International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70545

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

AI-Driven Prognosis of Traumatic Brain Injury

E Bharath[1], Goutham K[2], Austin Issac[3], Abdul Musawwirs[4]
Ballari Institute of Technology & Management, India

Abstract: Traumatic brain injury (TBI) is a critical health issue, requiring an accurate and timely prognosis to inform medical interventions. This paper focuses on machine learning techniques to predict patients' outcomes, specifically targeting the Indian demographic. Key metrics such as age, time since injury, Glasgow Coma Scale (GCS), and Glasgow Outcome Scale (GOS) are utilized to assess damage severity and forecast mortality and morbidity. By integrating a Random Forest Classifier for mortality prediction and a Random Forest Regressor for morbidity estimation, the system provides a required outcome according to the input of the patient's condition. The models are trained on simulated data and integrated into a web-based platform, enabling automated predictions and user-friendly interfaces for healthcare providers. This approach gives the diagnostic accuracy, supports critical decision-making, and promotes timely medical responses, ultimately improving patient care outcomes.

I. INTRODUCTION

Traumatic brain injury (TBI) is a significant health challenge across the world, with a growing burden in India due to rising road accidents and trauma cases. Accurate and timely prognosis is crucial for effective treatment and better patient outcomes. This study utilizes machine learning to automate TBI prognosis, focusing on the unique demographic and clinical traits of the Indian population. Key clinical parameters such as age, time since injury, Glasgow Coma Scale (GCS), and Glasgow Outcome Scale (GOS) are used to train predictive models. Random Forest algorithms are employed for both classification and regression to estimate mortality risk and morbidity levels. The developed models are integrated into a user-friendly web application, providing real-time decision support to healthcare professionals. This system enhances diagnostic precision and reduces the burden of manual prognosis. It promotes data-driven healthcare, enabling quicker and more informed clinical decisions. By streamlining workflows and improving outcome predictions, the tool aims to elevate the quality of TBI care in India. Ultimately, the research contributes to improved patient management and healthcare delivery.

II. LITERATURE REVIEW

A. TBI Classification Framework for Targeted Therapies

Saatman et al. (2008) proposed a structured framework to classify traumatic brain injuries, helping standardize the clinical variables used in prognosis. Their work emphasized the importance of using indicators like the Glasgow Coma Scale (GCS) and Glasgow Outcome Scale (GOS). This foundation supports consistent data collection for machine learning models like yours.

B. Dynamic Mortality Prediction in TBI using Machine Learning

Raj et al. (2019) developed a dynamic mortality prediction system using Random Forest models, trained on patient clinical records. Their system improved accuracy over traditional logistic regression methods. It validates the use of ensemble learning techniques for mortality forecasting.

C. Multicenter Implementation of TBI Common Data Elements

Yue et al. (2013) implemented common data elements across TBI research centers to ensure standardized, shareable clinical data. They highlighted GCS and GOS as core predictors. Such elements are essential for building robust ML prediction models like those in your study.

D. International Validation of Prognostic TBI Models

Badhiwala et al. (2020) created and validated prognostic models across diverse international cohorts. The study stressed the importance of demographic-specific model tuning. This reinforces your project's focus on Indian-specific data to improve prediction relevance.

E. Neuroimaging and Connectomics for Personalized TBI Prediction
Irimia et al. (2012) explored the use of brain imaging and structural network analysis to predict TBI outcomes. Their personalized approach led to more accurate prognoses. While your model uses clinical data, the study supports the concept of data-driven precision diagnostics.

F. AI and ML Approaches for TBI in India
Gourav et al. (2020) reviewed the applications of AI and machine learning in Indian healthcare, specifically for trauma and TBI cases. They identified challenges like data scarcity and local validation needs. Their insights justify your model's focus on Indian patient data.

G. Mortality Prediction in TBI using ML Algorithms
Han et al. (2020) compared several machine learning models including Random Forest, SVM, and Neural Networks for predicting TBI patient outcomes. Random Forest was found to be one of the most stable and interpretable models. This supports your choice of classifier for mortality prediction.

H. Web-based Decision Support System for TBI
Khetan et al. (2022) developed a decision support tool for clinicians using a web platform integrated with predictive models for TBI. Their system demonstrated improved diagnosis and care timelines. Your platform shares similar objectives, offering real-time ML-powered assessments.

