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Soil Fertility Analysis Using IoT

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Abstract: Soil is crucial for economic and social development as it provides the foundation for plant growth and life cycle. Agriculture heavily relies on resources like land and fertilizer to produce food. However, the National Academy of Agricultural Sciences (NAAS) reports that the annual soil loss rate in India is about 15.35 tonnes per hectare, which leads to the loss of 5.37 to 8.4 million tonnes of nutrients. This is due to intensive agricultural practices that cause nutrient imbalance and soil depletion, exacerbated by a lack of awareness about soil health. The declining soil health is one of the reasons for stagnant or decreasing crop yields, which will likely worsen in the future.

To address this issue, this project aims to use IoT technology to test different types of soil and determine their macronutrient (NPK) and micronutrient values. The measured nutrient values are compared to a dataset of healthy soil samples' ideal nutrient values using an easy-to-use interface that displays pictorial representations. The farmer receives a detailed soil report that compares the soil's micro and macro nutrient values to the ideal values, much like a soil health report card.

Keywords: Internet Of Things[IOT], Agriculture, Soil Health, Macronutrient, Micronutrient, Arduino UNO, Nitrogen Phosphorus Potassium [NPK], Soil Health Report Card.

I. INTRODUCTION

For centuries, agriculture has been a crucial part of the Indian economy. Despite being a major contributor to the GDP, traditional farming methods are still widely used, resulting in inefficient and labor-intensive processes that harm soil quality, crop yields, and productivity. With the decline in farmland availability, it is necessary to implement modern farming methods to improve performance and yield.

Plant growth relies on three primary components: nitrogen, phosphorus, and potassium. Nitrogen is crucial for leaf and vegetation growth, phosphorus for root and physical growth, and potassium for regulating water and nutrients in plant cells, flowering, and fruiting. Proper management and maintenance of these components can enhance soil quality and crop growth.

Chemical fertilizers are commonly used in modern agriculture, but overuse can cause soil nutrient depletion, leading to reduced soil fertility and crop yield. By providing accurate soil nutrient measurements, farmers can optimize fertilizer use and reduce the risk of nutrient depletion. The project aims to promote sustainable agricultural practices by reducing the excessive use of chemical fertilizers and mitigating soil pollution.

The project will collaborate with farmers, agriculture experts, and researchers to study diverse crop types, soil types, and climatic conditions. Data collection will involve surveys, interviews, and field observations to evaluate the effectiveness of modern farming techniques and provide recommendations for farmers.

The main goal of this project is to promote responsible and data-driven soil management practices to support the sustainability of modern agriculture. By reducing the excessive usage of chemical fertilizers, the project can help ensure soil remains healthy and productive for future generations.

II. LITERATURE SURVEY

[1] Maximizing crop yields by ensuring ideal soil and plant conditions is crucial in India, where the economy is largely based on horticulture. Crop production is dependent on the organic, physical, and chemical properties of the soil due to their interdependence. To maximize crop yield, it is crucial to monitor and manage these factors. The use of sensor systems in agriculture is growing because they have a wide range of applications and can assist farmers in making informed decisions. These systems use sensors to gather information on a variety of factors, including temperature, humidity, soil moisture, nutrient levels, and crop growth. Afterwards, the information is transferred to a computer or mobile device, where it can be analyzed and used to decide on irrigation, fertilization, and other aspects that affect crop yield. Manual data collection for some variables can be sporadic and result in variations from inaccurate estimation taking, which can make it difficult to control any important factors. This may lead to below-average crop yields and financial losses for farmers. The quantity of data that can be gathered and analyzed may also be constrained by the time and labor requirements of manual data collection.

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Comparing sensor systems to manual data collection, there are several benefits. They can continuously gather data, giving real-time updates on the condition of the soil and crops. This enables farmers to decide on irrigation, fertilization, and other aspects that affect crop yield in a timely manner. Due to the absence of human error, sensor systems are also more accurate and reliable than manual data collection. Finally, sensor systems can save farmers time and money because they require less labor than manual data collection.

