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Remote Sensing and GIS for LULC Change Detection: A Review of Techniques and Findings

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Abstract:** This research focuses land use land cover changes (LULC) caused by Agricultural growth, urbanization, and green changes. These changes significantly affect local ecosystems and agricultural methods, affecting the region's sustainability. The research uses modern Geographic Information Systems (GIS), Remote Sensing (RS) technologies, and machine learning models to examine LULC dynamics. It aims to visualize current patterns, detect historical changes, and estimate future trends, providing a holistic picture of land-use shifts. The study also aims to uncover the underlying causes of these changes, such as population growth, infrastructural development, and climate variations, and assess their effects on environmental health and agricultural output. The use of machine learning techniques to improve LULC analysis is an important part of the study. These methods improve the accuracy of change detection and future trend prediction, allowing for a data-driven comprehension of land-use patterns. This research gives useful information about the consequences of unplanned development and unsustainable practices. This research highlights the importance of sustainable land management practices in reducing negative outcomes. It recommends techniques to balance development and environmental conservation, addressing issues like habitat loss, soil degradation, and reduced agricultural yields. Finally, this research aims to contribute to regional planning and policymaking by giving evidence-based suggestions. Its conclusions will help to balance economic development and environmental preservation, providing the region's long-term survival. The dataset was used by experimental for LULC changes, Landsat satellite Data, Cartosat, Quick bird satellite, Sentinel-2A MSI, HyRANK dataset, Multispectral Landsat ETM+ and Hyper spectral DAIS Data.The The study aims to enhance ecological improvement and informed policymaking by addressing both present challenges and future threats.

***Keyword:** Geographic Information Systems, Remote Sensing, Land Use Land Cover Change detection, Sustainable Development, and Satellite Imaging.*

I. INTRODUCTION

Land Use and Land Cover (LULC) are essential kind the dynamic interactions between social activities and natural processes that constantly create and modify landscapes. LULC analysis is critical for determining the magnitude of changes over time, identifying patterns, and analyzing the environmental, economic, and social ramifications. This is especially important in areas undergoing rapid alteration due to causes such as agricultural expansion, urbanization, industrial growth, and climate differences. Paithan Taluka, located in Maharashtra's Chhatrapati Sambhajinagar district, provides a suitable case study for investigating these developments. Paithan, which has long been known for its agricultural prominence and cultural history, has seen substantial land use changes As the outcome of increased a population pressure, infrastructure increase and changing agricultural practices. Region's transition has resulted in the conversion of agricultural area to urban settlements, the expansion of industrial zones, and changes to forest cover and water bodies. While these changes help to drive economic progress, they also present issues such as biodiversity loss, soil de gradation, water resource depletion, and swings in agricultural production. Understanding LULC dynamics in Paithan Taluka is crucial to determining the long-term viability of its land resources. This study intends to provide a detailed and systematic study of LULC changes in the region using Remote Sensing techniques, Geographical information system (GIS) mapping, historical data exploration. By classifying distinct land cover types and identifying emerging trends across time, this study will focus on the primary driving components behind these changes, such as socioeconomic developments, governmental initiatives, and environmental considerations. Furthermore, the results of this study will have far-reaching ramifications for regional planning and resource management. Analyzing LULC transitions will help legislators, urban planners, and environmentalists develop methods that encourage sustainable land use while balancing economic growth and ecological conservation. This research's findings will help contribute to decisions on water management, agricultural sustainability, and urban expansion planning. In an era where land resources are under increasing stress as a result of human-caused changes, research like this are critical in ensuring that development is carried out in an environmentally responsible manner. Overcome the gap between scientific research and practical applications. This research needs to provide important advice for maximizing land usage while protecting Paithan Taluka's natural integrity.

