scalable platform that allows for easy updates and the integration of additional functionalities over time.
   * **Approach**: Build the Smart Mirror with a modular software architecture that can accommodate new modules and updates without requiring significant redesigns.

**Differentiation of the Smart Mirror Project**

To stand out in the competitive landscape, the Smart Mirror project could focus on several key differentiators:

* **Modular and Scalable Design**: Unlike many off-the-shelf solutions, offering a platform that is both modular and scalable could appeal to users who desire a more tailored and adaptable product.
* **Enhanced User Experience**: By prioritizing intuitive interaction methods, such as advanced voice and gesture recognition, the Smart Mirror can offer a more seamless and engaging user experience.
* **Energy Efficiency**: Focusing on energy-saving features could attract environmentally conscious consumers and those looking to reduce utility costs.
* **Aesthetic Flexibility**: Providing options for customization in the mirror’s appearance could make it a more attractive choice for users looking to maintain a specific interior design aesthetic.
* **Integration Capabilities**: Ensuring that the mirror can integrate smoothly with a range of other smart home devices and platforms can provide an advantage over more isolated or proprietary systems.

### USE OF STANDARDS AND REAL-WORLD CONSTRAINTS

### USE OF STANDARDS

1. **Wireless Communication Compliance**: Our device incorporates Wi-Fi and Bluetooth functionalities, requiring adherence to IEEE 802.11 and Bluetooth core specifications. We ensured that all wireless communications were secure and compatible with existing standards to prevent data breaches and interoperability issues.
2. **Accessibility Standards**: In designing the user interface, we followed the best practices outlined in the ISO standards for ergonomic design. Features like voice navigation and adjustable display settings were tested with user groups to ensure accessibility for users with varying abilities.
3. **UI and UX Design Standards**: Our design team employed established UI/UX design standards to create an intuitive and engaging user interface. This included adhering to guidelines for visual design, interaction design, and information architecture, ensuring a seamless user experience.

### REAL WORLD CONSTRAINTS

A screenshot of a document

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**Purchase Costs:**

A screenshot of a computer

Description automatically generated

## SYSTEM DESCRIPTION AND ARCHITECTURE

## SYSTEM OVERVIEW AND REQUIREMENTS

After conducting thorough research and exploring various articles, we embarked on developing a system that enhances daily routines by integrating smart technology directly into a household staple—the mirror. Our journey began with the ambition to create not just a mirror that reflects one's image but a dynamic interface that provides timely information and interactive capabilities.

From our research, we discovered numerous implementations of smart mirrors, some of which can be described as groundbreaking, pushing the boundaries of digital interaction within the home. However, many of these cutting-edge ideas come with high costs and complex technology requirements that are not feasible given budget constraints and ease of use for the average consumer. Therefore, our goal was to design a financially viable and user-friendly system that could be realistically implemented in a typical household.

Our system primarily revolves around four key elements: Display, Connectivity, User Interaction, and Real-time Processing.

We aimed to effectively connect these components to achieve our main objective: to deliver relevant and personalized information to users through an intuitive interface at the right time.

In our project, the definitions of these factors are:

* **Display**: The mirror itself, which serves as the interface displaying information.
* **Connectivity**: Integration with internet services and home networks to fetch and synchronize data.
* **User Interaction**: Methods through which users engage with the system, including voice, touch, and presence detection.
* **Real-time Processing**: The capability to process and update information instantaneously to ensure accuracy and timeliness.

To implement this system, we utilized IoT technology, which, as defined broadly, includes any device connected to the internet that can exchange data. The essence of IoT is creating a network of devices—ranging from simple sensors to sophisticated systems—that can communicate with each other.

Our Smart Mirror system is designed to gather data from various sources, such as weather updates, calendar entries, and news feeds. Sensors integrated within the mirror detect user presence to activate and deactivate the display, conserving energy and enhancing user interaction. This data is processed by a local controller within the mirror, which then communicates with a central server to synchronize information and ensure it is up-to-date.

This information is then formatted to be visually and interactively accessible through the mirror, allowing users to view their schedule, control smart home devices, receive news updates, and even play music through integrated services like Spotify. Additional functionalities like voice recognition and motion sensors enhance the interactivity, making the Smart Mirror a valuable addition to modern smart homes by providing a centralized platform for information and control.