[2] In order to determine the concentration of nutrients like nitrogen, phosphorus, and potassium (NPK) in soil samples, an electrochemical method known as conductivity measurement is used. Two or three electrodes made of steel, silver, platinum, graphite, or copper are submerged in the soil sample when using this technique. The conductivity of the electrodes is influenced by the amount of NPK in the soil, which changes the electrical signal that electronic control systems can detect. Although conductivity measurement is a trustworthy technique for analyzing nutrients, it can be time-consuming and expensive due to the need for expensive equipment and trained personnel.

Alternative techniques have emerged in recent years that are less expensive, take less time, and don't require as much expertise, like optical techniques. The foundation of optical methods is the interaction of light with the soil sample, and the optical characteristics of the soil change in response to changes in nutrient concentration. Therefore, even though conductivity measurement is a trustworthy method for analyzing nutrients, it can be costly and time-consuming. In comparison to electrochemical methods, optical techniques are becoming a more affordable and effective substitute for analyzing soil nutrients.

[3] It discusses how widespread deficiencies in secondary (Sulphur) and micronutrients (zinc, boron, manganese, iron) cause even balanced NPK fertilization to perform inefficiently. It also discusses the need to apply soil amendments (gypsum on sodic soils and lime on acid soils) in addition to these deficiencies. Additionally, overfertilization with nitrogen causes problems for the environment and human health in many areas by nitrate-enriching ground water and depleting soil of other plant nutrients.

It also revealed that the crop yield is the nominator in all terms used to calculate fertilizer use efficiency (agronomic efficiency or crop response ratio, recovery efficiency, physiological efficiency, and partial factor productivity), and that a good agronomy package (ideal date of sowing/transplanting, ideal seed rate/plant population, ideal spacing, ideal depth of planting, recommended crop variety/hybrid, good water and weed management) is necessary to obtain a good crop yield.

[4] The right kind and quantity of fertilizer application increases both the quality and yield of food raw materials because fertilizers are essential for plant growth and fertility maintenance, and because soil is a significant source of food. On the other hand, situations of both deficiency and excessive use result in issues like low quality and yield, unhealthful crops, higher input costs, or groundwater pollution. The three nutrients known as nitrogen, phosphorus, and potassium are the most significant and deficient. The fertility status of the soil can be determined and the appropriate amounts of fertilizer can be applied with the help of laboratory analyses and soil sampling procedures. Examples of these lab tests include the Dumas method for determining total nitrogen and the Olsen, Bray, or Mehlich methods for plants.

[5] It talks about using an electrochemical sensor and an Arduino to analyse soil nutrients. An electrochemical sensor generates an electrical signal that the Arduino can measure through the use of a chemical reaction. These sensors can also be used to detect the presence of particular nutrients in soil, though they are typically used to detect the presence of various gases and liquids.It is possible to programme the Arduino microcontroller board to read the electrical signals generated by the electrochemical sensor and transform them into useful data. The Arduino can analyze the data and determine the concentrations of various nutrients in the soil by using a programme created for this purpose.

[6] To assist farmers with crop selection, boost farm productivity, and increase crop yield, SoilMATTic was created to provide faster and more accurate soil analysis than the traditional method. The Arduino-based prototype automated every step of soil testing procedures, fertilizer recommendation, and macronutrient and pH analysis. To fully automate the chemical reaction of soil with chemical reagent during testing, it has stepper motors, pumps, and an onboard printer that prints out fertilizer recommendations. It effectively determines (1) Nitrogen, (2) Phosphorus, (3) Potassium, and (4) pH level of Philippine farmlands using digital image processing technique. Automated soil testing, image acquisition, image processing, training system, and recommendation make up the system's five stages.For the purpose of processing images, artificial neural networks performed quickly and precisely. 356 captured images were stored and managed by the system database, of which 70% were used for training, 15% for testing, and 15% for validation.