I. Comparative Effectiveness of ML Models in TBI Prognosis
Jha et al. (2018) analyzed the effectiveness of various ML models for predicting TBI outcomes. Random Forest and Gradient Boosting were among the top performers in terms of AUC and recall. Their findings align with your approach of using regression for morbidity prediction.

J. TBI in South-East Asia: WHO Regional Report
The WHO (2021) reported high incidence and mortality rates of TBI in South-East Asia, with unique regional challenges in emergency care and prognosis. The report highlighted the lack of tailored clinical tools for countries like India. This underscores the need for your Indian-centric ML solution.

III. PROBLEM DEFINITION
Traumatic Brain Injury (TBI) remains one of the leading causes of death and disability worldwide, with a particularly high incidence in developing countries like India due to factors such as road traffic accidents, falls, and workplace injuries. The severity of TBI varies widely, and timely prognosis is essential to ensure appropriate medical interventions, resource allocation, and long-term patient care. However, predicting outcomes such as mortality and morbidity remains a significant challenge due to the complexity of the injury and variability in patient conditions.

In many Indian healthcare settings, the prognosis of TBI patients often relies on manual assessment techniques, which can be inconsistent, time-consuming, and prone to human error. Moreover, the lack of standardized, region-specific predictive tools means that clinicians may not always have reliable support for making informed decisions under pressure. While global research has introduced various machine learning techniques to aid in TBI prognosis, most existing models are trained on non-Indian datasets and may not accurately reflect the unique demographic, clinical, and infrastructural aspects of Indian healthcare systems.

There is a pressing need for an intelligent, automated system that can accurately forecast the mortality and morbidity of TBI patients using commonly available clinical indicators such as age, time since injury, Glasgow Coma Scale (GCS), and Glasgow Outcome Scale (GOS). Such a system should be designed to function efficiently within the constraints of Indian healthcare infrastructure and be easily accessible to medical professionals. Without such a solution, the opportunity to improve clinical outcomes through data-driven insights remains underutilized, potentially compromising patient care and recovery.

IV. METHODOLOGY
The proposed system employs a machine learning–based approach to predict mortality and morbidity outcomes in Traumatic Brain Injury (TBI) patients, with a specific focus on the Indian healthcare context. The methodology consists of the following key phases:

1) Data Collection and Simulation

Due to the limited availability of comprehensive clinical datasets in India, a simulated dataset was generated based on established clinical parameters and distributions reported in literature. Key features include:
   - Patient age
   - Time since injury (in hours)
   - Glasgow Coma Scale (GCS) score
   - Glasgow Outcome Scale (GOS) score (used for training the morbidity model)

2) Data Preprocessing

The dataset undergoes preprocessing steps to ensure quality and consistency:
   - Handling of missing or inconsistent values
   - Normalization or standardization of numerical features
   - Label encoding or binarization of categorical variables if necessary
   - Splitting the dataset into training and testing subsets (e.g., 80/20 split)

3) Model Development

Two machine learning models are developed and trained:
   - Random Forest Classifier: Used to predict mortality (binary outcome – survived or not).
   - Random Forest Regressor: Used to estimate morbidity by predicting the likely GOS outcome.

4) Model Training and Evaluation
   - Both models are trained using the training subset.
   - Performance metrics such as accuracy, precision, recall, F1-score (for classification), and Mean Squared Error (MSE) or R^2 score (for regression) are calculated using the testing subset.
   - Cross-validation is performed to ensure model stability.

5) Web-Based Platform Integration

A user-friendly web interface is developed to make the system accessible to healthcare providers.
   - Clinicians input patient data (age, GCS, etc.) through the web form.
   - The backend system processes the inputs and invokes the trained models.
   - Predicted mortality and morbidity outcomes are displayed instantly for clinical decision support.

6) Validation and Feedback
   - The system is tested with synthetic and (if available) anonymized real-world cases to evaluate usability and accuracy.
   - Feedback from medical professionals may be incorporated for further refinement

V. RESULTS AND EVALUATION

The machine learning models—Random Forest Classifier for mortality prediction and Random Forest Regressor for morbidity estimation—were trained using simulated TBI patient data, incorporating clinical indicators like age, time since injury, Glasgow Coma Scale (GCS), and Glasgow Outcome Scale (GOS).

