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Smart Aquaponics System

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Abstract: Aquaponics is a sustainable source of food in organic agriculture. It is an integrated system of agriculture and aquaculture where the main intention is to reuse the nutrients being pulled out by fishes which are necessary for growing the plants without using the dangerous pesticides and insecticides, including their recycling. The main purpose of this system is to create an efficient and self-regulated environment for plants and fish. This automation system allows for precise monitoring and control capabilities, resulting in an optimized and sustainable environment for both plants and animals. The prototype of the automated aquaponic system showcased its capability to create a self-regulating environment for plant and animal. The integration of various sensors and components, along with the efficient coordination by the Arduino board, showcased the potential of the system for enhancing productivity and ensuring the well-being of plants.

Keywords: Aquaponics, sustainable agriculture, aquaculture, hydroponics, smart system, sensors, automation, water quality, pH levels, temperature, monitoring.

I. INTRODUCTION

The world is facing a number of serious issues of which climate variation, water scarcity, limited land resources, soil degradation, and food security are among the most significant. Some of the major factors responsible are agriculture, aquaculture, etc. Increasing use of resource and pollution caused by agriculture and aquaculture has incurred high burden to the environment. Untreated water containing fish faeces and other wastes which are highly concentrated with nitrogen waste (for example ammonia and nitrites and nitrates) from the aquaculture can deteriorate the water quality. This situation leads to eutrophication, bloom of phytoplankton in the water body which will harms marine lives by depleting oxygen in the water. Besides, use of chemical fertilizers in the agriculture that consists of metal like aluminium and other ions like sulphate ion, SO4-2 and bicarbonate ion, HCO3- alters the pH value and create toxicity in the water. This causes harm to the environment and also affects the quality of agriculture and hence the food reaching our houses.

Organic agriculture is one among the broad spectrum of production methods that are concerned to the environment. Aquaponics, despite the name, poses a revolutionary change to the Organic Agriculture Field. Aquaponics is a sustainable source of food in organic agriculture. Aquaponics is a developing technology and a bio-integrated system where the main intention is to reuse the nutrients being pulled out by fishes which are necessary for growing the plants without using the dangerous pesticides and insecticides, including their recycling.

It comprises the dynamic interaction of fish, plants, bacteria, and their aqueous environment. Aquaponics farming is an incredibly prolific way to grow organic vegetables, greens, herbs and fruits without using any agro-chemicals with the added benefit of fresh fish as a safe, healthy source of protein. Here, ammonia from the effluent produced by the fish will undergo nitrification process in which it will break down to form nitrite (NO2-) and then the nitrite (NO2-) is converted to nitrate (NO3-). Nitrosomonus and Nitrobacter Bacteria are responsible for converting ammonia to viable nitrate for biofilm plants. This water that contains nitrate is then fed to the hydroponics system and it will act as fertilizer for plants.

Aquaponics have proficient widespread expansion in the world not only for their higher yields, but also for their better use of land and water, modest methods of pollution control, enhanced management of productive factors, their higher quality of products and greater food safety. Aquaponics can be more productive and economically feasible in certain situations, especially where land and water are limited. This system can reduce water consumption compared to traditional farming. Besides that, unlike traditional farming, this system does not use any chemical and synthetic pesticides, herbicides and fertilizers in growing the crops. This will significantly reduce the harm to the nature. Hence, an integrated system of agriculture and aquaculture which is known as aquaponics system was introduced to reuse the water and reduce or even avoid the use of chemical fertilizers to produce high value horticulture crops.

II. EXISTING SYSTEM

Traditional aquaponics systems consist of several key components that work together to create a symbiotic relationship between fish farming (aquaculture) and soilless plant cultivation (hydroponics). Here's a description of the basic components and functioning:

1) *Fish Tank:* The fish tank is the central component of the aquaponics system. It houses the fish and provides an environment for them to thrive. The size of the fish tank depends on the desired fish species and the overall system's capacity.
2) *Grow Bed:* The grow bed is where the plants are cultivated. It is usually placed above the fish tank or adjacent to it. The grow bed can be filled with a growing medium such as gravel, clay pellets, or coconut coir, which supports the plant roots and helps with water filtration.
3) *Water Pump:* A water pump is used to circulate water between the fish tank and the grow bed. It moves the water enriched with fish waste from the fish tank to the grow bed, and then returns filtered and oxygenated water back to the fish tank.
4) *Biological Filter:* A biological filter, often referred to as a biofilter, is incorporated into the system to convert toxic ammonia produced by fish waste (via their excretions) into nitrates. Beneficial bacteria, such as Nitrosomonas and Nitrobacter, colonize the filter media and carry out nitrification, converting ammonia to nitrites and then to nitrates, which are essential nutrients for plants.
5) *Plants:* The plants cultivated in the grow bed play a crucial role in the aquaponics system. They absorb the nitrates and other nutrients from the water, acting as a biofilter that helps purify the water for the fish. The roots of the plants also provide a habitat for beneficial bacteria.
6) *Water Quality Monitoring:* Regular monitoring of water quality parameters, such as temperature, pH level, dissolved oxygen, and nutrient levels, is necessary to maintain optimal conditions for both the fish and plants. This monitoring helps ensure a healthy environment and supports the growth of both components.

The functioning of a traditional aquaponics system involves a symbiotic relationship between the fish and plants. Fish excrete waste, primarily in the form of ammonia, into the water. The water containing fish waste is pumped to the grow bed, where it flows through the growing medium. Beneficial bacteria present in the biofilter convert the ammonia into nitrates, which are then absorbed by the plant roots as nutrients.

As the plants take up the nutrients, they filter and purify the water, removing toxins and excess nutrients. The cleaned and oxygenated water is then returned to the fish tank, maintaining a healthy and suitable environment for the fish. This closed-loop system minimizes water waste and creates a sustainable cycle where fish waste nourishes the plants, and the plants, in turn, improve the water quality for the fish.

It's important to note that the effectiveness and success of a traditional aquaponics system depend on factors such as fish species selection, plant selection, water quality management, and proper system design and maintenance.

Conventional aquaponics systems heavily rely on manual monitoring and control, where parameters related to water quality, temperature, pH levels, and nutrient levels are typically monitored and adjusted by human intervention. However, this approach presents several limitations and challenges that can impact the overall performance of the system.

One significant drawback is the potential for inconsistencies in data collection. Manual monitoring introduces the possibility of variations in measurement techniques among different individuals, leading to inconsistencies in recorded values. Such variations can affect the accuracy and reliability of research findings and system management, hindering the understanding of system dynamics.

Human error is another concern associated with manual monitoring and control. Mistakes in recording measurements, misinterpretation of readings, or accidental data entry errors can occur. These errors can introduce inaccuracies and affect the overall understanding of system performance and health.

Traditional setups often lack the ability to remotely access and control the system, making it difficult to manage operations efficiently, especially in situations where the system is located in remote or inaccessible areas. This limitation restricts the ability to monitor and control the system in real-time and limits the potential for remote collaboration and data analysis.

One notable challenge is the delayed response to changing conditions. With manual monitoring, fluctuations in parameters such as temperature or pH may go unnoticed for extended periods, potentially impacting the health and well-being of both fish and plants. Without timely interventions, adverse conditions may persist, leading to suboptimal growth, stress, or even mortality.

The labor intensiveness of manual monitoring is another drawback. Regular monitoring, data collection, and adjustments demand significant time and effort. This can be particularly challenging for individuals managing large-scale aquaponics systems or overseeing multiple systems simultaneously. The labor-intensive nature of manual control may limit system scalability and efficiency.

Furthermore, manual monitoring provides periodic snapshots of system conditions, limiting the availability of real-time insights. Changes occurring between measurement intervals may go unnoticed, preventing prompt corrective actions. Real-time information is crucial for detecting trends, identifying issues, and optimizing system performance.

Subjectivity and bias are additional concerns associated with manual monitoring. The subjective judgments and interpretations involved in manual readings can introduce bias into data analysis and decision-making processes. Different individuals may have varying interpretations of acceptable ranges for parameters, potentially affecting the management and outcomes of the aquaponics system.

III. LITERATURE REVIEW

Aquaponics is integration of hydroponics with aquaculture. This method to produce food is gaining attention as a bio-integrated food production system. In this method we produce food locally and hence it provides healthy foods ,also increases the local economy[1]. Aquaponics is is a closed-loop recycling fresh water system between fish and plant. Wastes generated by the fish become nutrients for the plants after nitrification process[5]. Food-producing greenhouses – yielding two products from one production unit – are naturally appealing for niche marketing and green labelling[1].