Results of this study demonstrated 96.67 accuracy in identifying soil macronutrients and pH level, and through a generated report in printed form, recommend fertiliser for inbred rice plant, inbred corn, tobacco, sugarcane, pineapple, mango, coconut, abaca, coffee and banana.

[7] This paper is a survey to put into effect a technique that makes transport much more convenient for people who commute every day using the city's public bus system, for effective time management, and making it trouble-free, not just for the commuters but also for the transport department to create an effective public transport system. There are currently applications on the market that specify the route and timings and forecast the arrival times of various buses, but the survey presented here aims to develop an application that advances this technology by giving daily commuters access to information about the available seats and the current location of any bus in Real-Time via a cutting-edge and affordable wireless system. These methodologies present a review of strategies that can be used to satisfy the demands for public transport of various city sizes while offering incremental improvements in the bus system to meet the capacity requirements of various sized cities. They want to create a flexible, cozy, accessible, and dependable bus service that could promote a switch from private vehicles to public transportation.

III. PROPOSED SYSTEM

The proposed system is designed to measure nitrogen, phosphorus, and potassium levels in agricultural soil using a flow-through soil sensor framework. An Arduino UNO is used to convert the sensor readings into measurable units, which are then displayed on an LCD screen for easy access and interpretation by farmers. In addition to measuring nutrient levels, the proposed framework also provides farmers with a detailed soil health report by comparing the existing soil's micro and macro nutrient values with ideal values. This will help farmers gain a better understanding of the soil's health and condition.

IV. MODULES

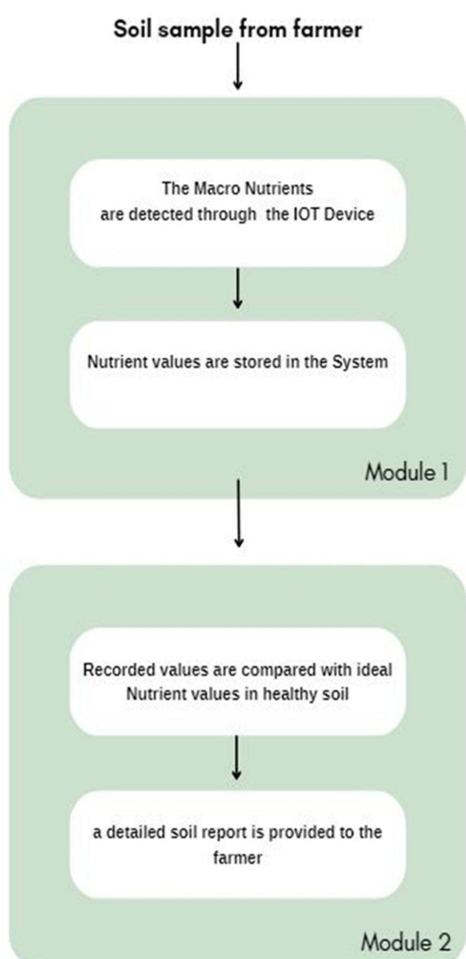

Figure 1: Architecture of the System

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A. Module 1: The Macro Nutrient Detection

The Macro Nutrients in soil, which are Nitrogen, Phosphorous and Potassium are detected using the Soil NPK sensor. The values of the macro nutrients are then stored in the system for further evaluations and comparisons

