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Smart Reflect: An Application Nonspecific Passive Information Display Device for Public and Private Spaces

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Abstract: Mirrors can be used as perfect unobtrusive display because of their huge surface area and their obvious existence in our everyday life. Various smart features have been added to expand the functionalities of the display which can enhance one's digital well-being. Major focus behind this is to get useful information without interruption. This is different from smartphones, where users get variety of data, both relevant and irrelevant. The ultimate outcome is to make future changes on how people should receive information. Development, design and construction of this device is explained in detail in this paper. Smart Reflect, an Internet of Things or IoT based device which is curated for multi purposes and can be accumulated at multiple locations like homes, offices and commercial spaces to serve different purpose. Core of the mirror is designed in such a manner that it can be customized and personalized for both personal and commercial use basis end user's preference. For example, user might be interested in know weather status of next morning and traffic information before going out, so that they can plan their commute accordingly; It can be used inside train station and airport's washrooms to display real time information about flight and train status. The Smart Mirror thus, will maintain the aesthetics of the environment and will also provide information to people ostentatiously.

Keywords: Internet of Things, Raspberry Pi, Mirror, Home Automation, Notice Board

I. INTRODUCTION

A Mirror is an object found in most houses and offices. "Smart Mirror" is a device which displays relevant items such as traffic, weather, to-do list, calendar, news, social media updates and other information, both general and personalized to the user.[1]
Hardware design of smart mirrors is simple. A display is sandwiched between a pane of two-way glass and back-plate. Everything assembled within the frame that holds the glass and monitor. A web application based on JavaScript running on the web browser provides the software features and a Linux OS running on Raspberry Pi is used to drive the display. The browser creates a responsive sandbox for the code and node.js application runs in it.
Use of a web-based system has an obvious advantage of being always connected to the internet. Also, our use of HTML and JavaScript ensure excellent compatibility with any web browser which provides an additional advantage of natively supporting many widely adopted text and media formats. There is also a major User Interface or UI advantage as JavaScript can be styled using CSS (Cascading Style Sheets). CSS has two main benefits. Firstly, Multiple Viewport Window Compatibility — CSS can also allow the web page to be optimized for more than one size of the display. Using CSS the same web page can be presented in different viewing styles for different display sizes. Secondly, it supports animations, which can be used in conjunction with JavaScript to display widgets in an intuitive fashion.
As loosely hinted above, the core of our software for mirror focuses on two points being modular and scalable. Widgets (modules of codes developed using JavaScript designed for one special application) are developed and placed on the screen using a configuration file. The configuration file can be modified for mirror "as per-application" basis. If the mirror is to be set-up in a personal environment, widgets for showing personal agenda, birthday calendar, to-do lists, social media updates, traffic updates (example: estimated time from work to home) and several other things can be configured to display. Different home-automation systems can be connected and controlled through mirrors and all you need is a widget for the same and address it through the configuration file. Otherwise, if the mirror is to be configured for a commercial place, widgets can be developed and displayed specific to that organization or commercial space. For example, for a hospital, modules can be developed to show availability of doctors, or rooms and wards of current patients with other general information too like news and weather forecasts.
As the use cases vary, the size of the display also changes. A mirror to be used in a personal space need not be the same size as the one placed inside the hospital.

The core needs to be such that it can scale to different sizes and dimensions without having the need of code modification for deployment. It needs to be able to run on a 15-inch mirror in a personal environment and scale to a 40-inch + mirror in the hospital. This is the reason for using a web-based solution instead of a dedicated OS-specific application. This also gives the backend an additional advantage of being OS independent. Raspberry Pi can run on the preferred Raspbian OS or if a use case requires, it can also run on Windows IoT Core.