## PROJECT PLAN AND TIMELINE

Our Smart Mirror project was meticulously organized into several critical phases, each designed to ensure the seamless development and deployment of the system. Here’s a brief overview of what we accomplished during each phase, along with the adjusted dates:

1. **Design and Planning (January 29 - February 5, 2024)**
   * We initiated our project with an intensive design and planning stage, setting clear objectives and specifications for the Smart Mirror. This early stage set the tone and direction for all subsequent efforts.
2. **Component Sourcing and Assembly (February 5 - February 12, 2024)**
   * Immediately following our planning phase, we sourced the required components, selecting optimal hardware such as sensors and displays. We then proceeded to assemble these components, constructing the initial prototype of the Smart Mirror.
3. **Software Development (February 12 - February 19, 2024)**
   * Simultaneous with hardware assembly, we embarked on the software development phase. Our team worked on crafting a user-friendly interface and integrating APIs for real-time data, alongside developing the connectivity features essential for IoT functionality.
4. **Integration and Testing (February 19 - February 26, 2024)**
   * Next, we integrated the hardware and software components. This stage was crucial to ensure that the system components functioned harmoniously. We conducted extensive tests to detect and resolve any integration issues.
5. **User Testing and Feedback Integration (March 26 - April 4, 2024)**
   * We then introduced the prototype to a select group of users to collect valuable feedback. This feedback was crucial for refining the user experience, prompting us to make specific adjustments to enhance the system's usability and functionality.
6. **Final Testing and Quality Assurance (April 4 - April 11, 2024)**
   * With user insights integrated, we moved to the final testing and quality assurance phase. Here, we ensured that the Smart Mirror adhered to all performance and safety standards, confirming that the product was ready for market release.
7. **Documentation and Project Reporting (April 11 - April 18, 2024)**
   * In the final week, we focused on documenting all the processes and outcomes of the project. This documentation is intended to serve not only as a project completion report but also as a valuable reference for future initiatives.

A green graph with numbers and a graph

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*Figure 1: Gannt Chart*

**Individual Team Contribution**

**Dagmawi Abera**

* **General Product Management**: Dagmawi spearheaded the overall management of the Smart Mirror project. His role was pivotal in orchestrating the project's progression, from inception through to completion. He ensured that all project phases were aligned with the timeline and objectives, facilitating a seamless workflow.
* **Meeting Coordination**: He was responsible for scheduling and leading all project meetings. This included preparing agendas, documenting proceedings, and following up on action items, ensuring that all team members were on the same page and that deadlines were met.
* **Project Support**: Dagmawi provided cross-functional support to both the hardware and software teams. His versatility allowed him to assist in troubleshooting issues across different segments of the project, contributing to a collaborative team environment.

**Hamede Abdulgafur**

* **Software Development Lead**: Hamede took charge of the entire software development process. His expertise was critical in designing and developing the software that powers the Smart Mirror, ensuring it met all functional requirements.
* **Module Integration**: He played a key role in integrating various software modules that enhanced the mirror’s functionality. This included customization of the user interface, integration of real-time data fetching modules, and ensuring smooth interoperability between different software components.
* **User Testing Oversight**: Hamede was instrumental in organizing user testing sessions. He gathered feedback from test users, analyzed it, and made necessary adjustments to the software, which was crucial for refining the user experience and ensuring the product’s market readiness.

**Noah Awol**

* **Hardware Integration Specialist**: Noah was tasked with the critical role of hardware integration. He managed the assembly and configuration of the hardware components that form the backbone of the Smart Mirror.
* **System Testing and Configuration**: His responsibilities extended to the initial testing and configuration of the hardware setup. Noah ensured that all components functioned correctly and met the specifications required for optimal performance of the Smart Mirror.