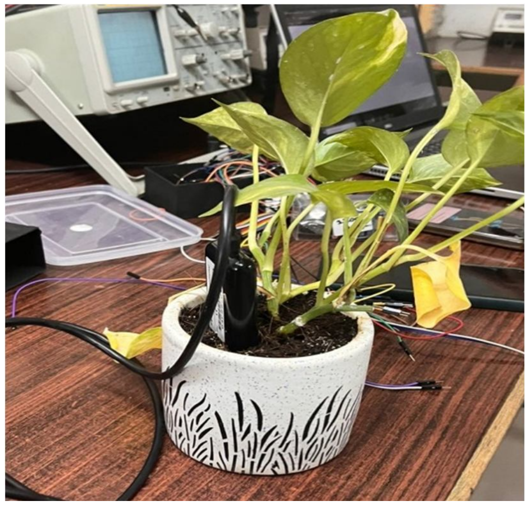


Figure 3.1 Nutrient value detection

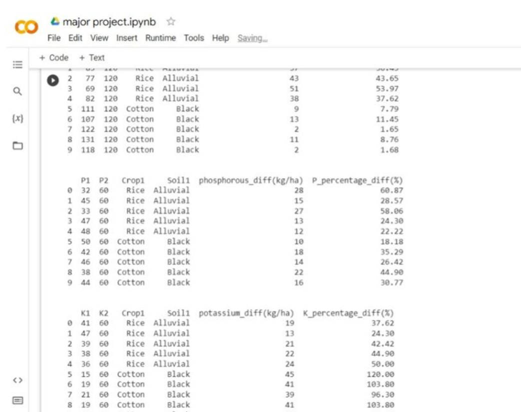
B. Module 2: Recording The Nutrient Values

Through LCD the Macro nutrients values are displayed and the values are stored into the system for further processes.

Figure 3.2 values displayed by the LCD

C. Module 3: Comparission Of Recorded Values With Ideal Nutrient Values

After the detection of the values of Nitrogen, Phosphorous and Potassium (NPK) in the soil, the data is then taken and compared with ideal values of the soil. The values are compared using different python libraries like Numpy, Pandas and then a Soil Health Card is given to the farmer.



2	77	120	Rice	Alluvial	43	43.65
3	69	120	Rice	Alluvial	51	53.97
4	82	120	Rice	Alluvial	38	37.62
5	111	120	Cotton	Black	9	7.79
6	107	120	Cotton	Black	13	11.45
7	122	120	Cotton	Black	2	1.65
8	131	120	Cotton	Black	11	8.76
9	118	120	Cotton	Black	2	1.68

	P1	P2	Crop1	Soil1	phosphorous_diff(kg/ha)	P_percentage_diff(%)
0	32	60	Rice	Alluvial	28	60.87
1	45	60	Rice	Alluvial	15	28.57
2	33	60	Rice	Alluvial	27	58.06
3	47	60	Rice	Alluvial	13	24.30
4	48	60	Rice	Alluvial	12	22.22
5	50	60	Cotton	Black	10	18.18
6	42	60	Cotton	Black	18	35.29
7	46	60	Cotton	Black	14	26.42
8	38	60	Cotton	Black	22	44.90
9	44	60	Cotton	Black	16	30.77

	K1	K2	Crop1	Soil1	potassium_diff(kg/ha)	K_percentage_diff(%)
0	41	60	Rice	Alluvial	19	37.62
1	47	60	Rice	Alluvial	13	24.30
2	39	60	Rice	Alluvial	21	42.42
3	38	60	Rice	Alluvial	22	44.90
4	36	60	Rice	Alluvial	24	50.00
5	15	60	Cotton	Black	45	120.00
6	19	60	Cotton	Black	41	103.80
7	21	60	Cotton	Black	39	96.30
8	19	60	Cotton	Black	41	103.80
9	23	60	Cotton	Black	37	89.16

Figure 3.3 comparison of NPK values

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V. RESULT

In order to gather different soil samples, such as red and black soil, we conducted research on the different soil types and the ideal nutrient values that correspond with them. We created our own Arduino Soil NPK Metre and successfully implemented the interfacing of the Soil NPK Sensor with Arduino. The code was uploaded to an Arduino UNO board, and the LCD was made available for initialization alongside the NPK sensor.