II. LITERATURE SURVEY

This research paper focuses on Land Use Land Cover Changes (LULCC) using Remote Sensing and Geographic Information Systems (GIS). The study utilizes Landsat 5, 7, and 8 datasets from the USGS Portal to analyze six land cover classes: bare lands, bushlands, farmlands, forests, grasslands, and water bodies. The methodology includes both unsupervised and supervised classification techniques. Unsupervised classification was performed using Maximum Likelihood, while supervised classification was conducted using the ISODATA (Iterative Self-Organizing Data Analysis) technique.The results indicate significant land cover changes over the past 30 years. Water bodies, farmlands, and bare lands have increased by 314.86%, 160.45%, and 73.18%, respectively. In contrast, forests, bushlands, and grasslands have declined by 45.94%, 38.73%, and 29.66%, respectively. These findings highlight substantial landscape transformations, likely driven by natural and anthropogenic factors. [Maina J, Wandiga S et al. 2020]

Land Use Land Cover (LULC) patterns are influenced by both natural and human factors. These patterns include forests, water bodies, agricultural fields, and other land types. Remote Sensing (RS) and Geographic Information System (GIS) technologies play a crucial role in identifying changes in land cover and understanding their impact on the environment and society. By analyzing satellite imagery and spatial data, RS and GIS provide valuable insights for land management, urban planning, and environmental conservation. This research utilizes various approaches and software tools for RS and GIS, including Multi- Criteria Analysis (MCA), Maximum Likelihood Classification (MLC), Machine Learning Algorithms (MLA), Google Earth Engine (GEE), Change Detection (CD), Normalized Difference Vegetation Index (NDVI), Synthetic Aperture Radar (SAR), Decision Trees (DT), hybrid methods, transition matrix analysis, Corine land cover nomenclature, and unsupervised categorization. Additionally, supervised classification is performed using the ISODATA and MLA techniques. The findings indicate that previous studies using these methods have achieved accuracy assessments ranging from 75% to 95%, demonstrating their effectiveness in LULC analysis. [Kabir Abdulkadir Gidado et at. 2018]

Geographic Information System (GIS) and Remote Sensing (RS) data are fundamental in studying Land Use Land Cover (LULC) changes and classifications. This research utilizes multi-temporal Landsat images, processed using ArcGIS 10.3, to analyze LULC transformations. The final results categorize LULC into three main classes: vegetation, water bodies, and built-up areas. The classification was performed using the Maximum Likelihood Algorithm (MLA), which effectively identified LULC changes. The overall classification accuracy achieved was 100%. [Mohd Khairul Amri Kamarudin et al. 2018]

Land Use Land Cover Changes (LULCC) play a significant role in land management, reflecting the impact of both human and natural stressors on the Earth's environment and resources. This study aims to map and monitor spatial and temporal changes using Landsat 2, Landsat 5, and Landsat 8 satellite images. LULC classification was performed using the Maximum Likelihood Algorithm (MLA), followed by post- classification comparison to assess changes over time. The classification achieved a kappa value of approximately 78%, indicating a high level of agreement with reference data. The findings reveal a significant decline in wetlands and bare land, with an average decrease of about 97% [C.E. Akumu, S. Dennis, C. Reddy 2018]

This research goal is to create bivariate maps that accurately demonstrate land use and land cover combinations. We ensure that the maps are simple intuitive, and comparable to traditional mapping systems by employing a gridded frame and uniform colors. The Gestalt principle uses primary and secondary contrasts to visually arrange information. Demonstrated the relationship between land use and land cover using bivariate maps, statistical legends, and Sankey diagrams, which are frequently confused but distinct. These methods show how land cover types intersect with land use and demonstrate the extent of human effect. Future work can enhance map visualizations and automate symbology to facilitate spatial pattern exploration. [Georgianna Strode et al. 2017]

This research using the Remote Sensing and GIS Technique find out the LULC changes and Characteristics of Remote Sensing Data Acquired for the Study Satellite data IRS-LISS III, Indian-Linear, and Remote-Imaging, Sensing-Self. These are the Land use/Land Cover Class Rural, Urban, Agriculture, Fallow Land, Forest Plantation, Scrub land, Waterlogged Area, River, Pond, and Lakes. Final conclusion of Since 2001, the Ambala district witnessed major land use changes, with scrubland, wetlands, and rivers dissipating as a result of urbanization and agricultural expansion. Urgent conservation measures are required to restore these habitats and stop further environmental degradation. [Priyanka 2017]

