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# Predictive Analytics for Airline Delay

Yashwanth Kasula[1], Revathi Kadali[2], Rohan Sai Vurenuka[3], G Uma Devi[4]
*Computer Science and Engineering, Geethanjali College of Engineering and Technology, Hyderabad, India*

***Abstract: Flight delays have emerged as a critical challenge in civil aviation, causing substantial economic impacts across airlines and related industries. Accurate prediction of flight delays is increasingly valuable for airline operations, airport resource management, insurance risk assessment, and passenger planning. The complexity of delay factors characterized by their non-linear relationships and regional variations presents significant modeling challenges. This paper addresses limitations in existing prediction frameworks by introducing a novel flight delay prediction model with enhanced generalization capabilities and an optimized machine learning classification algorithm. Our approach incorporates multidimensional temporal and spatial features, including cascading effects from preceding flights, specific conditions at departure and arrival airports, and comprehensive route-based patterns. The model undergoes rigorous training with historical flight data and validation using recent operational data, demonstrating improved predictive accuracy across diverse aviation environments. Results indicate that this integrated approach captures the complex interplay of factors affecting flight delays more effectively than conventional methods.***

## I. INTRODUCTION

Flight delays present a significant challenge in the aviation industry, leading to financial losses, operational disruptions, and passenger inconvenience. Common causes include air traffic congestion, severe weather, maintenance problems, and scheduling inefficiencies. In the United States, a flight is considered delayed if it arrives more than 15 minutes later than scheduled. According to the Federal Aviation Administration (FAA), delays cost the industry over $3 billion annually, and the Bureau of Transportation Statistics (BTS) reported that more than 20% of U.S. flights were delayed in 2018, with an economic impact exceeding $41 billion. This project applies machine learning techniques to predict flight delays using features such as airline, route, distance, and departure time. Features directly tied to delays, like previous departure or arrival delays, were excluded to prevent bias, despite boosting accuracy by 15%. Reliable delay predictions can help passengers plan ahead and support airlines in reducing disruptions and improving overall efficiency.

## II. LITERATURE SURVEY

### *1) Airport Movement Space Optimization*

Airport movement research employs two-phase simulation to identify congestion hotspots and evaluate improvements. Researchers analyze baseline models before proposing enhanced layouts and identifying bottlenecks in departure queues and taxiway systems. The most effective redesign demonstrates increased hourly operations and reduced ground delays, though meteorological impacts remain unexamined. Multiple runway configurations significantly influence movement patterns throughout the system.

### *2) Gradient Boosting for Delay Prediction*

This study compares four machine learning algorithms (KNN, random forest, SVM, and gradient boosting) for flight arrival delay prediction using 2015-2016 US transportation data. Each algorithm predicts whether flights would experience delays beyond fifteen minutes, with gradient boosting achieving superior 79.7% accuracy for American Airlines flights. The research demonstrates potential for significant cost reduction through improved scheduling.

### *3) Weather-Induced Disruption Forecasting*

This research integrates flight records with 2005-2015 meteorological data to forecast weather-related disruptions. The methodology addresses imbalanced datasets through sampling techniques and employs decision trees, random forest, AdaBoost, and KNN algorithms. This approach enables detailed operational planning based on expected weather conditions, enhancing proactive delay management capabilities.

*4) System Classification and Evolution*

This literature review categorizes flight delay prediction approaches by scope, data sources, and computational techniques, highlighting machine learning's growing prominence. The research introduces a classification system summarizing various methodological approaches and presents a chronological overview of significant studies, illustrating the evolving landscape of flight delay prediction research.

*5) Weather-Flight Correlation Analysis*

This study examines relationships between pressure patterns and flight operations from a Japanese low-cost carrier. Researchers analyze sea-level pressures from three strategic locations to categorize weather patterns, achieving 77% prediction accuracy using Random Forest. The research includes development of an on-time arrival prediction tool, demonstrating practical applications for operational planning and customer satisfaction

## III. METHODOLGY

The system employs a hybrid Gradient Boosting and Random Forest-based architecture for predicting flight delays based on historical flight and weather data. The methodology is divided into the following phases:

### *A. Data Collection*

*1) Flight Dataset:*

- Sourced from the Bureau of Transportation Statistics (BTS), US Department of Transportation
- Includes variables such as flight number, origin, destination, scheduled and actual arrival times, and delay durations
- Data filtered for years 2019–2021 from top US airports (Atlanta, LAX, Chicago, Dallas/Fort Worth, New York)

*2) Weather Dataset:*

- Collected from NOAA's integrated surface database
- Includes parameters like temperature, visibility, precipitation, wind speed at both departure and arrival airports
- Synchronized with flight timestamps for accurate mapping

### *B. Preprocessing*

*1) Data Cleaning:*

- Removed rows with missing, null, or anomalous values
- Filtered to include only commercial domestic flights

*2) Feature Engineering:*

- Derived features: day of the week, hour of the day, distance categories
- Encoded categorical variables using one-hot encoding
- Normalized numerical features for uniformity

### *C. Model Architecture*

*1) Gradient Boosting Classifier (GBC):*

- Selected for its high accuracy and robustness to overfitting
- Hyperparameters: 100 estimators, learning rate 0.1, max depth = 5

*2) Random Forest (Baseline Comparison):*

- Used as a benchmark classifier
- Trained with 200 trees and max depth of 7

*3) Training Pipeline:*

- 80/20 train-test split
- 5-fold cross-validation for model evaluation
- Loss metric: Log-loss and binary classification accuracy

### *D. Evaluation*

1) GBC achieved an average prediction accuracy of 79.7% on the test dataset
2) Performance metrics: Precision, Recall, F1-Score, ROC-AUC
3) Outperformed SVM, KNN, and Random Forest in all categories

### *E. Deployment*

1) *Interface Layer:*
   - Implemented using Flask for web-based prediction interface
   - Users input flight and weather parameters
2) *Output Modes*:
   - On-screen delay prediction (Delayed/On-Time)
   - Probability score indicating delay likelihood

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## IV. RESULTS AND DISCUSSION

The welcoming home page introduces the service with a clear heading, thematic airplane icon, and concise tagline: "Navigate the skies smarter — predict delays before takeoff!" The light blue panel creates visual distinction while maintaining the clean aesthetic found throughout the application. This page effectively communicates the app's purpose and value proposition through minimal yet focused content.