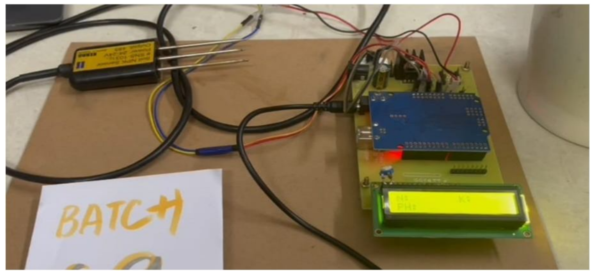
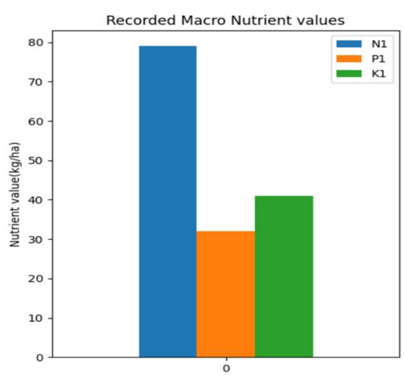
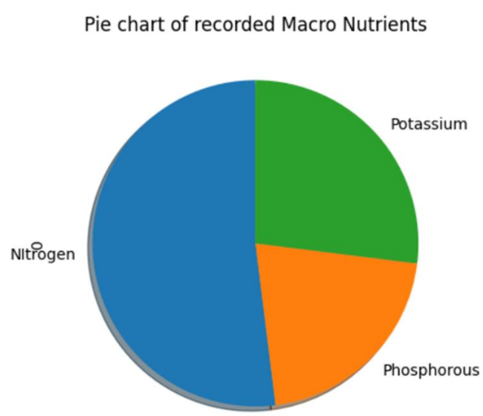


Figure 5.1 Implementation of circuit diagram

Figure 5.2 Readings on LCD display





RECORDED MACRO NUTRIENT VALUES(Kg/Ha

N1	P1	K1	N2	N_diff(kg/ha)	N_diff(%)	P2	P_diff(kg/ha)	P_diff(%)	K2	k_diff(kg/ha)	K_diff(%)
79	32	41	120	41	41.210000	60	28	60.870000	60	19	37.620000

Figure 5.3 Detailed analysis of soil sample received

Following the determination of the levels of nitrogen, phosphorus, and potassium (NPK) in the soil, data is collected and contrasted with ideal values obtained from the sources (NAAS 2009).[5] "Crop Response and Nutrient Ratio", Policy Paper No. 42, Acharya N.G. Ranga Agricultural University and National Academy of Agricultural Sciences, New Delhi. These sources provided a detailed analysis of how to increase the nutrient content in the tested soil as well as the ideal values of N, P, and K nutrients in soil, specific to the soil type.

VI. CONCLUSION AND FUTURE SCOPE

The significance of sustainable farming practices and nutrient management in maintaining soil health and increasing crop yields is showcased in this project. By utilizing IoT technology to analyze soil nutrient data, valuable insights have been obtained into the nutrient composition of various types of soils. These insights can assist policymakers and farmers in making data-driven decisions. This project sets the foundation for further research and development in the field of precision agriculture.

By analyzing soil nutrient data using IoT technology, this project highlights the importance of sustainable farming practices and nutrient management. The information collected will be utilized to develop a machine learning model that can recommend the appropriate type and amount of fertilizer based on soil nutrient composition. This will help farmers make informed decisions, minimize fertilizer waste, and increase crop yields.

Furthermore, this project endeavors to enhance the IoT prototype used for soil nutrient analysis by integrating micro-nutrient analysis to provide a more comprehensive understanding of soil health.

The future work of this project has the potential to significantly enhance the efficiency and sustainability of agriculture by decreasing resource consumption and improving crop yields while promoting sustainable farming practices..