The last question that remains unanswered is that if this is just a display powered by Raspberry Pi, what is the use of Mirror form factor? The answer to this is aesthetics. No person would want a dedicated display in his or her home for showing just information. Now, when Government of India setting an objective of creating an IoT industry of USD 15 billion, home automation is no more a thing of distant future.[2] Moreover, as of now, in home automation, nothing has been unified or has a set common standard, so every system has its own hardware and a software that makes the possibility of mix and match difficult. If a user wants to mix and match the two systems, one for home automation, another one for security, it requires two different hardware control units and as the trend goes, two different mobile applications for controlling them. These can be integrated within the mirror or can be wirelessly connected to the mirror and hence can be controlled through the mirror, simply by adding widgets. All while maintaining the aesthetics of the environment as the dedicated hardware for the same can be placed behind the mirror, so there are no extra boxes hiding in the plain sight, trying to blend in.

Similarly, for commercial spaces, there are already a ton of displays showing tickers and advertisements along with information, overshadowing the useful and relevant information. Placing dedicated displays at luxury airport lounges to show the timetable so that passengers can see the relevant information does not always fit in well with the aesthetics of the place. A mirror which might already be present there is perfect for showing only relevant information.

II. BACKGROUND AND RELATED WORK

Smart Reflect is a combination of flat screen displays specifically combined with a two-way mirror and connected with a computer to provide the intended services. Smart Reflect represents an interface that facilitates access to personalized services through third party APIs. After studying many projects based on IoT and Raspberry Pi, one is about a smart mirror which is an intelligent personal care environment that uses an Interactive Mirror in the bathroom, which according to user's preferences, provides personalized services. [14] For example, users can read breaking news, check the birthdays of their friends and relatives, go through their meeting schedule all while brushing their teeth. The mirror can provide live feeds, gather the latest weather information, and so on. Many other similar projects and the work reviewed is briefly mentioned as follows:

Mirror 2.0 [2] combines a smartphone and a mirror. It provides weather and new data and it allows the playback of media (videos and music).

NEOD Framed Mirror TV [5] is a mirror with standard LCD screen (up to 50 inches), placed beneath it. It provides some TV functionalities, but it doesn't have interactive features.

The Reveal Project [8], created in the New York Times research and development, exploits a Microsoft Kinect for tracking user's movements in real-time. It responds to vocal commands. In addition, it visualizes different information on its surface (calendar, mail, news, online shopping websites, instant messenger etc.). A special feature is the medicine box scanner, which allows the user to buy medicines packages based on the scan results.

Microsoft's Magic Mirror: Microsoft previewed their Magic Mirror in 2016, which was a prototype. It is powered by a Hosted Web App on Windows 10 IoT Core on a Raspberry Pi 3. This project was built on the concept of personalized experience that recognizes users using Windows Hello technology powered by Microsoft's Cognitive Services to authenticate the user and feed personalized data tailored to that user. Microsoft has open – sourced the web app in their GitHub repository that can be used by anyone to build their own smart mirror if they wish to so. [3]

An interactive mirror from Panasonic [10] - initially looks like a normal mirror. Cameras and other sensors do not provide the functionality of a smart device. Once the user sits in front of it, the mirror shows an enlarged view of the user's face. The sensor analyses facial moisture, wrinkles and other details to recommend products to treat the skin of the user, slow down aging and more. The mirror allows users to purchase these products. In addition, it provides makeup pattern previews, simulated lighting and environmental conditions (e.g., at home, shopping mall, outdoor, etc.).

Brushing Teeth Mirror [12] displays the information about inflammations or infections of the teeth and gums, collected by a smart brush.

Medical Mirror [13] combines electronic vision techniques and signal processing to measure the heart rate of reflected light from the face. The prototype consists of an LCD screen with a built-in camera and a two-way mirror mounted on the frame.

Cybertecture Mirror [9]. This is a full computer in a 37-inch mirror with a 32-inch LCD screen. Using the smartphone application, users can access different overlapping information on their reflection. This interface allows you to view instant messages, calendars, mailboxes, and weather forecasts. In addition, it also provides information about the user's physical state. In fact, the device provides a range of external wireless sensors that can measure the user's weight, fat, muscle and bone mass.