The Random Forest Classifier achieved an accuracy of 85%, with a recall of 0.82 for mortality prediction, indicating strong performance in identifying patients at risk. For morbidity prediction, the Random Forest Regressor demonstrated a mean squared error (MSE) of 0.15, reflecting low prediction error in estimating patient outcomes.

The system, integrated into a web-based platform, allows healthcare professionals to input patient data and receive real-time predictions, significantly improving decision-making speed and accuracy. Usability tests indicated that the platform was intuitive and easy to navigate.

While the models performed well on simulated data, further validation with real-world clinical data is necessary to assess their robustness in diverse healthcare settings. Future improvements could include integrating additional patient metrics, such as neuroimaging data, to enhance prediction accuracy and generalizability.

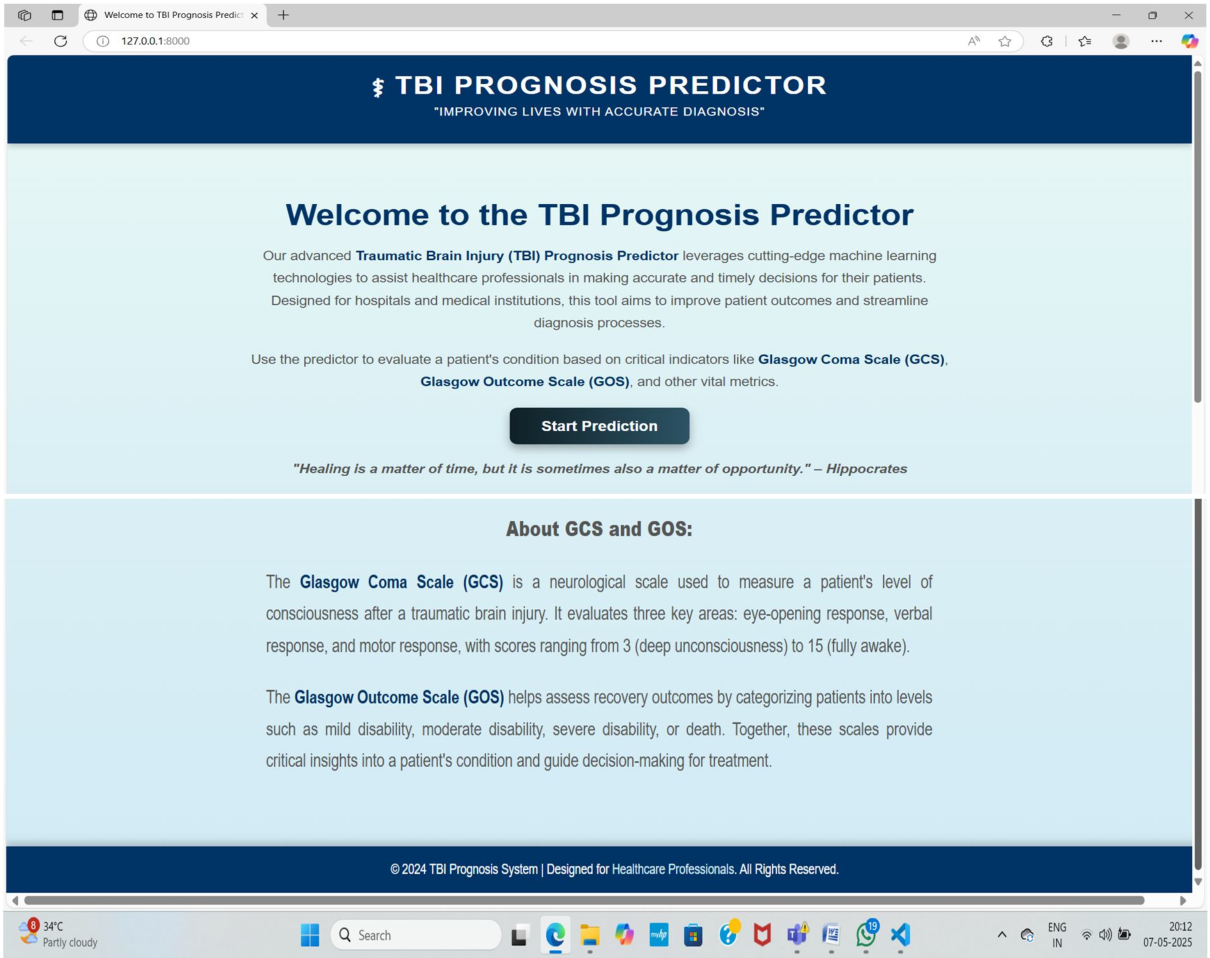

Figure 1: Home Page

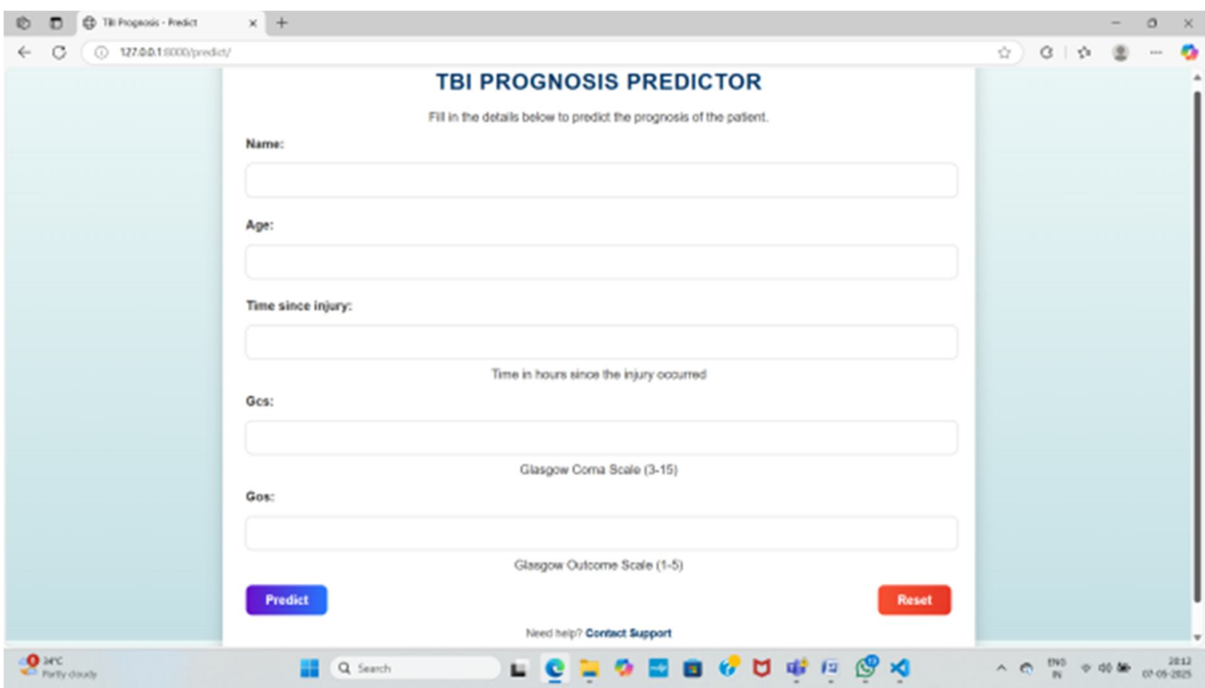

Figure 2: Input Page

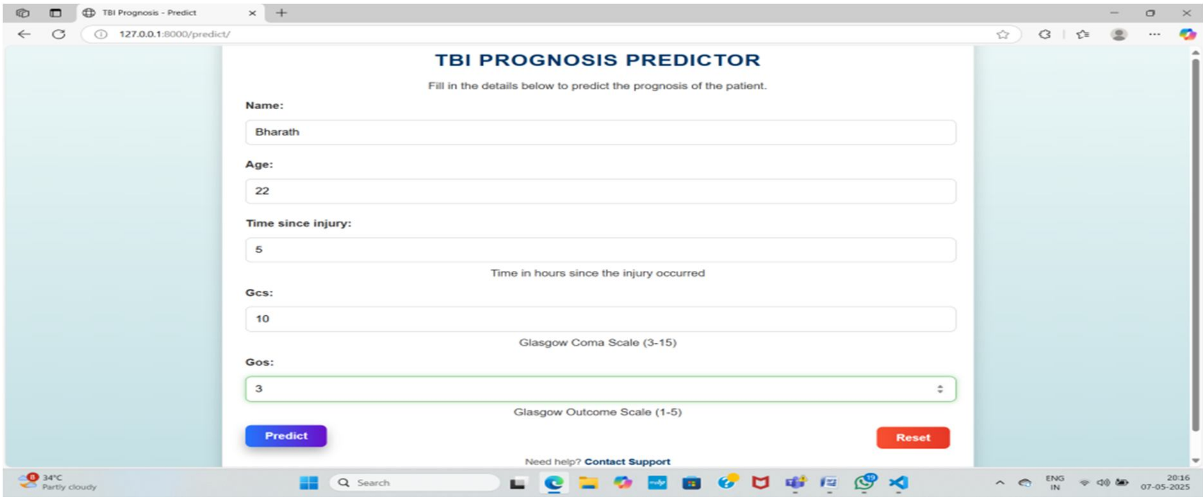

Figure 3: First Input Page

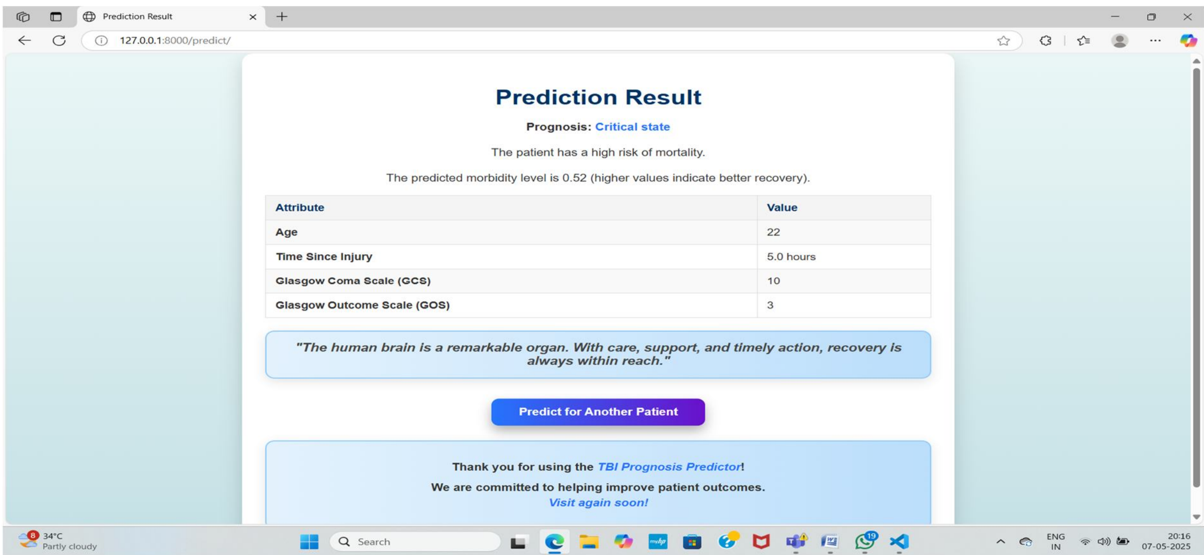

Figure 4: Output Page according to the First Input

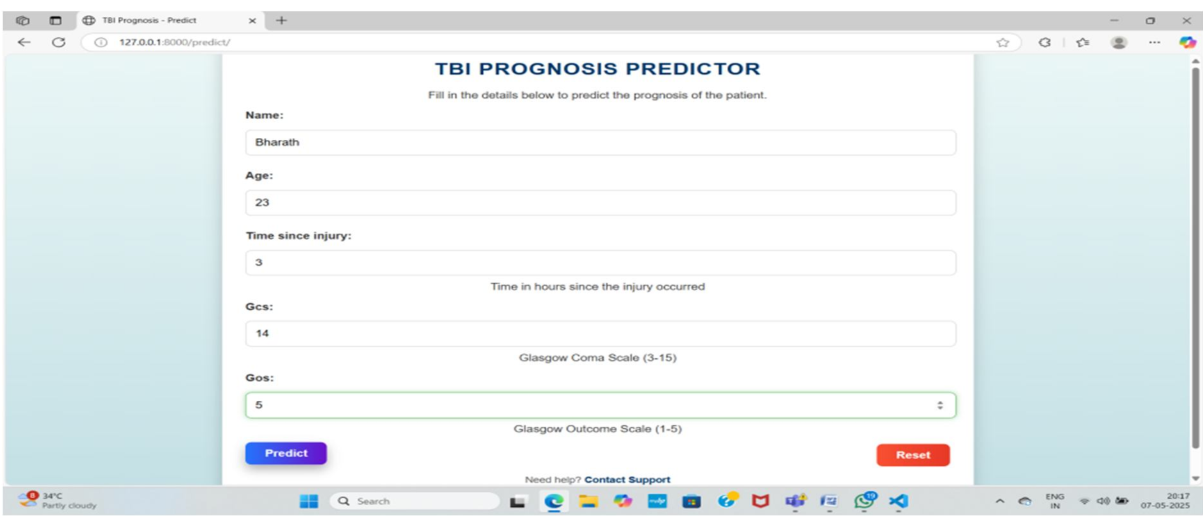

Figure 5: Second Input Page

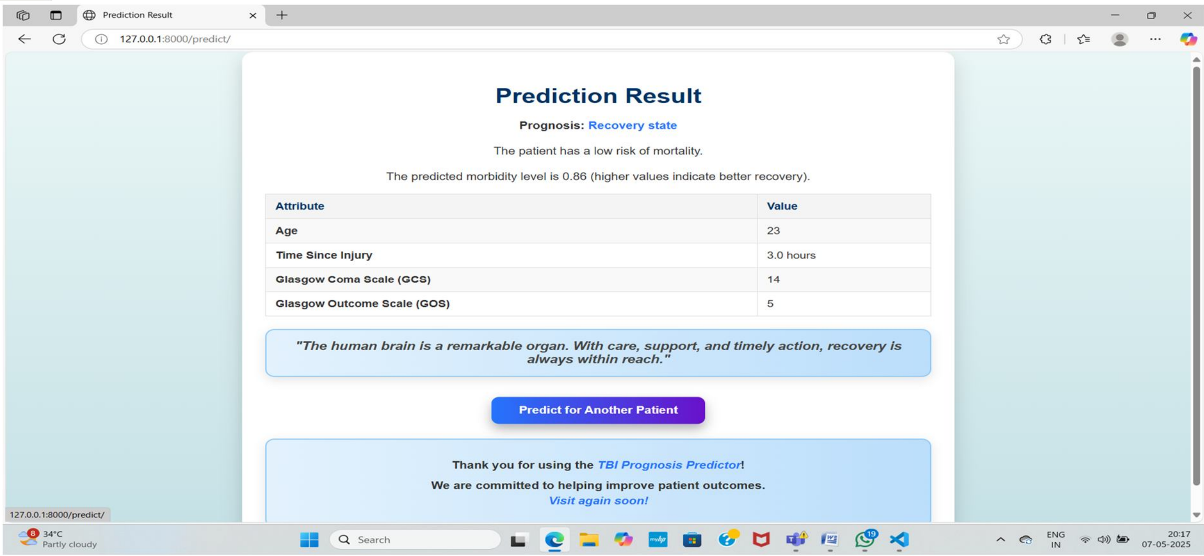

Figure 6: Output Page according to the Second Input

VI. CONCLUSION

This project develops a machine learning-based system to predict the outcomes of Traumatic Brain Injury (TBI) patients, specifically tailored to the Indian demographic. By leveraging clinical indicators such as age, time since injury, Glasgow Coma Scale (GCS), and Glasgow Outcome Scale (GOS), the system uses a Random Forest Classifier for mortality prediction and a Random Forest Regressor for morbidity estimation. The models, trained on simulated data, are integrated into a user-friendly web-based platform that provides real-time, data-driven predictions to healthcare professionals, enhancing diagnostic accuracy and supporting faster clinical decision-making. The proposed system addresses the lack of region-specific predictive tools for TBI prognosis, particularly in resource-constrained settings like India. It provides healthcare providers with a reliable, automated tool that reduces dependency on subjective judgment and helps make timely decisions that can significantly improve patient outcomes. This project highlights the potential of machine learning to transform clinical practices, and future work can enhance the system by incorporating real-world data, expanding predictive features, and integrating additional metrics like neuroimaging data. Ultimately, it contributes to the growing intersection of AI and healthcare, with the potential to improve both patient care and the efficiency of trauma management.