## COMPONENTS OF THE SYSTEM

**Hardware Components:**

1. **Raspberry Pi**
   * **Purpose**: Acts as the central computing unit of the Smart Mirror, managing software operations and data processing.
2. **Display Monitor**
   * **Purpose**: Displays the interface of the Smart Mirror, showing real-time information and user interactions.
3. **Two-Way Mirror**
   * **Purpose**: Functions as a standard mirror while allowing the display monitor's content to be visible through the glass when activated.
4. **Speaker**
   * **Purpose**: Provides audio output for interactions, including feedback from voice commands and music streaming via connected services.
5. **PIR Motion Sensor**
   * **Purpose**: Detects the presence of individuals in front of the mirror to activate the display or adjust settings based on user proximity.
6. **Microphone**
   * **Purpose**: Captures voice commands from users, facilitating interaction with the Smart Mirror’s software functionalities.

**Software Components:**

1. **Module Integration through Magic Mirror**
   * **Purpose**: Integrates various functional modules that enhance the usability of the Smart Mirror, such as displaying information and user interaction.
2. **Direct Service API Integration**
   * **Components**:
     + **News API**: Fetches and displays the latest news headlines.
     + **OpenWeather API**: Provides current weather conditions and forecasts.
     + **Calendar**: Integrates with user’s personal calendar to display upcoming events and reminders.
3. **Voice Recognition**
   * **Purpose**: Allows users to interact with the Smart Mirror through voice commands, making the interface hands-free and more accessible.
4. **Google Personal Assistant**
   * **Purpose**: Integrates with Google Home for expanded voice command capabilities, allowing users to control other smart home devices, ask questions, and manage tasks directly through the Smart Mirror.
5. **Custom API Integration**
   * **Example**: Spotify
   * **Purpose**: Enables music streaming directly through the Smart Mirror, allowing users to play music via Spotify through voice commands or interface interaction.

A computer programing software

Description automatically generated with medium confidence

*Figure 2: System/ Block Diagram.*

## PIR SENSOR

**Overview**

The PIR (Passive Infrared) Motion Sensor is a critical component in the Smart Mirror system, used primarily for detecting the presence of a person near the mirror. This sensor operates by sensing the infrared radiation (heat) emitted naturally by bodies, which enables it to detect movement within its range without direct contact.

**Functionality**

The functionality of the PIR Motion Sensor in the Smart Mirror is twofold:

1. **Energy Efficiency**: The sensor helps conserve energy by activating the display only when it detects motion. This means that the mirror remains in a low-power state until someone approaches, reducing unnecessary power consumption.
2. **User Interaction**: By detecting user presence, the sensor ensures that the mirror displays information exactly when it is needed, enhancing user convenience and interaction with the device.

**Implementation**

The PIR Sensor is strategically placed within the mirror assembly to cover the intended area of detection effectively. It is connected to the Raspberry Pi, which processes its signals to determine whether to activate or deactivate the display based on the presence or absence of motion.

**Advantages**

* **Non-intrusive Detection**: The sensor operates without any physical interaction from the user, making it ideal for integration in personal and home devices where user-friendliness is key.
* **Low Power Consumption**: PIR sensors are known for their low power requirements, which is beneficial for keeping the overall energy consumption of the Smart Mirror low.
* **High Sensitivity**: Capable of detecting even slight movements, ensuring that the mirror activates promptly when a user approaches.

**Applications**

Within the Smart Mirror, the PIR Motion Sensor not only enhances the practicality of the device by saving power and providing timely information but also contributes to a seamless and modern user experience. Its responsiveness makes the Smart Mirror appear intuitively interactive, as it 'wakes up' from a dormant state as soon as the user is nearby, ready to display useful information or take voice commands.

A green and white electronic device

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*Figure 3: PIR Motion Sensor*

## Display Monitor and Internal Components

**Overview**

The Display Monitor in the Smart Mirror is a high-resolution LCD screen that serves as the primary interface for displaying information and user interactions. It is situated behind the two-way mirror, allowing displayed content to be visible to the user when activated, while maintaining the functionality of a traditional mirror when inactive.

**Functionality**

* **Content Display**: The monitor displays various types of information such as news updates, weather forecasts, calendar entries, and more, depending on the software configurations and user preferences.
* **Interaction Interface**: It also serves as the visual interface for user interactions, displaying menus, application icons, and responsive animations that guide the user through different functions.

**Implementation**

The Display Monitor is carefully integrated behind the two-way mirror to ensure optimal visibility and functionality. It is connected to the Raspberry Pi, which drives the display based on the inputs received from the software applications and user interactions via the touch interface or voice commands.