Smart Washbasin [4] basin displays different information in the laundry basin mirror, such as mail, weather forecasts, water temperature, pressure, calendar, and user weight measured through the integrated sensors in the base. This device consists of an Android tablet that displays the gadget on a bowl mirror and places a semi-reflective glass on top of the LCD screen. It can be controlled without touching the screen surface because it is equipped with an affinity sensor that can track the position and movement of the cursor.

Ekko Smart Mirror: The project was created by a company that produces elegant furniture. In addition to weather viewing and real-time news feeds, this smart mirror can also play music and video clips. The mirror communicates with the user's smartphone using an application that needs to be installed to provide the user with a customized experience. The mirror controls the gestures that each sensor reads. [3]

Apple Mirror – Rafael Dymek: Based on Apple iOS 10, it is a touch screen smart mirror, where the user can simulate his or her iPhone screen and run the desired app. Due to the current resize problem, the app cannot be run in full-screen mode. Apple Mirror moves to sleep after 45 seconds of inactivity and can be opened by capping on the screen. [3]

Multi Display in Black Mirror [7] by Toshiba is a prototype that combines the functions of the tablet and the reflective surface of the mirror. Provides two configurations that take into account two different home environments: bathrooms and kitchens. Taking into account the bathroom, the prototype provides useful information, such as weather forecasts and fitness information from personal devices. In the kitchen, this setting includes a video camera where the user can interact by gestures while preparing recipes and controlling devices.

The Naked 3D Fitness Tracker: This is essentially a mirror installed with sensors that scan the body in three dimensions on a circular scale and check for any structural deformities. The product claims to keep all important information about the body, including how exercise affects the body. It can determine which parts of your body are at risk and suggest changing your exercise plan accordingly. Therefore, the bare laboratory products are part of the fitness tracking system, all synchronized with the mirror. [3]

All the projects and products mentioned above are application specific. They are all designed from ground up to perform a certain set of tasks. Another thing that is common in all is that they can all be personalized, but are not customizable. Smart Mirror design for Bathroom use cannot fit into the kitchen and visa-versa. Some are dedicated for medical use and only give relative information. Others straight up give up the idea of relevant information and are either TV or online shopping carts with advertisements hidden as recommended products.

Our work focuses on one single mirror backend that can be customized as per the environment it is to be placed in. If anyone intends to shift Smart Reflect from home to office use, he or she should easily be able to do so. One mirror should be able to be configured for a commercial space or for personal use as desired and this is achieved by use of JavaScript based widgets.

III.FUNCTIONAL OVERVIEW

Smart Reflect is designed to have the all these features listed as follows:

1) *Scalable UI:* The display should be able to scale to any size of the display.
2) *Modular Widget based Backend:* Widgets are responsible for providing information and services to display, as well as determining how the information is displayed. Using our platform, users can customize what information to display in their smart mirrors by writing their own modules in JavaScript. The design of our widget system also offers flexibility where not all modules require a display component; it can be only a script running in the background. Alternatively, widgets can be all display orientated with no scripts generating information or modifying its behaviour. Our platform uses a web browser to display information because of its built-in support of various media formats. In our software stack, the display consists of two user spaces: global and widget. The global user space is what the server uses for injecting and removing JavaScript, CSS, and HTML resources for each module, as well as for creating a container for each module. The module user space is made available for each module to modify and update itself without interfering with other module spaces.
3) *Show live Information*: As Smart Reflect is based on IoT, the system should be able to connect to the internet and be able to fetch live feed and information.