A. Considerations and Key Elements

Hydroponics - In Hydroponics we produce plants in a soilless .All the required nutrients are dissolved in water and thereby provided to the plants. This technique is based on chemical formulations that deliver precise concentration of mineral elements.

Nutrients in Aquaculture –In aquaponics system nutrients are provided through the fish excreta . Fish excreta contains nutrients like ammonia ,nitrate , nitrate ,phosphorous, potassium and other micronutrients required in the production of hydroponic plants.

Nutrient concentration – This is an important factor to be considered . If the fish in an integrated system are producing more nutrients than the plants this can assimilate and the losses incurred, the nutrient concentrations will increase over time. Conversely, if the nutrient production by fish is less than the assimilation by plants and losses, the nutrient concentrations will decrease. Finally, if the nutrient production, assimilation, and losses are in balance, the nutrient concentrations will remain constant over time in the steady state of the system without additional nutrient supplementation.

Plants in aquaponics – The selection of plants to be adapted in aquaponics depends upon factors like, stocking density of fish in fish tank and also the nutrient concentration in fish excreta. Green vegetables like spinach, basil that requires low to medium nutrition supply are very well adopted to aquaponic systems. Plants like tomatoes , cucumbers have higher nutritional demand . These plants are grown in heavily stocked and well established aquaponics system.

Media moisture – Media moisture is the soil water content in the media base . This measurement is only necessary when is used the media-base type in the hydroponic component[9]. A moisture sensor is implemented in this practice .

Fish species – Several fishes are adapted in aquaculture system. Warm and cold water fish species are used . The most commonly used fish spaces in aquaponic is Tilapia . Fish species like rohu ,pangasius can also be used. Fish species should be chosen taken into account factors like water temperature , local availability and also market demand.

Water quality – Good water quality conditions are required for raising fishes in aquaponic system . Some important parameters of water quality includes dissolved oxygen ,concentration of ammonia, nitrate, nitrate ,chlorine , carbon dioxide and other characteristics. Regular water quality monitoring is essential for fish health.

Component ratio – Volume of fish tank to the volume of hydroponic media is known as component ratio. This is an important factor to be considered for aquaponic system .This ratio depends upon factors like which type of fish species is used ,fish density ,feeding rate ,plant species, etc.

Aquaponics is a sustainable source of food in organic agriculture [4]. The key design requirements for Aquaponic system are reliability and accuracy . To overcome the fundamental issues like cost, food quality control and limited growth , an automated system with the help of sensors interface with the Arduino board is designed[10]. A smart aquaponic system can be designed to automatically watering the plant and maintaining the temperature of water[6]. Some common challenges in aquaponics include maintaining water quality parameters, managing nutrient balance, preventing disease outbreaks, and automating system monitoring. Arduino, an open-source electronics platform, can be used to overcome these challenges as it can make process of monitoring and controlling system efficient and easy. Smart aquaponic system can continuously monitor and control various sensor factors[5].

A smart aquaponics system based on IOT that could control and monitor the degree of acidity, water level, water temperature, and fish feed that were integrated with internet-based mobile application. In this system, there is a sensor installed to retrieve data, which was then transmitted to IoT Cloud server that could be accessed in real time through the internet network. Thus, the quality and water circulation were well preserved[7].

While perhaps not suited to growing vast fields of grain, aquaponics can now grow any vegetable and many types of fruit crops, and do it in a way that is even more productive on a square foot basis, even in an urban setting[11].

IV. METHODOLOGY/EXPERIMENTAL

A. Components

1) Hardware

a) Arduino Board: Arduino Uno
b) Sensors: temperature sensors, pH sensors, water level sensors, LDR Sensor, Humidity sensors, Soil Moisture sensor.
c) Actuators: Submersible motor pumps, LED lights
d) Relay Modules
e) Breadboard
f) Jumper Wires, Connectors, resistors, Arduino Power cable

