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Design Of Interactive Smart Mirror System for Digital Information Display Based on Multitasking Approach Using Raspberry Pi

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Abstract— The average time humans look in the mirror is in the early morning when they will get ready for work. A person can rarely focus on other activities such as watching television for the latest news, checking the clock for the correct time, or even checking the weather forecast. Therefore, the purpose of this research is to design an interactive smart mirror that functions as a personal digital assistant to provide a schedule of daily activities, including recognizing the owner's face for access to the smart mirror, displaying weather forecasts, displaying the date and time, as well as the latest news. Unlike most smart mirrors in previous studies, this smart mirror design is connected to a facial recognition system. This will work for such security systems that the user will be granted access to the system only when the system detects that it is the owner. The method used in the research is the agile methodology for the project's flexibility and structured work organization. Experiments will be carried out on all test data starting from the accuracy of turning the smart mirror on and off, loading the weather on average 5 seconds after internet connection, making sure the Pi-camera component is active, and checking for face profiles. The system will test the data on each unit individually and as a whole to ensure efficiency and reliability. The experimental results in this study provide an accurate value of 100%.

Keywords— Smart Mirror, Prototyping, Raspberry Pi, Voice Recognition, Facial Recognition, Touch Screen, IoT.

I. INTRODUCTION

Our lifestyle has evolved so that managing time is the most important thing. In today's world, people need to be connected, and they are willing to have access to information quickly, whether through the television or the internet. People need to be informed and in touch with the current affairs happening around the world [1]. In another vein, people spend an average of 20-30 minutes in front of a mirror daily, and an intelligent proposal would be to make the mirror smart since we spend that much time before it. [2] Many items which are an important part of our daily lives are being upgraded to become "smart" so that they can serve us even better. In recent times, there has been an increase in the integration of household appliances and items with technology to increase their utility, normally referred to as the Internet of Things (IoT). One of such household items is the mirror, a simple reflective surface that allows us to carry out the grooming and other related activities. A Smart Mirror falls into a category of things called the internet of things (IoT) [3]. The internet of things (IoT) describes the network of physical objects embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet [4].

An interactive Smart Mirror is under the IoT technology concept of the "Smart Home". It is an electronic device integrated with a mirror. It doubles as the traditional mirror but provides additional users such as information sources, smart home control, and various other functionalities. The smart mirror has its applications in both home and commercial usage. The home provides activities such as schedules, appointments, reminders, dates, time, weather forecasts, trending news, etc., while other activities such as brushing and bathing are being carried out. In commercial usage, these smart mirrors can be placed at strategic locations like boutiques. Whereas one is trying on a product like a shirt or glasses, additional information such as price tags, similar products, and sizes are shown on the mirror. It has a similar application in cars, offices, salons, etc.

The smart mirror integrates seamlessly into an existing environment like a normal mirror while providing additional usage by integrating technologies such as artificial intelligence (AI), motion and gesture detection, internet connection capabilities, etc.

According to the findings of study, the construction of a smart mirror can be done in a variety of unique and intriguing ways. Some of the solutions are already on the market, while others are only prototypes or Do-It-Yourself (DIY) projects made by enthusiasts for their own use [5]. One of the enthusiasts has created a system that shows fundamental pieces of information such as the date, the time, and the weather. Integration with social networks is also possible, enabling users to access their various social profiles in any environment, even the restroom.

The remote controller or the mobile application may be used to control the mirror, depending on your preference. A person's weight, heart rate, and body fat percentage can be monitored via sensors that are built right into the mirror, in

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addition to the functions already described. Samsung introduced its Smart Window in 2012 at the Consumer Electronics Show [6] in Las Vegas. Smart Window is a window that can also function as a gadget. While functioning as a window, this gadget gives users access to various applications, such as checking the weather or interacting with friends and family. It displays various statistics, including the amount of weight a person has [6]. The Magic Memory Mirror [7] is another high-tech mirror that can be purchased right now and is on the list. This mirror has replaced traditional dressing rooms in some retail establishments specializing in apparel sales. Customers can communicate with the mirror by using the smartphone application. They can see their costumes from any angle thanks to the mirror, and it also allows them to alter their appearances by altering the color of their clothing or by adding accessories to what they are wearing [8].