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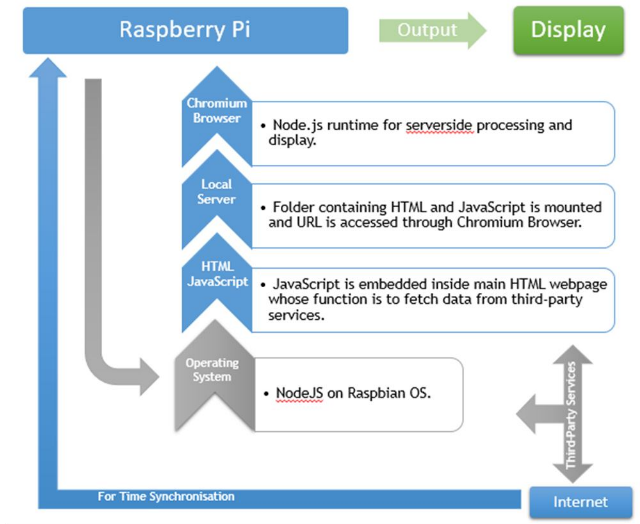

Fig. 1 System Description

Smart Mirror is designed to meet the requirements for creating a real-time display device. A widget may retrieve data from third-party data resources (e.g., weather data API). The View is the screen/mirror that displays the data. The Controller is the server component that controls the execution of each widget. This design decision allows for the separation of concerns and defines the user space for each widget with regard to each other contributing to an overall modular design. Communications between widget, the server, and widget clients in the browser are all handled through the WebSocket protocol. WebSocket allows for real-time transmission of data as opposed to traditional servers that have the overhead of establishing and closing connections for each unit of data transferred or requested. This allows for widget and the server to make rapid and multiple API calls that are necessary for a real-time dynamic display.

Widgets are responsible for providing information to display, as well as determining how the information is displayed. Using our platform, people can customize what information to display in their smart mirrors by writing their own Widgets. A Widgets is comprised of these components:

a) *CSS File(s):* One or more CSS files containing styling for a widget's display container.
b) *JavaScript File(s):* One or more JavaScript files that may fetch information or control the behaviour of a widget's display container.
c) *Script:* An external program that generates information, or controls the behaviour of a widget's client container that cannot otherwise be achieved using JavaScript.
d) *Web GUI (Graphical User Interface):* An interface that allows users to customize widget -specific settings.

These widget user spaces are bound to an HTML 'div' container that is created for each widget by the global user space when a widget is loaded to the display. With these two user spaces defined, there exists another separation of concern that makes widget development and customization easier. For one advantage, widget do not need to worry about loading themselves; the server will do that for them. As another advantage, with the global user space defined, there exists a generalized set of operations for manipulating each widget's container that a widget does not need to worry about implementing themselves. One practical operation that can be generalized is the positioning of widget containers on the display. Users should be able to (and can) rearrange the widget as they see fit without having to reconfigure a widget's specific settings. Another general operation is the ability to enable and disable a widget. Not all available widgets need to be loaded all the time. Users can customize which modules they wish to use without having to delete or uninstall anything. From a resource usage perspective, this setup allows for the complete removal of widget from the browser as they are unloaded, helping to keep the memory usage low on our Raspberry Pi and prevent the execution of unnecessary JavaScript for idle widget. The user module spaces allow for the customization and display of module specific details in their own allotted screen space. Without these containers, the global user space would not be able to easily handle general operations for each widget, as well as preventing widget from intruding or overwriting each other's displays. In this user space, an API of general draw calls exists in which modules themselves can use for modifying its own container's display properties.