**Advantages**

* **High Visibility**: Even behind the two-way mirror, the monitor offers clear and vibrant display quality, ensuring that information is easily readable.
* **Versatility**: Supports various multimedia formats and can dynamically change display content based on user interactions or predefined schedules.

**Display Monitor Motherboard**

**Overview**

The motherboard within the display monitor of the Smart Mirror is crucial for controlling the screen and interfacing with the Raspberry Pi. This built-in motherboard is responsible for processing the input signals and managing the display output, ensuring that images and information are correctly rendered on the screen.

**Specifications**

* **Processor**: Includes a small, dedicated processor capable of handling display signals and graphics processing tasks.
* **Memory**: Equipped with a modest amount of RAM to manage the display functions and buffer inputs.
* **Connectivity**: Features various input ports such as HDMI, VGA, or DisplayPort, which allow it to receive video and data signals from the Raspberry Pi.
* **Firmware**: Runs firmware that controls the display settings, such as brightness, contrast, and response time adjustments.

**Functionality in Smart Mirror**

* **Signal Processing**: Converts digital signals received from the Raspberry Pi into visual data that can be displayed on the LCD screen. This includes decoding and scaling up video streams if necessary.
* **Power Management**: Manages power distribution to the display components, ensuring energy efficiency and longevity of the screen.
* **Display Quality Control**: Adjusts display parameters like brightness, color balance, and refresh rate in real-time to ensure optimal image quality based on the content being displayed and ambient lighting conditions.

**Implementation**

In the Smart Mirror setup, the display monitor's motherboard is typically integrated directly into the back panel of the LCD display. It receives data from the Raspberry Pi through a digital interface (commonly HDMI), processing this data to render the user interface of the Smart Mirror on the two-way mirror.

**Advantages**

* **Real-time Performance**: Ensures smooth and responsive display performance, crucial for a dynamic interface like that of the Smart Mirror.
* **Customization Capability**: Allows for the adjustment of display settings via software, enabling the customization of visual output to suit different lighting conditions and user preferences.
* **Reliability**: Designed specifically for continuous operation, the motherboard enhances the reliability and overall lifespan of the display in daily use scenarios.

**Speaker**

**Overview**

The speaker component in the Smart Mirror provides audio output capabilities, crucial for voice feedback from virtual assistants and media playback.

**Functionality**

* **Audio Feedback**: Offers audio responses to user commands, facilitating interactive voice communication.
* **Media Playback**: Plays music or other audio content streamed through connected services like Spotify.

**Implementation**

The speaker is integrated into the mirror’s frame, ensuring that sound is directed towards the user for clear audibility. It is connected to the Raspberry Pi, which controls audio output based on the user’s interactions and settings.

**Advantages**

* **Sound Clarity**: Designed to offer clear and crisp audio, enhancing the user experience, especially in voice interactions and media playback.
* **Discreet Integration**: Positioned to be unobtrusive yet effective, maintaining the aesthetic appeal of the Smart Mirror while providing functional audio output.

A rectangular black box with a colorful design

Description automatically generated A pair of black rectangular speakers with red wires

Description automatically generated

*Figure 4: Display Monitor and Speaker*

## RASPBERRY PI 4 Model B

**Overview**

The Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers significant enhancements in processor speed, multimedia performance, memory, and connectivity compared to earlier versions. This makes it an ideal choice for demanding projects like the Smart Mirror, where multiple functionalities need to be managed simultaneously.

**Specifications**

* **Processor**: Quad-core ARM Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
* **Memory**: Options of 2GB, 4GB, or 8GB LPDDR4-3200 SDRAM
* **Connectivity**:
  + Gigabit Ethernet
  + Dual-band 802.11ac Wi-Fi
  + Bluetooth 5.0
* **USB Ports**: 2 USB 3.0 ports and 2 USB 2.0 ports
* **Video Output**: Supports dual displays via a pair of micro HDMI ports, supporting up to 4K resolution
* **Power Requirement**: 5V DC via USB-C connector (minimum 3A) or GPIO header (minimum 3A)

**Functionality in Smart Mirror**

* **Data Processing**: The Raspberry Pi 4 Model B handles all the computational tasks required by the Smart Mirror, including running the operating system, software applications, and processing inputs from various sensors and the internet.
* **Multimedia Output**: Capable of driving high-definition display outputs, it ensures that the content on the Smart Mirror is crisp and engaging.
* **Peripheral Management**: Manages various peripherals including the PIR sensor, microphone, speaker, and display monitor through its multiple connectivity options.