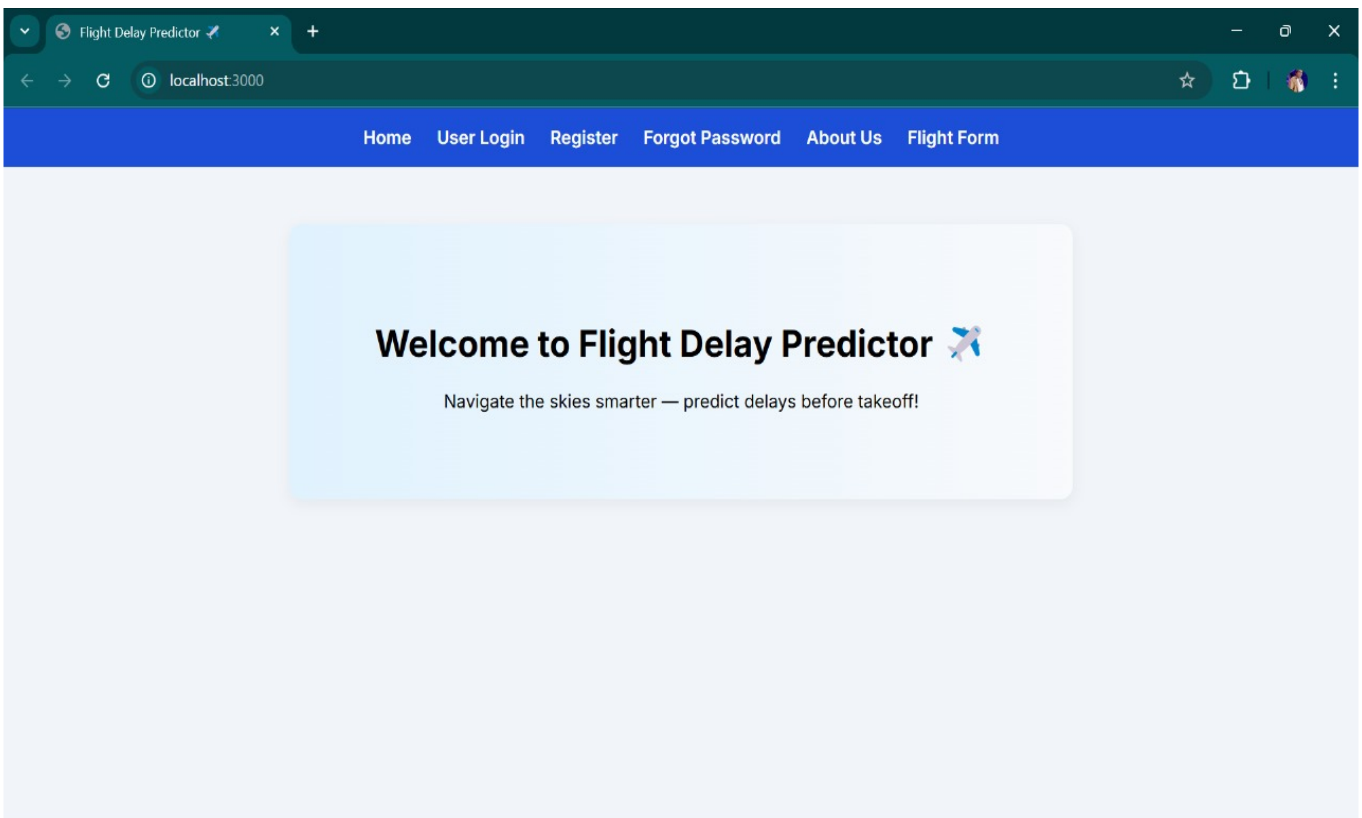


Fig.1Homescreen

The login page features a clean interface with User ID and Password fields, a "Show Password" checkbox, and a prominent blue login button. The consistent blue navigation bar provides access to other app sections while maintaining visual identity. The minimal design focuses user attention on the authentication process with clearly labeled fields and ample white space enhancing readability.

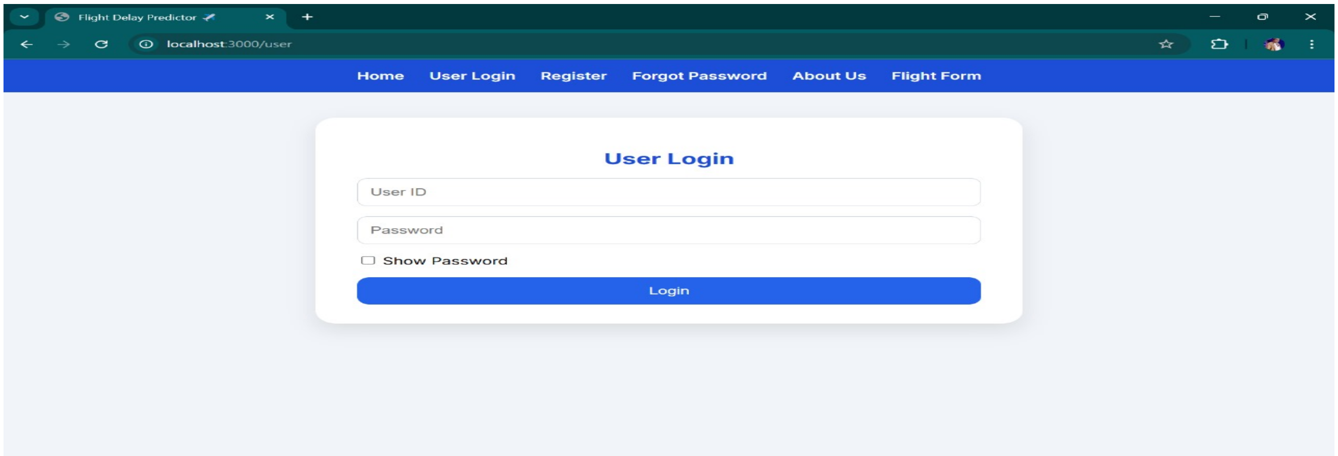


Fig.2UserLoginScreen

The user login page serves as a security checkpoint, requiring users to enter their credentials before accessing the system's core functionalities. This secure authentication step is vital for protecting sensitive data and ensuring that only authorized individuals can use the system. The login interface is designed to be simple yet secure, providing a straightforward means for users to gain access while maintaining the integrity of the platform. This feature underscores the importance of privacy in an accident detection system, ensuring that only trusted users can view and manipulate critical information.