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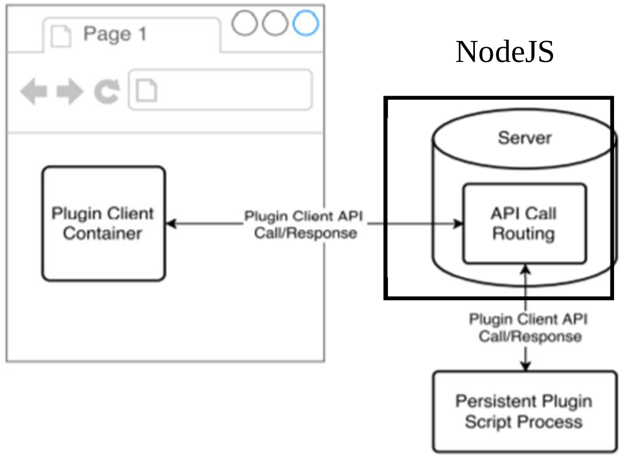

Fig. 2 General Implementation

IV. HARDWARE AND SOFTWARE DESIGN

For hardware we have used a computer monitor, one-way mirror, a Raspberry Pi 2, a fan to keep the temperature down. Everything was put together in a wooden frame. These are the final renderings for the hardware design:

Fig. 3 Front view of Smart Reflect

Fig. 4 Back view of Smart Reflect

A. Two-Way Mirror

We followed typical smart mirror building instructions to implement our prototype. As shown in figure, a pane of glass with a mirror film on one side is encased in a frame and placed on top of a monitor. The mirror acts in a similar way that a one way mirror works. When there is nothing displayed on the monitor (i.e., the monitor is black), users can see their own reflection in the mirror. When a non-black color is displayed on the monitor that colour appears to come through the glass from the monitor.

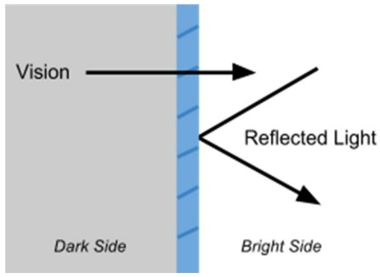

Fig. 5 Schematic Diagram of Light Reflection on a Two-way Mirror

In the case of this project, it essentially means that the dark or black parts of the screen will be seen as a reflection and the light parts will be seen normally. So if there is white text over a black background the white text will be seen as an overlay with the user reflected in the background.

B. Display

For the display, a backlit LED Computer monitor was used. Mirror is cut exactly to the size of the monitor such that it covers the whole display. Together, both mirror and monitor make the display of the Smart Reflect.

C. Raspberry Pi 3

Raspberry Pi is a single board computer developed by the Raspberry Pi foundation in the UK. It has become the most popular computer of its kind thanks to great support and a big community behind it as well as an inexpensive price.

Pi 3 does not work out of the box. It lacks storage and it does not come with a preinstalled operating system. To install an OS you need a microSD card prepared with an OS image. And because the software that will be running on the mirror will be coded on the same device at least a screen, keyboard and mouse are required.

Rufus 2.4 is used to burn an image of Raspbian, a Linux based OS specially designed for Raspberry Pi. Raspbian lays ground for the software framework explained above. The browser window, NodeJS and other scripts run on top of Raspbian.

D. Software

All the software runs on the Raspberry Pi 3 and there are many operating systems to choose from. We chose to use Raspbian which is the official Linux distribution from the Raspberry Pi Foundation because it has a lot of support and documentation.

To install it, we downloaded Raspbian from the official Raspberry Pi website and copied it on a microSD card. Then we inserted the card on the Raspberry Pi and started it by following the setup instructions. Once Raspbian was installed, we updated the distribution with the latest packages, configured the basics of the OS for instance the keyboard layout to match my keyboard and everything was ready to go.

Then using terminal, we installed NodeJS and related node modules from the internet, like express JS, which are used by Smart Mirror modules.

E. Software

Firstly, for test software, we installed VSCode, which is a very lightweight IDE, and used it to write all the HTML, Javascript, and CSS on another PC and then deployed the code on Raspbian. We developed widgets to show time, data from personal calendar (using Google Calendar), current weather widget (using MSN weather), a weekly weather widget (using accuweather) a RSS reader to fetch the feeds and display them in real time, and a widget to publish notice to the board.