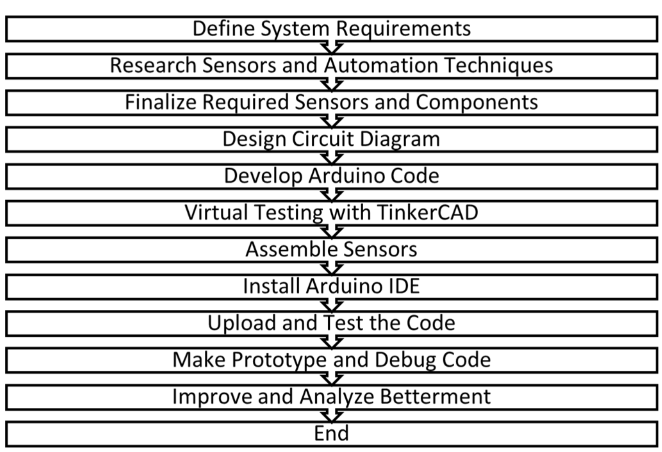
2) *Software*

a) Arduino IDE: The integrated development environment used to write, compile, and upload code to the Arduino board.
b) Arduino Libraries: Libraries specific to the sensors and actuators used in the project, which provide pre-built functions to interface with the components.
c) Arduino Programming Language: Based on C/C++, it is used to write the code that controls the behaviour of the aquaponics system.
d) Sensor Libraries: DHT Sensor library.
e) TinkerCAD : For Hardware Designing

B. Steps

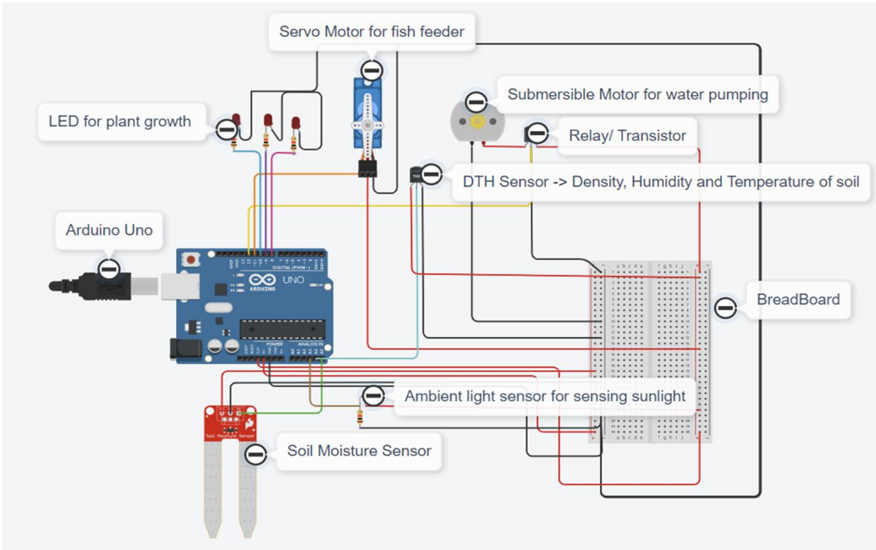
1) Define System Requirements:
2) Research on Sensors and Automation of system
3) Finalize and require Sensors and required components.
4) Design circuit diagram.
5) Develop the Arduino Code
6) Virtually testing code with design circuit on TinkerCAD.
7) Assembling sensor
8) Install the Arduino IDE on your computer.
9) Upload and Test the Code
10) Making prototype and debugging code
11) Improving and analysing betterment

C. Flowchart



V. PROPOSED SYSTEM

The automated aquaponics system incorporates various components and sensors to create an efficient and self-regulated environment for plants and fish. The system utilizes an LDR sensor to measure sunlight intensity and adjusts the blue LED lights accordingly to provide optimal lighting conditions. Humidity and temperature sensors monitor the environmental conditions, ensuring they are within the desired range. The moisture sensor detects soil moisture levels, and if the moisture is below a certain threshold, the system activates drip irrigation to water the plants. Additionally, the system constantly checks the water level in the fish tank, and if it is low, a submersible motor is triggered to refill the tank from a separate water source. The Arduino board acts as the central control unit, running the programmed code that reads sensor data, controls the actuators, and regulates the system's operations. This automation system allows for precise monitoring and control, creating an optimized and sustainable environment for both plants and fish in the aquaponics system.



VI. RESULTS AND DISCUSSIONS

The prototype of the automated aquaponics system showcased its capability to create an efficient and self-regulated environment for plants and fish. By incorporating various components and sensors, including an LDR sensor, humidity and temperature sensors, and a moisture sensor, the system achieved precise monitoring and control of environmental parameters.