**Implementation**

In the Smart Mirror, the Raspberry Pi 4 Model B is integrated into the chassis behind the two-way mirror. It connects to all other hardware components to form the central control unit of the device. The system runs a custom-developed software stack that interfaces with various APIs and controls the user interaction elements of the mirror.

**Advantages**

* **High Performance**: With its improved processor and memory options, the Raspberry Pi 4 Model B can handle multiple tasks efficiently, from sensor data processing to video streaming.
* **Enhanced Connectivity**: The inclusion of faster Ethernet and dual-band Wi-Fi ensures that the Smart Mirror can connect reliably to home networks for real-time data updates.
* **Dual Video Support**: The ability to support dual video outputs is particularly useful for future expansions or for more complex user interface requirements.

A close-up of a green circuit board

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*Figure 5: Raspberry Pi 4 Model B*

## Two – Way Mirror

**Overview**

A two-way mirror, also known as a one-way mirror or semi-transparent mirror, is a critical component in the Smart Mirror system. It combines the functionality of a traditional mirror with the ability to display digital content from an LCD screen positioned behind it. This mirror has a reflective coating on one side and is transparent from the other, allowing light from the display monitor to pass through selectively.

**Specifications**

* **Material**: Typically made from glass or acrylic, coated with a semi-transparent layer of metal.
* **Transparency**: Allows approximately 70-80% of light to pass through from the display behind it, while reflecting about 20-30% on the front side.
* **Thickness**: The thickness can vary, but for most smart mirror applications, it ranges from 3mm to 6mm, balancing durability and clarity.

**Functionality in Smart Mirror**

* **Display Interface**: The primary function of the two-way mirror in the Smart Mirror is to serve as the interface through which digital content is viewed. While it reflects like a normal mirror when the display is off, it becomes a window to the digital content when the display is activated.
* **Aesthetics and Privacy**: It maintains the aesthetic of a traditional mirror, ensuring that the technology behind it is invisible when not in use. This not only enhances the decor but also adds an element of privacy, as the technological components are hidden from view.

**Implementation**

In the Smart Mirror setup, the two-way mirror is precisely positioned in front of the LCD display. This placement is critical to ensure that the displayed content is visible through the mirror without compromising its reflective quality. The mirror and display must be aligned perfectly to maximize visibility and readability of the screen content through the mirror.

**Advantages**

* **Dual Functionality**: Combines the functionality of a standard mirror with the ability to display digital information, offering a high-tech solution without sacrificing the utility or aesthetics of a mirror.
* **Seamless Integration**: Enhances the environment by integrating digital features into a familiar, everyday object without altering its traditional appearance or function.
* **User Experience**: Elevates the user experience by providing interactive and real-time access to information in a way that blends naturally into personal and home spaces.

A mirror with a rectangular object on it

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*Figure 7: Two Way Mirror*

## Microphone

**Overview**

The microphone in the Smart Mirror system is a crucial hardware component designed to capture voice inputs from users. This enables interactive voice commands, allowing users to control the mirror and access its features hands-free, enhancing convenience and accessibility.

**Specifications**

* **Type**: Typically, a small, high-sensitivity condenser microphone suitable for consumer electronics.
* **Sensitivity**: Designed to pick up human speech from a distance, ensuring clear audio capture even in relatively noisy environments.
* **Directionality**: Often omnidirectional to capture sound from multiple directions, although directional microphones can also be used to reduce background noise.
* **Integration**: Compact and discreet, easily integrated into the mirror’s frame without being visually obtrusive.

**Functionality in Smart Mirror**

* **Voice Command Reception**: The primary role of the microphone in the Smart Mirror is to receive voice commands from the user. These commands can control various functions of the mirror, such as turning the display on or off, switching between different content types (news, weather, calendar), or adjusting volume settings.
* **Interaction with Virtual Assistants**: The microphone enables integration with virtual assistants like Google Assistant. This allows the Smart Mirror to function as part of a connected home system, enabling it to execute more complex tasks like setting reminders, playing music, or controlling other smart home devices.
* **Feedback System**: In addition to receiving commands, the microphone can help the system provide auditory feedback to the user, confirming actions or providing requested information verbally.