This study emphasizes the usefulness of remotely sensed data for evaluating land cover changes. The findings demonstrate that 16.69% of farmland, 54.33% of forest, and 21.98% of other areas remained consistent across three decades, whereas only 30% of the overall area preserved the same land cover type. Spatial pattern measurements provide quantitative insights into these transitions, which improves our understanding of spatiotemporal land cover dynamics. Using NASA Landsate TM and ETM+data and rcGIS software unsupervised classification and then supervised (MLC) Maximum likelihood classification. [Mukesh Singh Boori and Vít Voženílek 2014]

This research uses a dynamic model of land-use change, the land-use structure change index approach, and an ecosystem service value measurement model to examine the influence of land-use change on ecosystem service value in Chengdu City. In this research used Food production data-Sichuan Statistical Yearbook-Correcting value equivalents-National grain purchase price data using ArcGIS Software. The analysis found that development land increased while cultivated and unused land dropped. ESV increased by 1.559 billion yuan from 2005 to 2014, but fell by 947.77 million yuan from 2014 to 2020. Forest land provided the most ecosystem services, emphasizing its vital ecological function. [Zhigang Li, Jiaxing Zhu, Yangjie Tian 2024]

The study investigates the influence of LULC changes on LST and the urban heat island effect, finding that built-up areas rose while vegetation dropped. LST increased from 35.39°C to 39.96°C (2008-2018), with Nowshera's mean LST rising by 5.4°C. Built-up and unoccupied terrain had the greatest temperatures, demonstrating a consistent warming trend. The study employed Landsat-5/TM (2008) and Landsat- 8/OLI_TIRS (2018) from USGS to examine LULC and LST. Images with <10% cloud coverage were selected for accuracy using supervise classification with maximum likelihood classifier. [Muhammad Ibrahim and Muhammad Jamal Nasir 2024]

Sr. No	Author and Title	Year	Method/ Technique	Database	Result
1.	Mohamed Ali Mohamed, Julian Anders and Christoph Schneider Monitoring of Changes in Land Use/Land Cover in Syria from 2010 to 2018 Using Multitemporal Landsat Imagery and GIS	2020	Supervised classification, Maximumlikelihood classification.	Landsat-5 TM and Landsat-8 OLI data analyze Urban & Peri-Urban areas, Cultivated areas, Forests, Rangelands, Bare areas, and Water bodies.	86.4%
2.	D Gupta et al 2021 A Reviewon Land- use and Land- change with Machine Learning Algorithm	2021	Random Forest, SVM, Neural Networks, Spatial Transformation, Principal component analysis (PCA)	Spatial Transformation , Remote sensing and Field data	Field development results improve dramatically when high-resolution multispectral satellite imagery is processed to reduce defects and improve data correlations.
3.	Zhang, Ce Harrison, Paula A.; Pan, Xin; Li, Huapeng; Sargent, Isabel; Atkinson, Peter M. Scale Sequence Joint Deep Learning (SS-JDL) for land use and land cover classification	2020	(CNN), Multi-scale Deep Learning Multilayer perceptron's (MLP)	Land Use (LU) and Land Cover (LC) data are collected through field surveys and manually digitized by 322 photogrammetrists at Ordnance Survey, Britain's National Mapping Agency.	Combining LU-CNN, LC-MLP, and joint distribution modeling improves classification accuracy, with SS-JDL providing the highest accuracy and efficiency.
4.	Afera Halefom, Asirat Teshome, Ermias Sisay, Imran Ahmad Dynamics of Land Useand Land Cover Change Using Remote Sensing and GIS: A Case Study of Debre Tabor	2018	Unsupervised classification Arc GIS10.3 and ERDAS IMAGE14 software.	Landsat 7, Landsat 8.	52%
	Town, South Gondar, Ethiopia				
5.	Giles M. Foody Status of land cover classification accuracyassessment	2002	Confusion matrix, kappa coefficient quantitative metric	Thematic map	Thematic maps from remote sensing struggle with accuracy issues, highlighting the need for better assessment methods and transparency.