In addition to the items that have already been described, there are also efforts on a more modest scale that entail stitching together various components to accomplish the functionality of a smart mirror. Most of these are completed as do-it-yourself projects and are utilized for personal or academic purposes [9]. It was intended to offer a smart mirror product that was commercially viable at an affordable price while providing high-end functionality like facial recognition, gesture and voice control, and other similar features. The bathroom mirror that Max Braun made himself stands out from the rest of these DIY projects [8]. This mirror does not give as many functions as those that are sold, but it still meets the purpose of a smart mirror since it displays the fundamental information that a person needs when they are in the bathroom. This includes the weather, the time and date, and the news. Building a one-of-a-kind intelligent mirror is a component of a great number of other projects. However, this developed interactive smart mirror has more integrated multitasking features that display real-time information such as date, time, weather forecast, trending news headlines, etc., with the aid of a Raspberry Pi 4, making it more robust and intelligent than the existing ones.

II. RESEARCH METHODOLOGY

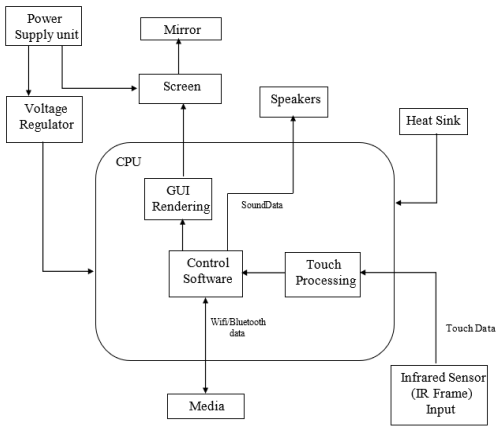

Figure 1. Hardware Subsystem Block Diagram

The flow hardware sub-system block diagram shown in Figure 1 is utilized throughout the stages of this study. The smart mirror consists of three major sub-systems that perform major relevant tasks.

1) Touch sub-system: This is the main input system of the smart mirror that uses infrared technology (IR). When a touch input is received, the IR frame transmits the coordinates of this touch to the Central Processing Unit (CPU), and since the touch events/coordinates have been programmed in the CPU for the provided coordinates, the CPU acts.

2) Output sub-system: A display sub-system and a voice Detection sub-system. The two outputs are produced based on the input commands. These outputs may either be as a display on the Graphic User Interface (GUI) interfaced with the screen connected to the USB port or as a resulting sound from the speaker connected with the microphone to another USB port. The output is a 22" display screen connected to the pi board using an HDMI to USB adapter based on the specifications in Table I. The display is placed behind the two-way mirror, which has a 0.6 reflective coefficient and 0.4 transparency coefficient allowing it to be reflective while simultaneously allowing the user to view the display behind it. The screen displays information like calendar, weather, etc., while allowing users to interact with it using the touch input.

TABLE I
Screen Resolution

Size	22"
Resolution	1080*1080
Frequency	60Hz
Aspect ratio	16:9
Clock rate	100MHz

3) Control sub-system (Voice control and facial recognition): This sub-system involves the CPU, which the Raspberry Pi 4B powers. The raspberry Pi 4 is a microcomputer with a sizable amount of computing power usually used by educators and hobbyists for Do-It-Yourself (DIY) projects. It is relatively cheap and boasts a computer with CPU speeds of 1.5Ghz and RAM up to 8GB. The operating system installed is Raspbian. Raspbian is the official operating system of the Raspberry Pi. Raspbian is a version of Linux explicitly built for the Raspberry Pi. It is downloaded, and the software is etched onto a 32GB SD card. The overall process is:

- Format the SD card using the SD Memory Card Formatter software.
- Raspbian OS from the Raspberry Pi website.
- Etch the Raspbian OS into the SD Card using etcher.
- Insert the SD Card, which now has the Raspbian OS, into the Raspberry Pi.
- Configure the name and password on boot.

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- The Control sub-system (Raspberry Pi) is ready to be integrated with other sub-systems.

Installed in the raspberry pi is the open-source Magic Mirror software [9] for Raspberry Pi, which was developed using Electron Js and JavaScript, and some of the tools used or modules.