**Implementation**

In the Smart Mirror, the microphone is strategically positioned to optimize voice capture while maintaining the aesthetics of the design. It connects directly to the Raspberry Pi, where voice data is processed. Voice recognition software running on the Pi analyzes the audio input to interpret commands and trigger appropriate actions.

**Advantages**

* **Hands-free Operation**: Enhances user convenience by allowing for hands-free control, making the Smart Mirror more accessible and user-friendly.
* **Enhanced Accessibility**: Particularly beneficial for users with mobility or vision impairments, as it allows easy control without the need to physically interact with the device.
* **Integration Flexibility**: The use of a microphone enables the mirror to integrate seamlessly with broader smart home ecosystems, offering users a unified home automation experience.

A black and silver usb device

Description automatically generated

*Figure 7: Raspberry Pi compatible microphone.*

A close-up of a computer part

Description automatically generated

*Figure 8: Hardware Integration*

## Software Integration and walkthrough

**MagicMirror²**

**MagicMirror²** is an open-source platform designed primarily for building a smart mirror interface. It runs on a hardware base, typically a Raspberry Pi, and uses a variety of modular components to display personalized information such as weather, news, calendar, and more.

**Core Functionality:**

* **Modular Design:** MagicMirror² operates using modules, which are individual components that can be added, removed, or customized according to user preferences. Each module corresponds to a specific functionality.
* **Customizable Layout:** Users can configure the position and appearance of each module on the mirror’s display via a configuration file.
* **Extensibility:** Developers can create their own modules or utilize a wide range of existing third-party modules that integrate additional functionalities like voice commands, online service integration, and more.

**System Requirements:**

* **Raspberry Pi** (or any compatible Linux system)
* **Node.js:** Provides the runtime environment for running JavaScript on the hardware.
* **Electron:** Facilitates the graphical output necessary for displaying the interface on a monitor, turning the Raspberry Pi and the monitor into a smart mirror.

**Main Code Used to Configure MagicMirror²**

The primary configuration file for MagicMirror² is **config.js**, which is located in the root directory of the MagicMirror² installation. This file is what we used to specify which modules in our smart mirror.

var config = {

address: "localhost", // Address to listen on, can be:

// - "localhost", "127.0.0.1", "::1" to listen on loopback interface

// - another IP, to listen on a specific interface

// - "", "0.0.0.0", "::" to listen on any interface

port: 8080,

ipWhitelist: ["127.0.0.1", "::ffff:127.0.0.1", "::1"], // Set [] to allow access from anywhere

useHttps: false, // Support HTTPS or not, default "false" will use HTTP

language: "en",

timeFormat: 24,

units: "metric",

modules: [

{

module: "alert",

},

{

module: "clock",

position: "top\_left"

},

{

module: "calendar",

header: "US Holidays",

position: "top\_left",

config: {

calendars: [

{

symbol: "calendar-check",

url: "webcal://www.calendarlabs.com/templates/ical/US-Holidays.ics"

}

]

}

},

{

module: "currentweather",

position: "top\_right",

config: {

location: "New York",

locationID: "", //ID from http://bulk.openweathermap.org/sample/; remove the < and >

appid: "YOUR\_OPENWEATHER\_API\_KEY"

}

}

]

};

if (typeof module !== "undefined") {module.exports = config;}

**Explanation of the Configuration Code:**

* **address and port:** Define the IP address and port number on which the MagicMirror² server will run. It can be set to listen on all network interfaces or just localhost.
* **ipWhitelist:** Controls which devices can connect to the MagicMirror². Setting it to an empty array allows connections from all IPs.
* **language, timeFormat, units:** Define the default language, time format (12 or 24 hours), and measurement units (metric or imperial) used by the modules.
* **modules:** This is an array where each object represents a module. Common attributes for a module include:
  + **module:** The name of the module directory.
  + **position:** Where on the screen the module will be displayed.
  + **config:** Specific configurations for each module, such as personal API keys, personalized messages, or custom settings relevant to that module.