6.	L. E. Christovam, G. G. Pessoa, M. H. Shimabukuro, M.L.B.T. Galo Land use and land cover classification using hyperspectral Imagery: evaluating the performance of spectral angle mapper, support vector machine and random forest	2019	Spectal Angle Mapper SAM, Support Vector machine SVM, and Random forest RF	HyRANK dataset	RF outperforms SVM, SAM on HyRANK, with principal components boosting RF's accuracy and reducing fitting time by 28%.
7.	Anuj Karpatne, Gowtham Atluri, James H. Faghmous, Michael Steinbach, Arindam Banerjee, Auroop Ganguly, Shashi Shekhar, Nagiza Samatova, and Vipin Kumar Theory-guided Data Science: A New Paradigm for Scientific Discoveryfrom Data	2017	Data mining and machine learning primarily for classification, change detection, or predictive modeling	(Theory-guided data science TGDS)	This research introduces TGDS, integrating scientific knowledge with data science to improve model performance and future research.
8.	Mahesh Pal, Paul M. Mather An assessment of the effectiveness of decision tree methods for land cover classification	2003	MLC-Maximum Likelihood Classification and ANN-Artificial Neural Networks for classification accuracy	Multispectral Landsat ETM+, Hyper spectral DAIS Data.	ML achieves 95% accuracy compared to 86% for unboosted DT in high-dimensional data.
9.	Qin Leia, Hong Jinb, Jia Lee, a, Jiang Zhonga Land use and land cover change simulation enhanced byasynchronous communicating cellular automata	2024	Artificial neural network (ANN), (CA) Cellular automation , Kappa coefficient, confusion matrix	DEM Data	The ANN-ACCA models accurately models LUCC with more accuracy, especially in higher areas, surpassing the ANN-CA.
10.	Hafiz Usman Ahmed Khan Land Useand Land Cover Simulation	2023	AI, DL and Machine learning, maximum likelihood classifier (MLC), (ANN), (SVM), (RF) Random Forest	DEM, land-cover data, topographic data, satellite imagery, GIS datasets.	High data quality, compatibility, availability, and validation ensure reliable and accurate LULC simulation results.
11.	Mohammed Kareem Sameer1, Adnan Muttashar Hamid, Remote Sensing and GIS Techniques in Monitoring Land Use Land Cover Change	2023	ARC map software, spatial and historical analysis techniques.	Quick bird satellite data, thematic Map data, Spectral bands, Wasteland.	This research area experienced a rise in urban areas, agricultural, and expanding land, whereas wasteland decreased considerably due to population growth and land use changes.