The LDR sensor effectively measured sunlight intensity and adjusted the blue LED lights accordingly, ensuring optimal lighting conditions for the plants. This feature significantly improved plant growth and health in the prototype

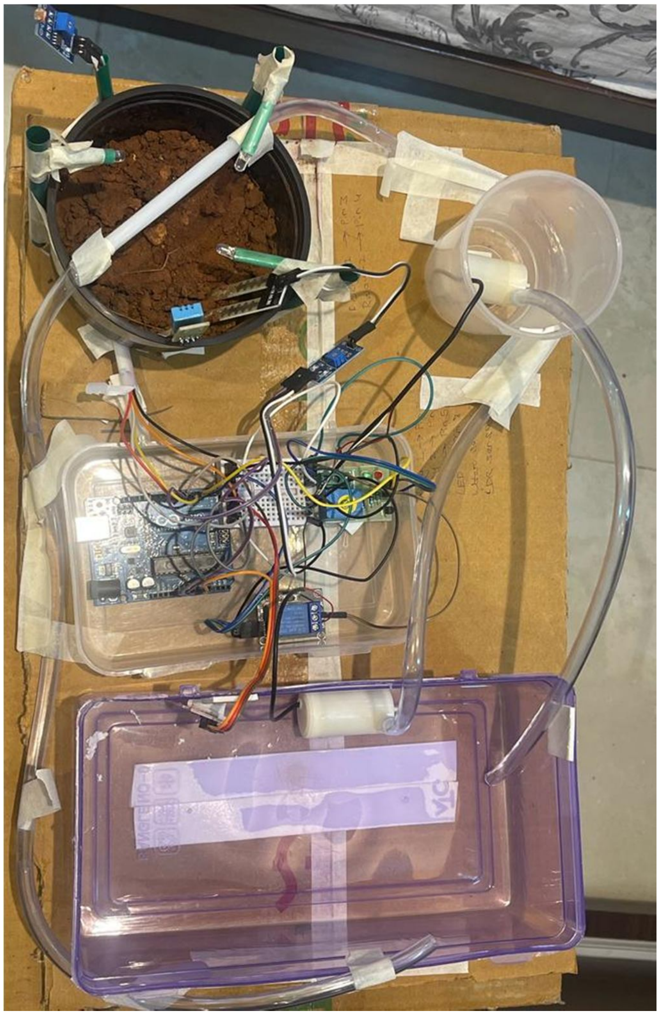
The humidity and temperature sensors successfully monitored the environmental conditions, maintaining them within the desired range. This self-regulation contributed to a stable and suitable environment for both plants and fish, enhancing their overall well-being.

The moisture sensor accurately detected soil moisture levels, triggering the activation of drip irrigation when moisture fell below a specific threshold. This mechanism efficiently watered the plants, maintaining optimal soil moisture levels and promoting their growth.

The system's continuous monitoring of the water level in the fish tank proved to be effective. Whenever the water level dropped below a certain point, a submersible motor was automatically triggered to refill the tank from a separate water source. This ensured a consistent water level, providing a suitable habitat for the fish.

The Arduino board served as the central control unit, running the programmed code that read sensor data, controlled the actuators, and regulated the system's operations. Its reliable performance coordinated the system components, enabling accurate data acquisition and timely actuation of actuators in the prototype.

In conclusion, the prototype of the automated aquaponics system demonstrated precise monitoring and control capabilities, resulting in an optimized and sustainable environment for both plants and fish. The integration of various sensors and components, along with the efficient coordination by the Arduino board, showcased the potential of this system for enhancing productivity and ensuring the well-being of plants and fish in aquaponics environments.



VII. FUTURE SCOPE

A. Integration of Additional Sensors

As part of our project, we can incorporate a number of extra sensors to enhance the functionality and sophistication of our aquaponics system. Some examples include a nitrogen sensor, a ph value sensor, a total oxygen measurement sensor, and others. This will give us more in-depth information about how our project is operating and could make it run more smoothly in general.

B. Mobile App or Online Interface

Using the most recent technology, the Flutter development system, we can create a web app interface that allows users to comprehend the system's overall operation as well as the status of all sensors, plants, and fish. They can also receive and provide feedback on the system as a whole.

C. Smart Alerts and Notifications

By developing an app, we can alert the user whenever something happens, such as when the tank is empty or the feeding time is approaching, and we can also alert the user when one of the system's sensors stops working. This will keep the user informed and prepared for manual actions and the status of the entire system.