**Voice Recognition Module (MMM-GoogleAssistant)**

**Overview:** MMM-GoogleAssistant module integrates Google Assistant to MagicMirror², enabling users to interact with the mirror using voice commands. It can process spoken commands and display information or control smart devices.

**Technical Flow:**

* **Initialization:** The module initializes Google Assistant SDK with user credentials.
* **Voice Detection:** Utilizes a microphone to detect spoken words.
* **Query Processing:** Sends queries to Google Assistant and fetches the response.
* **Display:** Visual responses are shown on the mirror.

Pseudo Code:

Initialize GoogleAssistant with Credentials

On Voice Detected:

Record Audio

Send Audio to GoogleAssistant API

Receive Command or Query Response

Display Response on Mirror

End

**Direct Service APIs**

**News Module (newsfeed)**

**Overview:** This module fetches and displays news headlines from a specified RSS feed.

**Flow:**

* **Initialization:** Configures news URLs and update intervals.
* **Data Fetching:** Periodically checks the RSS feed for new articles.
* **Display:** Updates the mirror display with the latest headlines

Pseudo Code:

Initialize Newsfeed with Feed URL

Every 30 Minutes:

Fetch Latest News from Feed

Update Display with New Headlines

End

**Weather Module (currentweather)**

**Overview:** Shows current weather information fetched from OpenWeatherMap API based on user location.

**Flow:**

* **Setup:** User provides API key and location details.
* **Data Retrieval:** Retrieves current weather data at regular intervals.
* **Display:** Shows weather information like temperature, weather conditions, and icons.

**Pseudo Code:**

Initialize Weather with API Key, Location

Every 10 Minutes:

Fetch Current Weather from OpenWeatherMap

Display Weather Data on Mirror

End

**Calendar Module (calendar)**

**Overview:** Displays calendar events by fetching data from a provided iCal URL.

**Flow:**

* **Configuration:** Setup with URL of the iCal calendar.
* **Update Cycle:** Regular updates to fetch upcoming events.
* **Display:** Events are shown on the mirror.

**Pseudo Code:**

Initialize Calendar with iCal URL

On Start and Every 2 Hours:

Fetch Calendar Events

Update Display with Upcoming Events

End

**Custom API Module (Spotify - MMM-NowPlayingOnSpotify)**

**Overview:** Connects to Spotify to display information about currently playing tracks on the user's account.

**Flow:**

* **Authentication:** Uses Spotify's OAuth to authenticate and get access tokens.
* **Data Fetching:** Regularly checks Spotify's API to get current playback state.
* **Display:** Updates the mirror with current track information.

**Pseudo Code:**

Initialize Spotify with Client Credentials

On Token Expire:

Refresh Token

Every 10 Seconds:

Fetch Current Playback Info from Spotify

If New Song Playing:

Update Display with New Track Info

End

Each of these components is designed to operate within the modular architecture of MagicMirror², allowing them to be easily configured or swapped based on user preferences. The use of Node.js provides a robust platform for handling web requests, asynchronous data updates, and user interactions through a variety of input devices and APIs.

## Result and Prototype

**Integration and Functional Testing**

As part of the Smart Mirror project development, comprehensive integration and functional testing were conducted to ensure that all components not only functioned individually but also operated seamlessly together. The testing phase was meticulously planned to cover all aspects of system functionality, including hardware component integration, software application performance, and user interaction capabilities.

**Successful Integration**

* **Hardware and Software Integration**: The Raspberry Pi, display monitor, two-way mirror, microphone, speaker, and PIR motion sensor were successfully integrated. Each component was methodically tested to confirm operational functionality before integrating with the Raspberry Pi to ensure seamless communication and performance.
* **Software Module Integration**: All software modules, including the direct service APIs for news, weather updates, and calendar integration, were successfully implemented. Custom API integration for services like Spotify and the voice recognition functionality for Google Assistant were also effectively incorporated into the system.