1) Magic Mirror Software Magic Mirror: An open-source modular smart mirror platform that Magic Mirror developed. Converting a mirror in your hallway or bathroom into a personal assistant is now possible thanks to the Magic Mirror, which comes with an expanding variety of modules that can be installed. The Magic Mirror software is built around an extensible plugin framework and employs Electron as its application wrapper. Installing a web server or a browser is therefore not required any longer.

2) JavaScript: This is an interpreted programming language with object-oriented capabilities that can be used for both client-side and server-side functionalities.

3) Full Calendar: This is a module for rendering full calendar functionalities.

4) Open Weather Map API: This is an API for fetching real-time weather.

5) News API: This is an API for fetching real-time news headlines.

6) Spotify player API: This API enables music players on the interface.

7) To-do list: This is an API that helps set up to-do lists or plan schedules.

8) MMM Face recognition: This API helps build a real-time facial recognition system.

9) Google Assistant: The Google Assistant feature is integrated to work with the smart mirror.

A way of assessing a person's voice by making use of the characteristics of the speaker's voice is referred to as a Voice Recognition system. The information is then compared to the characteristics of previously recorded signals stored in a database within the central processing unit. If the answer is true, the file name or the file number is displayed. The voices that had been trained were put to the test, and the findings showed that the system was able to verify your voice based on the word that was spoken by the user, the pitch that was used, and how it interacted with the speaker. Face Recognition Process developed a system that applied artificial intelligence in computer vision. The system was trained with visual data such as images (images with faces) and stored in a database for identification/recognition on retrieval.

Based on a Linux-powered Raspberry Pi machine, the system controls all the logic necessary for the design. It consists of ports that will be interfaced with the Pi camera. Running on raspberry pi in CPU, we used a facial AI algorithm with an AI camera interfaced with the GUI for the display.

III. Result and Discussion

The developed Smart Mirror is designed and implemented so that only when an authorized user appears in front of the mirror is their customized data displayed after proper authentication. In the flowchart in Figure 2, the system boots, initializes its requirements and fetches the data needed. It then displays the GUI. Simultaneously, the touch and display sub-systems will listen for action while in the wait-state. If a touch action is received, the system checks the coordinate and, if valid, executes the command; else, it goes back to the default wait-state. If shutdown action is received, the system shuts down.

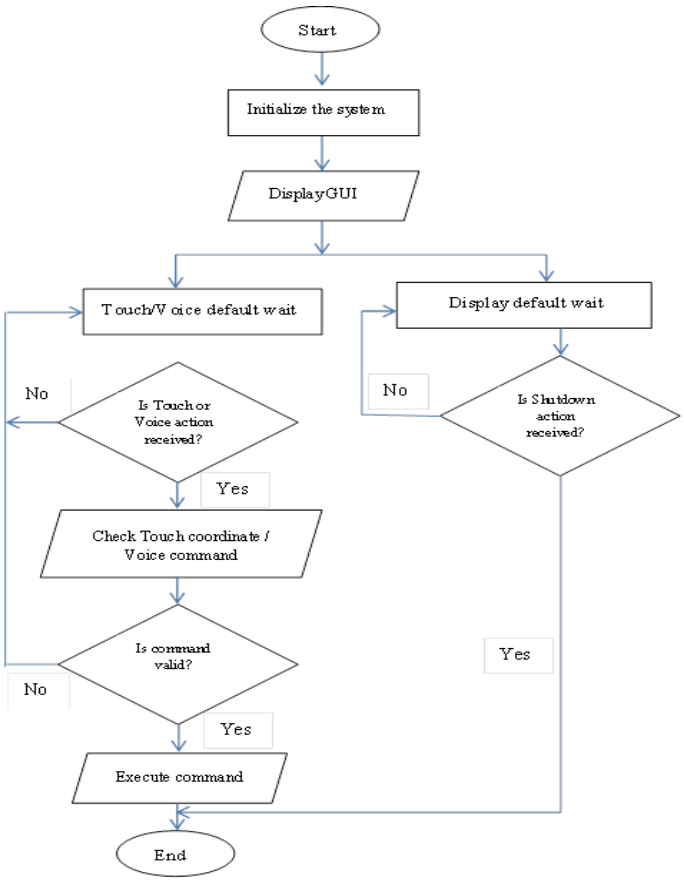

Figure 2. flowchart of the smart mirror

1) Real-time Date and Time Display: This functionality fetches a date and time from the server and renders it to the user. This functionality came with the Magic Mirror software.