12.	Shehla Gul, Tehmina Bibi Monitoring of Land Useand Land Cover Changes Using Remote Sensing and Geographic Information System	2022	Supervised Classication , Maximum Likelihood technique, Accuracy Assessment	Landsat-5,7,8 Satellite data.	15.78% increase in vegetation and a 9.41% decrease in barren area.
13.	Aziz Makandar and Shilpa Kaman, Land Use Land Cover Study Of Sentinel-2a And Landsat-5 Images Using Ndvi And Supervised Classification Techniques	2008	ArcGIS software Supervise Classification technique, Maximum Likelihood Classification	Sentinel-2A MSI (Multispectral Imager), Landsat-5TM(Thematic Mapper).	88.16% of overall Accuracy.
14.	Samuel Adingo, Xiaodan Li, Xue-Lu Liu, Jie-Ru Yu Analysis of Land- Useand Land-Cover Changes in YongDeng County Using Remote Sensing and GIS	2020	ArcGIS (version 10.3) Supervised, Maximum Likelihood classification	Landsat Data and Geospatial data. .	Urbanization has changed 4.5 km² of grassland, 3.21 km² of bare ground, 2.51 km² of farming, and 1.7 km² of woods into construction land, necessitating immediate conservation.
15.	Dires Tewabe, Temesgen Fentahun	2020	ENVI and Arc GIS software, kappa coefficient, accuracy assessment	Land sat TM 30 From USGS	Agricultural land expanded by 15.61% and residential areas by 8.05%, with an overall Accuracy of 91.40%.
16.	H.T.T. Nguyen, Q.T.N. Chau, A.T. Pham, H.T. Phan1, P.T.X. Tran, H.T. Cao1, T.Q. Le, D.T.H. Nguyen Land Use/Land Cover Changes Using Multi- Temporal Satellite	2020	ArcGIS software.	Landsat 5, 8 from USGS	Accuracy 84.55%
17.	Millary Agung Widiawaty, Arif Ismail, Moh. Dede, N. Nurhanifah,210 Modeling Land Use and Land Cover Dynamic Using Geographic Information System and Markov-CA	2020	Markov-CA, logistic regression method, Buffering based on visual-supervised classification, overall accuracy, overall kappa	CNES-Airbus satellite imageries-Markov- CA. Data, ASTER DEM, BNPB data,BIG Tanah Air-Geoportal. Water bodies (WB), Mangroves (MA), Plantations (Pt), Non-vegetated (NV), Built- up area (BA), Agricultural land (AL), Marsh (Mr). Salt area & Fisheries (SF)	Built-up areas increased by 20.67%, while agricultural land decreased by 18.5%, due to increased density of roads and proximity to urbanized regions.

18.	Nabil Zerrouki, Fouzi Harrou, Member, IEEE, Ying Sun, Lotfi Hocini, A Machine Learning-based Approach for Land Cover Change Detection Using Remote Sensing and Radiometric Measurements	2019	ENVI1 Software, NN, SVM, random forest, and weighted random forest algorithm (WRF)	SZTAKI Dataset.	Findings show that the suggested detection strategy accurately detects land cover changes and outperforms methods such as NN, Random forest, SVM.
19.	B V Ramanamurthy and N Victorbabu, Land Use Land Cover (LULC) classification with wasteland demarcation using Remote sensing and GIS Techniques	2021	Arc GIS and ERDAS software, Un- Supervised Classification, Supervised classification	Landsat-7 Satellite data	The study correctly recognized woodland areas (98% accuracy) and wastelands (85% accuracy).
20.	Ritu Saini, Pradeep Aswal, Mohd Tanzeem, Sanyam S. Saini, Land Use Land Cover Change Detection using Remote Sensing and GIS in Srinagar, India	2019	ERDAS, IDRISI and ArcGIS Software Supervised classification, MLC, LCM (Land Change Modular).	Landsat-5, 8 satellite data	Vegetation, forest areas developed, but barren land and water areas dropped. 0.33 km² of water, 10.11 km² of forest, 6.57 km² of vegetation, and 22.48 km² of barren land were converted to urban areas.

Table 1: The Different Methodology And Various Database

III. METHODOLOGY

This research will use a complete methodology that includes remote sensing, GIS analysis, and field surveys. High-resolution satellite images will be used to classify land cover types and track their evolution over time. The imagery will be processed and analyzed with advanced algorithms to detect minor changes. We are utilizing the following methods. Ground-truthing will be carried out through focused field surveys to evaluate the Remote sensing data and improve the study's accuracy.