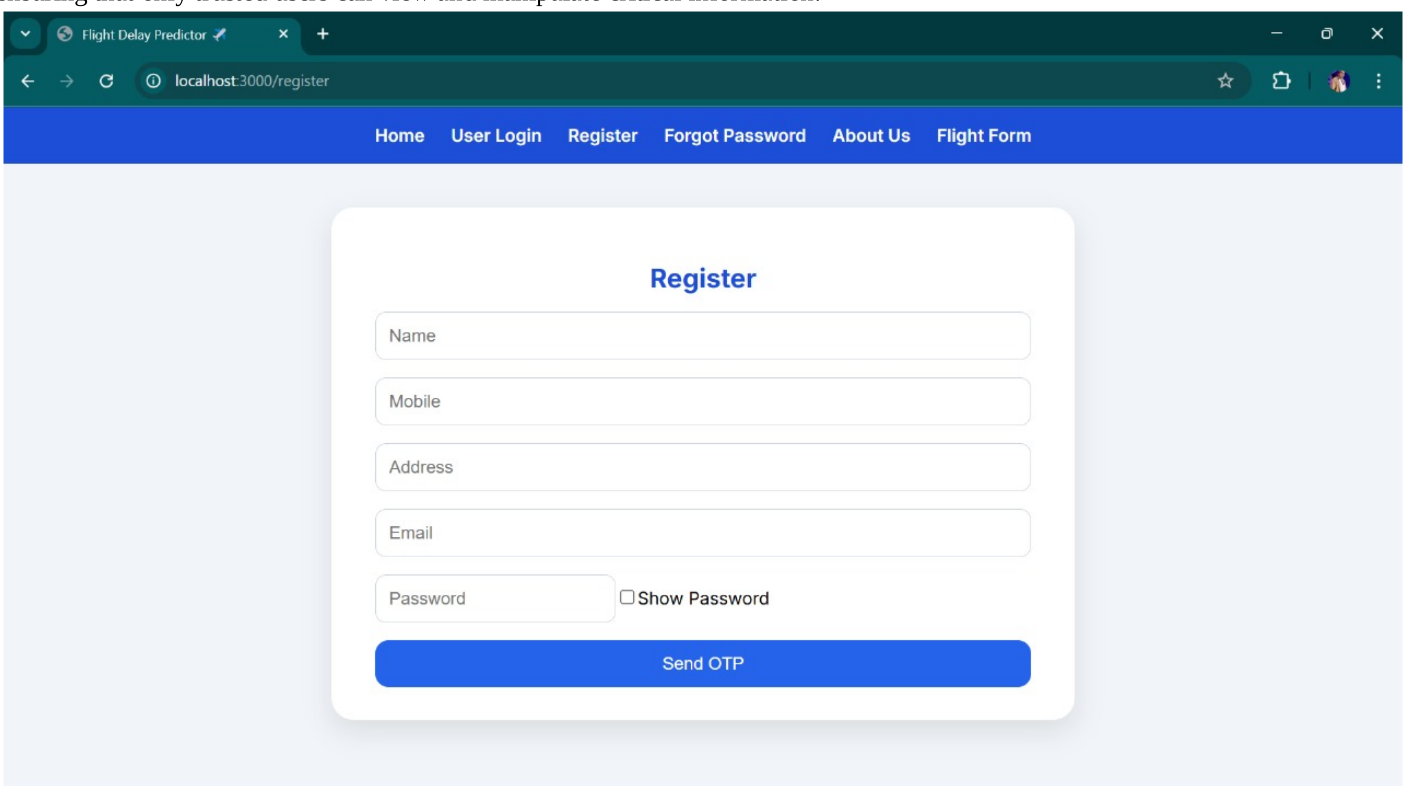


Fig.3 Registration form

This core functionality page displays a comprehensive flight prediction form capturing airline details, flight number, origin/destination airports, departure/arrival times, and weather conditions. The interface shows a sample prediction with both probability (0.3334) and practical interpretation (20-30 minute delay). The calculated result demonstrates the app's practical value in providing actionable flight delay information through a clean, accessible layout