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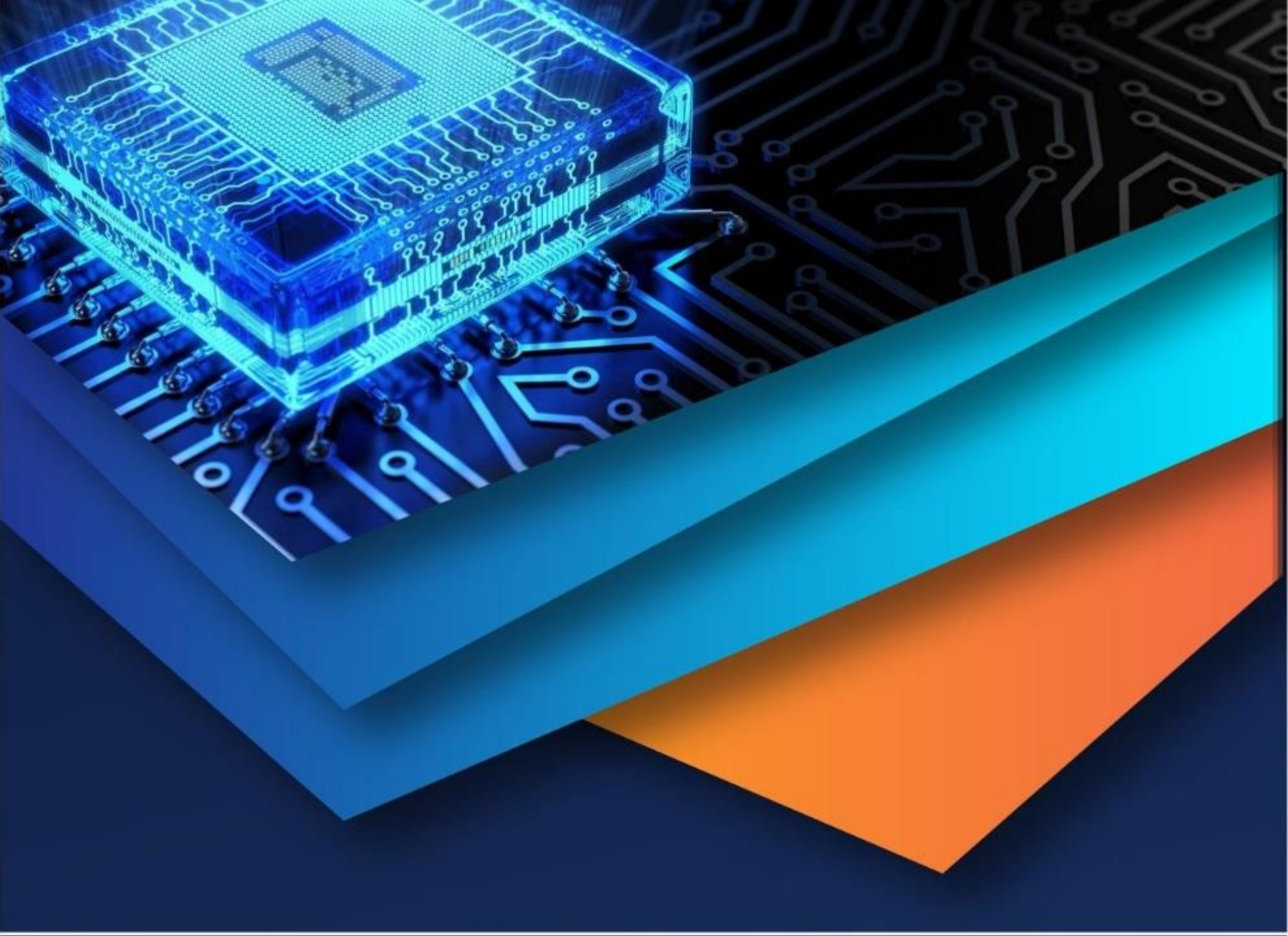

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