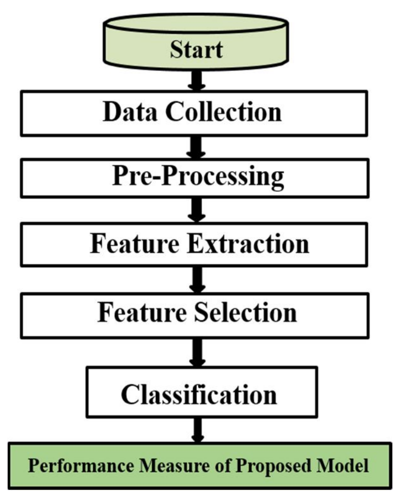

Fig. 1: A Possible Nested Architecture

GIS will play an important role in facilitating spatial analysis by overlapping multiple layers of data such as topography, hydrology, and land use for the correlations Changes in land cover and environmental variables. These methods were chosen based on their ability to provide solid, high-quality data that allows for a more detailed understanding of LULC dynamics. The goal of this work is to create a thorough portrayal of LULC changes by combining remote sensing, GIS, and ground truthing.

IV. DISCUSSION

This research found a significant increase in scientific literature on remote sensing-assisted analysis of LULC changes. This expansion demonstrates the expanding significance of remote sensing technology in land use observing, planning, and management. The increasing importance of remotely sensed data demonstrates how useful it is in collecting geographical and temporal changes in land cover, allowing for more informed decision-making for sustainable land use practices. This review's most significant discovery is the use fine-scale remotely sensed data in LULC analysis. These high-resolution databases offer unique insights about land cover transformations, allowing researchers to investigate patterns and trends with greater accuracy. The availability of many different satellite imagery, such as Landsat, Cartosat, LiDAR, ultra-high spatial resolution images, hyper spectral data, and Google Earth products, has increased the ability to assess and understand LULC changes. These datasets can be used separately or together to provide a thorough picture of land use dynamics. Despite great advances, there are still problems and possibilities for future improvement in remote sensing applications for LULC analysis. Concerns about data accessibility, processing complexity, and the need for enhanced analytical techniques persist. Furthermore, combining remote sensing with additional geospatial tools, such as Geographic Information Systems (GIS) and machine learning techniques, could improve the precision and application of LULC analyses. To maximise the potential of remote sensing in LULC studies, future research should focus on refining classification methods, improving data integration methods, and resolving spatial and spectral resolution limits.

Overall, while remote sensing has made significant contributions to LULC monitoring and management, ongoing technological and scientific advances are required to overcome current challenges. Strengthening interdisciplinary cooperation and harnessing emerging technologies will be critical for improving the accuracy and effectiveness of LULC change detection and sustainable land use planning.

V. CONCLUSION

The research is likely to reveal major modifications in LU patterns in a Paithan Taluka, particularly loss of farming land due to urbanization. These findings highlight the environmental implications of such changes, which include risks to biodiversity, soil health, and water resources. The research also highlights agricultural production concerns, such as arable land loss and decrease of critical natural resources. This study establishes the groundwork for establishing strategies to promote sustainable land use in Paithan Taluka by giving vital insights into the ecological implications of LULC alterations. It helps to better understand the essential balance between development and sustainability., ensuring that future growth complies with sustainability standards.

This study paper highlights the accuracy of current machine learning methods in Land Use Land Cover classification, with SS-JDL achieving the maximum accuracy and efficiency. RF beat SVM and SAM, with principal components enhancing accuracy while cutting fitting time by 28%. ANN-ACCA outperformed ANN-CA in LUCC modeling, obtaining higher accuracy in more areas. Woodland classification achieved the highest accuracy at 98%, with an overall accuracy of 91.40% in detecting changes in land cover. These findings highlight the importance of high-quality data, validation, and better assessment methods for dependable LULC simulations and sustainable land management.

VI. SCOPE OF THE STUDY

This research will focus on the entire geographical area of Paithan Taluka, analyzing LULC changes from the year 2000 to the present. The study will emphasize the environmental and agricultural impacts of these changes, including:

1) Urbanization Impact: Examining how urban expansion has influenced agricultural land, assessing range of land conversion, consequences for local food production, land management.
2) Land Management Practices: Evaluating the effectiveness of current land management strategies in addressing the challenges posed by LULC changes.

The study will concentrate on the physical and ecological dimensions of land use changes, providing a thorough investigation of their environmental and agricultural consequences, while not delving deeply into Social or economic factors.