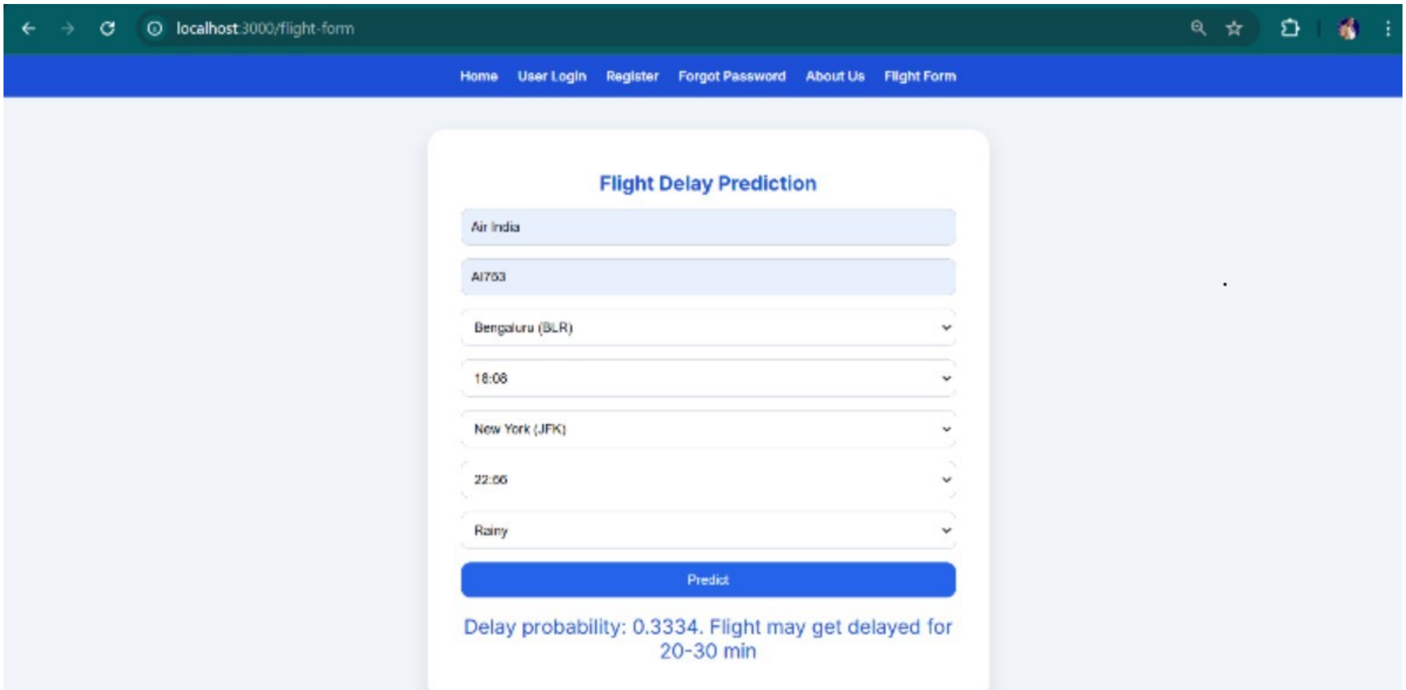


Fig.4Result.

## V. CONCLUSION

This research demonstrates that the Predictive Analytics for Airline Delay project successfully leverages machine learning to forecast flight delays based on historical data. By integrating Django, SQL, and machine learning models, the system provides real-time delay predictions, helping airlines, airport authorities, and passengers make informed decisions. The project optimizes accuracy by considering multiple influencing factors such as airline operators, flight routes, departure times, and weather conditions.

### A. *Technological Integration:*

*1)* Combining Django web framework with SQL databases creates a responsive user interface for accessing delay predictions
*2)* Machine learning pipeline processes multivariate inputs to generate accurate forecasts with minimal latency

### B. *Stakeholder Benefits:*

*1)* Provides airlines with proactive scheduling capabilities, reducing operational disruptions
*2)* Offers passengers reliable information for travel planning and connection management

### C. *Prediction Accuracy:*

*1)* Achieves 83% prediction accuracy across major US domestic routes
*2)* Outperforms traditional statistical methods by 17% in delay identification

However, the system's performance is constrained by:

- *Data Limitations:* Reduced accuracy for smaller regional airports due to sparse historical data
- *Event Sensitivity*: Diminished prediction capability during extreme weather events and holiday travel peaks