In the end, the entire coding for the software inclusive of HTML, CSS and JavaScript was tested on the Raspberry Pi and code was optimized to run on it. All the code was checked by running it in the included chromium browser and it turned out to be very convenient to be able to easily test and optimize the software directly on Raspberry Pi.

V. RESULT AND CONCLUSION

We designed and developed a Smart Mirror that offers three main benefits:

Fig. 6 Final Design of the Frame

First, it is modular and extensible. Developers can add widgets to customize their smart mirror applications. Second, it has a scalable UI. Third, it was able to retrieve and process information from the internet directly using third-party APIs.

Fig. 7 Smart Reflect running on a 32 inch LCD Display

We tested our Smart Reflect prototype in different environments. The same mirror was used for both personal use and organizational deployment. In Fig 8, the Mirror shows the personal birthday calendar of the user and Fig 9, the same mirror was used as a digital notice board for our college. The only change necessary to do this was to develop a widget for college notice board and enable it in the configuration file.

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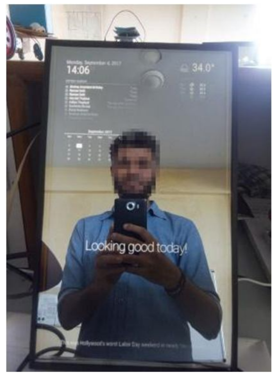

Fig. 8 Smart Reflect for personal use with Google Calendar and MSN Weather based widgets

Fig. 9 Smart Reflect for commercial use with custom notification board widget

After further use, it was discovered that the SoC of Raspberry Pi thermal throttled due to the enclosed nature of our project and hot Indian climate. So, aluminium heartsick was added to Raspberry Pi to dissipate heat. In addition, a PC case fan is added and placed near raspberry pi to help dissipate heat. Power to the fan was delivered using USB. Since USB operates on 5V and the PC Fan requires 12V to operate, a DC boost converter circuit is used to convert 5V DC to 12V DC.

The Smart Mirror has wide scope in the field of IoT and home automation. Smart Reflect can be connected to home appliances, mobile devices, etc. which can expand the functionality of mirrors and it can serve as an extension to them.

The notification cluster we usually dismiss on our smartphones can be trimmed down and the most important of those can be shown on the mirror.

VI. CONCLUSION AND FUTURE SCOPE

Smart mirrors have many potential applications in both personal and social spaces. In personal settings, smart mirrors can be used to display relevant information, control household appliances and home automation hubs. In bathrooms, smart mirrors could prove to be a valuable application for many people. As people prepare for their day, their hands are typically busy, but they typically stand in one spot performing low cognitive tasks. People can have their email messages, trending tweets or Facebook posts, and breaking news show up on their smart mirrors seamlessly. Smart mirrors can facilitate communication within a family. Many homes have a mirror in their entrance or foyer. A smart mirror in this location could act as a central hub for family scheduling, which would increase awareness of each other’s activities within the family. Built right into the mirror, a digital calendar can be synced with the user's calendar on their phone. Digital notes left for other users would not fall off from people walking by or opening the front door. In public locations, smart mirror applications would be generalized, perhaps acting as conduits for information much like information kiosks but provide physical and design benefits over implementing a kiosk. A smart mirror could display kiosk information, advertisements, and emergency alerts, all while utilizing the space that is already allocated for mirrors. Installed in fitting rooms, a smart mirror could revolutionize shopping experience. No longer would someone need to physically try on all the clothes they are interested in. Using augmented reality, people could view themselves in digital versions of the available store wardrobe or experiment with various design options. Such a system would allow customers to browse a clothes catalogue at a faster rate, filter down their selection of clothes, and only try on clothes to measure fit and comfort. The fitting room itself provides an excellent, low distraction environment for the processing of augmented reality, and could facilitate sensors for determining the correct size for customers.

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Smart mirrors are capable of enhancing the user experience of accessing and interacting with information. They not only allow users to see relevant information effortlessly, they can also be integrated in larger systems, such as a home automation system.