D. Integration with IoT Platforms

By utilizing an IoT-based system, we can give the user the ability to control the entire system using his mobile device and will be present with all necessary information. We can also give the user the ability to control the system's components, sensors, feeds, etc. via a device connected to an IoT-based system.

E. Expansion and Scalability

Depending on the needs of the farmers or users, we can expand the scope of our project, and when a smaller scope is required, we can remove the components that aren't specifically needed for that farmer or user.

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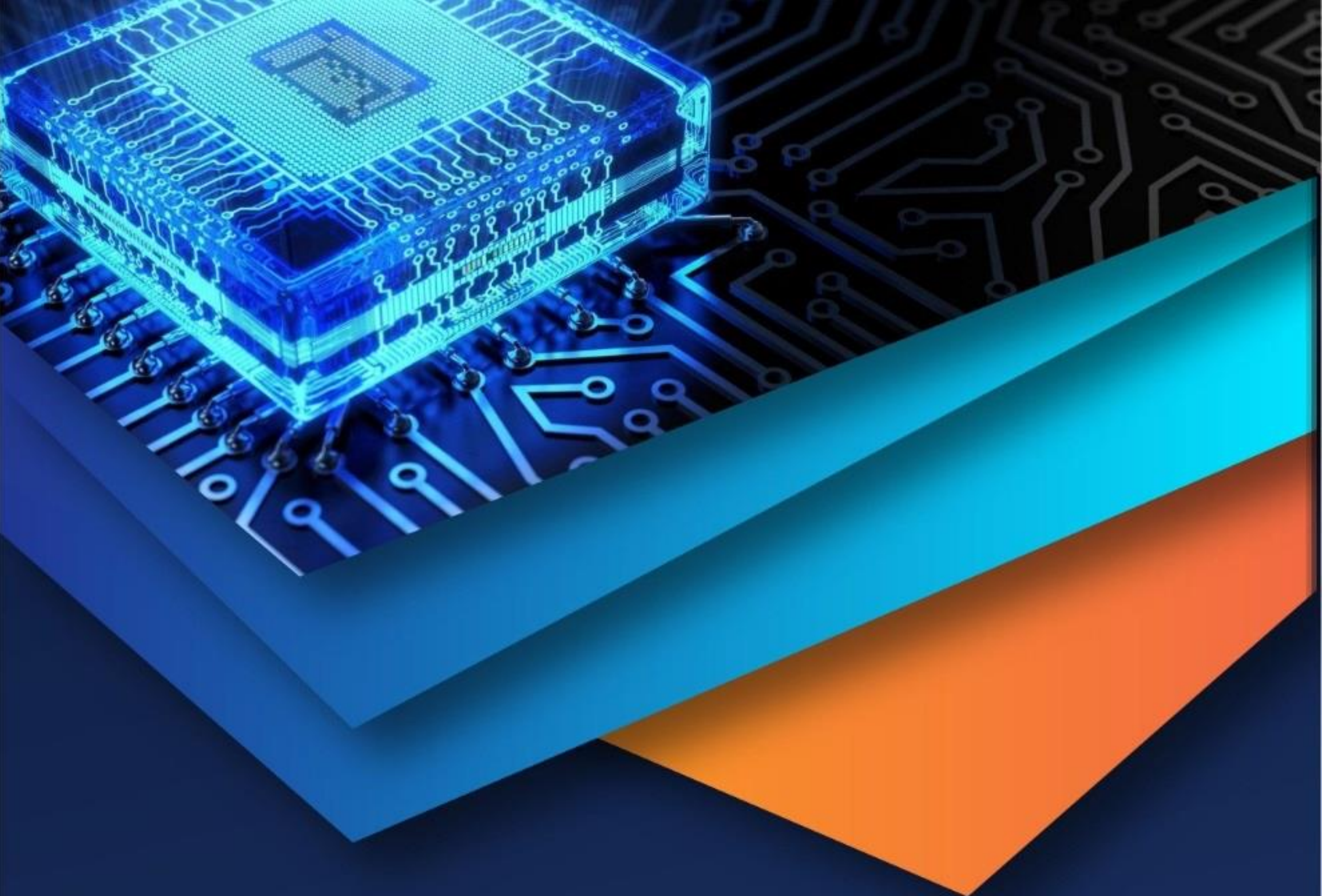

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