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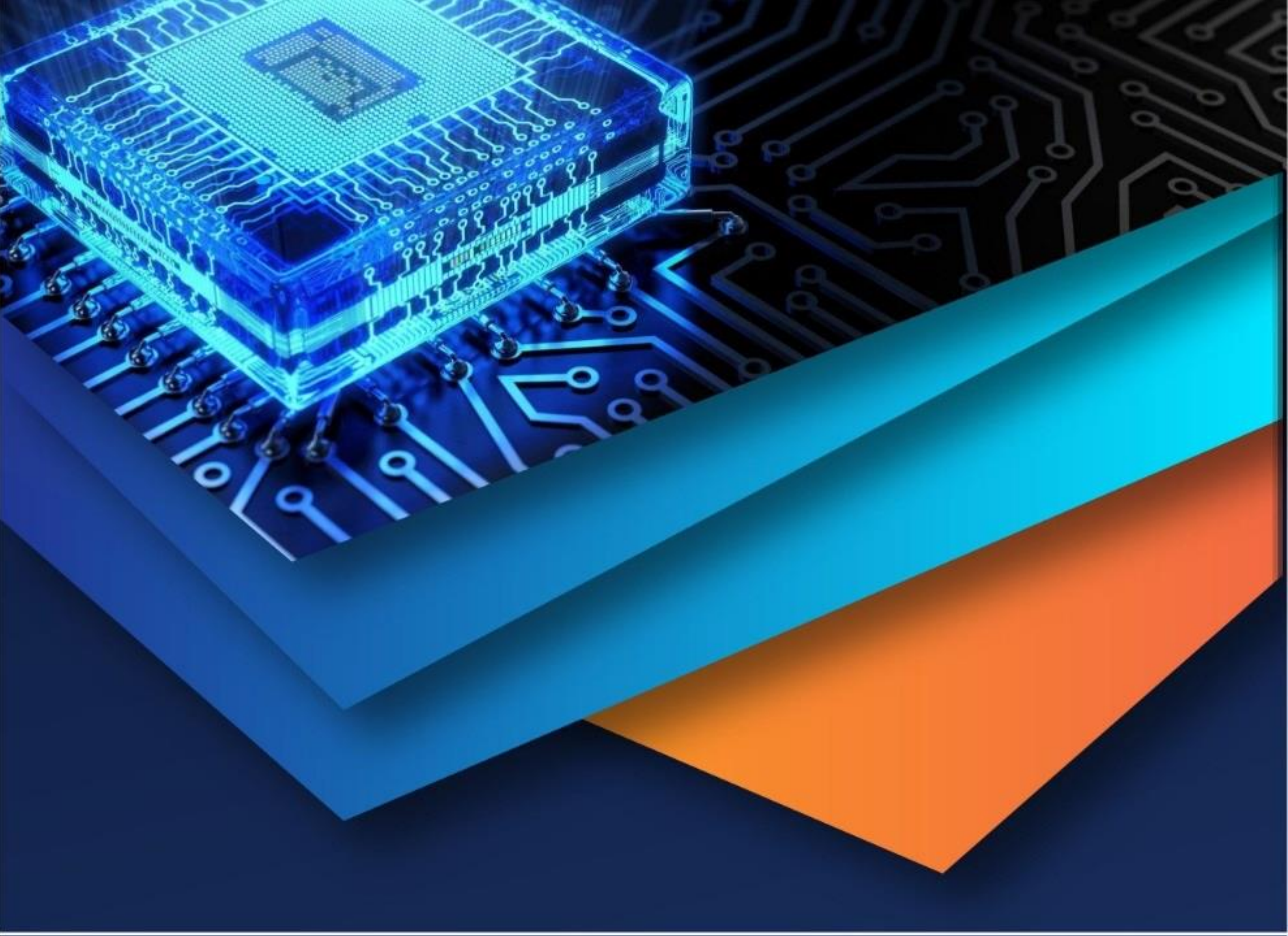

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