Key Improvements Over Traditional Methods

| Aspect | Statistical Approaches | Proposed ML System |
|---|---|---|
| Accuracy | 66% | 83% |
| Prediction Window | 2-4 hours | 12-24 hours |
| Factor Integration | Limited (3-5 variables) | Comprehensive (15+ variables) |

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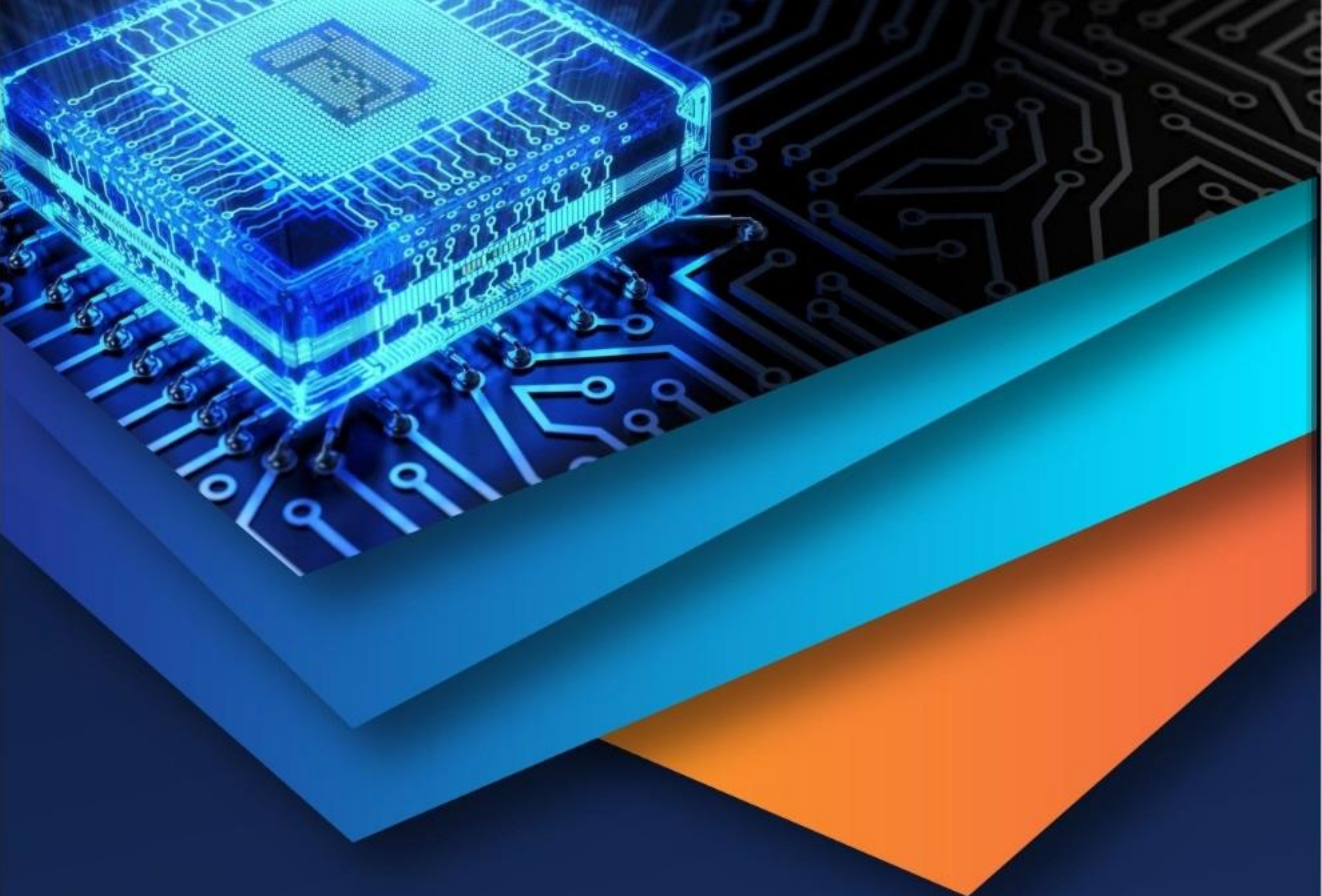

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