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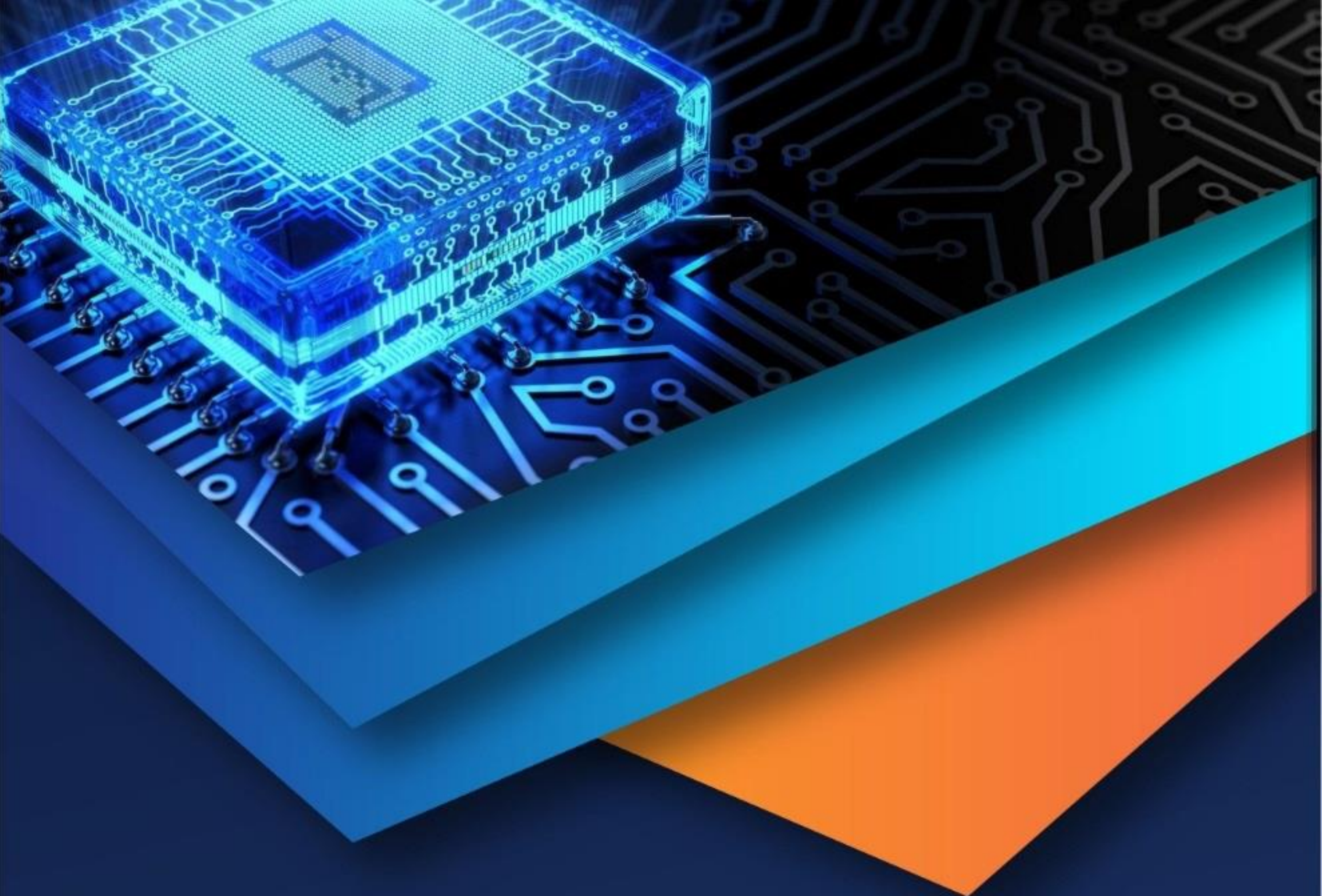

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