**Functional Testing**

* **System Responsiveness**: Tests were conducted to evaluate the responsiveness of the Smart Mirror to user commands, both through touch interaction and voice commands via the integrated microphone. The system demonstrated prompt responses with no noticeable lag, providing a smooth user experience.
* **Sensor Performance**: The PIR motion sensor’s functionality was rigorously tested to ensure it accurately detected user presence and triggered the display effectively, enhancing energy efficiency by turning the display on and off based on user activity.
* **Audio and Visual Feedback**: The speaker and display monitor were tested for clarity and performance. Audio feedback from the speaker was clear and well-timed with user interactions, while the display monitor showed excellent color accuracy and brightness, effectively visible through the two-way mirror.

**User Experience Testing**

* **User Interface (UI) Usability**: A group of potential users was invited to interact with the Smart Mirror to assess the intuitiveness of the UI and the ease of navigating through different functionalities. Feedback was overwhelmingly positive, with users appreciating the simplicity and responsiveness of the interface.
* **Real-World Usability**: The Smart Mirror was installed in a home environment to test its performance under daily usage conditions. This test confirmed the system’s reliability and the practical benefits of its features, such as checking the day’s schedule, getting updates on weather conditions, and streaming music or news.

**Results**

The integration and testing phases of the Smart Mirror project were highly successful, confirming that all system components worked harmoniously and as planned. The device met all specified requirements, providing a robust, user-friendly, and responsive experience. Users particularly valued the hands-free control and the personalized information access, which significantly enhanced their daily routines.

The project team documented all test procedures, outcomes, and user feedback, which will serve as valuable resources for future enhancements and iterations of the Smart Mirror. Overall, the Smart Mirror project not only achieved its goals but also set a high standard for future smart home technology integration.



*Figure 9: Project Prototype*

## Future Changes and Improvements

**Enhanced Sensor Integration**

* **Advanced Motion Sensors**: Upgrade to more advanced motion sensors that can differentiate between different types of movement and even identify specific users. This could allow for personalized interactions and settings based on who is in front of the mirror.
* **Environmental Sensors**: Incorporate environmental sensors such as ambient light sensors or humidity sensors. These could adjust the display brightness and offer weather-appropriate suggestions, like reminding a user to take an umbrella if it’s predicted to rain.

**Improved Connectivity and Integration**

* **Broader Smart Home Compatibility**: Enhance the mirror’s ability to integrate with a wider range of smart home systems and IoT devices. This could include controlling lighting, thermostats, or even security systems directly from the mirror.
* **Seamless Multi-Device Synchronization**: Improve the synchronization capabilities with other devices, such as smartphones or tablets, allowing for a more seamless transition of tasks and notifications between devices.

**Software and Interface Upgrades**

* **Personalization Algorithms**: Develop more sophisticated algorithms that learn from user behavior to personalize content and notifications more effectively.
* **Augmented Reality Features**: Implement augmented reality (AR) capabilities for new interactive experiences, such as trying on virtual clothes or previewing makeup.

**User Interaction Enhancements**

* **Gesture Control**: Introduce gesture control features that can interpret different hand movements for controlling the interface, reducing the need for voice commands or physical touch.
* **Voice Command Improvements**: Enhance the voice recognition engine to better understand and process natural language, accommodating a broader range of accents and speech patterns.

**Aesthetic and Design Modifications**

* **Customizable Frames**: Offer customizable frames in various styles and materials to better match users’ home decor.
* **Slimmer Profile**: Work on reducing the depth of the mirror, aiming for a sleeker, more modern look that can be mounted more easily in a variety of settings.

**Energy Efficiency and Sustainability**

* **Low Power Display Technologies**: Research and implement lower power display technologies that can offer the same brightness and clarity while reducing energy consumption.
* **Recyclable Materials**: Increase the use of recyclable or biodegradable materials in the manufacturing process to enhance the sustainability of the product.

## CONCLUSION AND ACKNOWLEDGMETNS

**Conclusion**

The Smart Mirror project successfully demonstrated the feasibility and utility of integrating smart technology with everyday objects to enhance personal productivity and convenience. Through meticulous planning, rigorous testing, and detailed implementation, the project team was able to deliver a fully functional Smart Mirror that not only meets but exceeds the initial project specifications. This innovative mirror effectively combines information display, interactive user interfaces, and real-time data integration in a seamless manner, offering users a unique blend of functionality and convenience. The success of this project opens the door to further innovation in smart home technology and sets a promising pathway for future enhancements and integrations that could redefine the way we interact with our living environments.

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