Figure 3: Date-Time Functionality of The Smart Mirror

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2) Realtime Weather Display: This functionality fetches the weather forecast based on one's present location. It provides a pictorial Image, the temperature, and a written Description of the current weather, this information helps you to plan out your day. This was done using the Open Weather Map API with the location set as Awka, Nigeria.

Figure 4: Weather Functionality of The Smart Mirror

3) To-Do List: This API is a medium through which you can write into or read a local to-do list. This functionality's advantage is that one is less likely to forget what they must do for the day if it's in their face.

Figure 5: To-Do List Feature of The Smart Mirror

4) Facial Recognition Functionality: This functionality is a medium by which the camera module recognizes the face of the person presently using the mirror. If the person is a registered user, their profile comes up and shows their face on the facial recognition interface, and if they're not a user, it remains as the default guest interface. To implement using the MMM face recognition module was used.

Figure 6: Face Recognition Module

5) User Interface of the Smart Mirror: The integrated features of the mirror when the user has been verified and login

Fig 7: User Interface of Smart Mirror

The performance of the smart mirror depends on the functional reliability of the smart mirror, the facial recognition responsiveness, and the voice recognition responsiveness. Overall System Test of the Smart Mirror in Table II.

The functional reliability of the mirror is the quality of how persistent the mirror is at performing both its traditional functionality and the newly added smart functionality. The user should experience a seamless integration between these two functionalities; one should not get in the way of the other. The user should be able to interact with the smart mirror by voice or touch while performing traditional activities in front of the mirror. The more seamless the experience, the higher the functional reliability.

The facial recognition responsiveness can be calculated using the performance metrics calculation described by Aneidu et all [10]. The performance of the facial recognition system is within the accepted limits for an FRS, which is 90% accuracy, 80% on precision, and 90% on Recall. The facial recognition system detected and analyzed the individuals' faces within seconds persistently.

The voice recognition system has similar metrics as the facial recognition system. It is accurate to detect voice commands even in other background sounds. The precision of the VRS is also quite important as it distinguishes different words that may be similar to ensure that the commands received and executed are the intended voice commands. The google voice assistant is known to be a reliable voice recognition software.

TABLE II
Overall System Test of the Smart Mirror

Feature	activity	Expected response	Actual response
On/Off	Power the system on and off	The system should correctly boot up within 1 minute and shut down within 30 seconds	The system correctly boots up within 1 minute and shuts down within 30 seconds
Music Player	Play music files stored within the system.	The touch control should activate the player, and music should play seamlessly in the background.	The music plays seamlessly in the background.

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Feature	activity	Expected response	Actual response
Touch interactions	The user should interact with various aspects of the applications	All modules that interact with touch controls should activate at the touch event.	The modules all activate when touched
Touch Accuracy	The user should touch various parts of the applications	The system should respond to all inputs within +/- 1mm of the center of the physical input.	The system has 90% accuracy
The software loads the full data	Turn on the mirror, and observe each feature	The features should load data from each of their libraries	The correct data loads, and it is displayed correctly
GUI Visibility	Turn on the mirror	The GUI should be easily seen through the mirror	The GUI can be seen through the mirror
Feature interactivity	Start up the software and interact with the various features	The feature should interact accordingly	The features interact accordingly
GUI loading time	Restart the software about four times	The start-up time should be about 1 minute or less	The software starts up and shuts down within 30 seconds

IV. CONCLUSION

The smart mirror project's goal is to provide a more modern interaction with our traditional home appliances in line with the trend of IoT devices which aim to increase our interconnectivity hence improving our life by optimizing daily tasks. The mirror displays real-time information such as date-time, weather forecast, and trending news headlines, and it keeps us informed in this age of rapid information cycles. The smart mirror can be used in a variety of situations such as a store, hotels, and even offices can use smart mirrors to pass information to personnel, as people are more attracted to it.

This paper proposes the construction of a commercially viable smart mirror by implementing affordable hardware and open-source code to deliver the desired features. With greater optimization and streamlining of the process, the mirror can be produced at prices well in the range of the average Nigerian. The work is recommended for a future upgrade in developing the smartness of the mirror.

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