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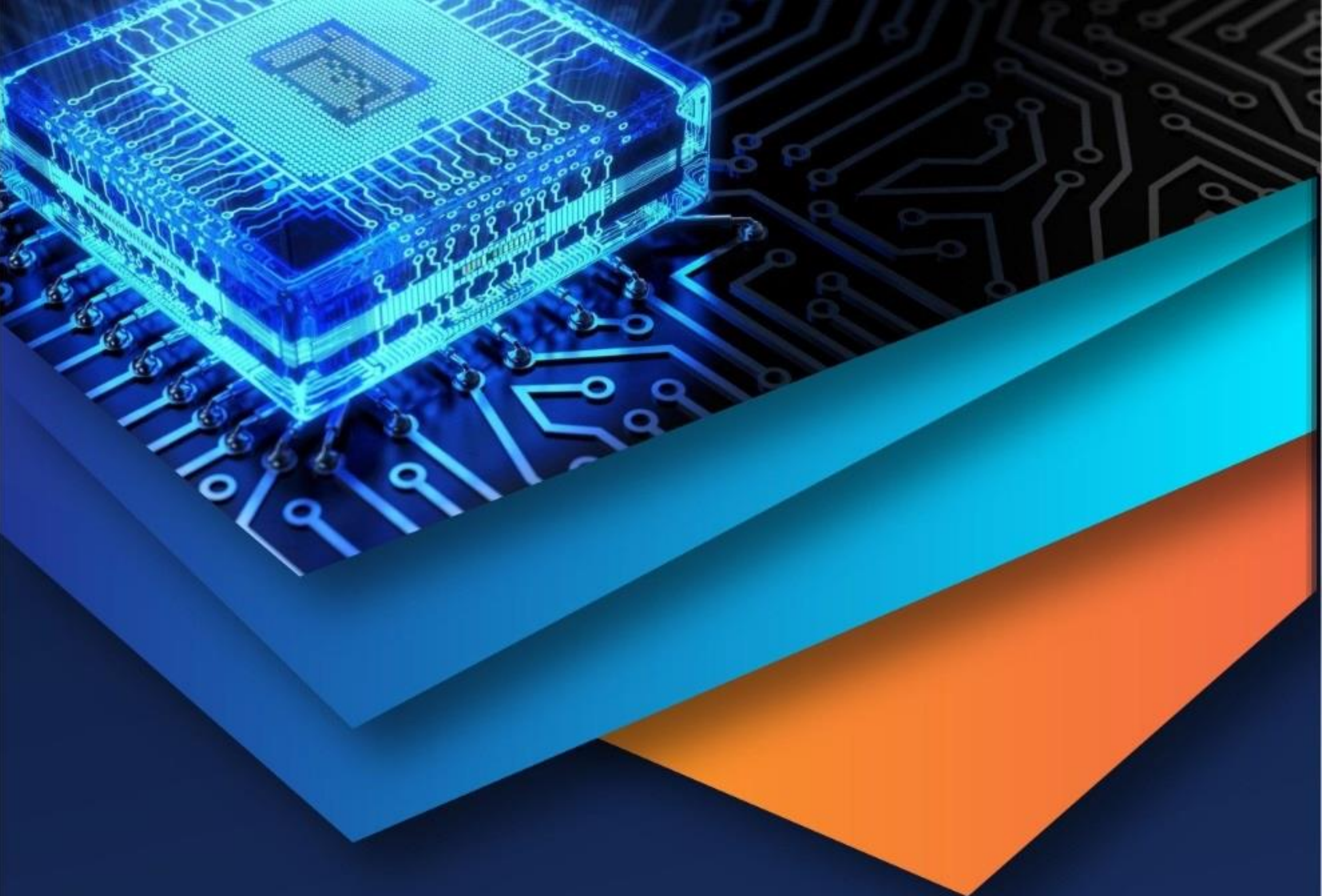

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