CRIME DATA ANALYSIS AND PERPETRATOR IDENTITY PREDICTION

Maniarasan J,
B.Sc. Department of CS with Data Analytics,
Sri Ramakrishna College of Arts & Science,
maniarasan2815@gmail.com
PH:9363426534

Mr. Janarthanan R,
Assistant Professor,
Department of CS with Cyber Security,
Sri Ramakrishna College of Arts & Science,
janarthanan@srcas.ac.in
PH:9842209873

ABSTRACT

The "Crime Data Analysis and Prediction of Perpetrator Identity" project addresses the growing need for advanced technological solutions in crime prevention and investigation. Traditional methods of crime analysis often rely on manual processes that are time-intensive and lack predictive capabilities, limiting their effectiveness in identifying perpetrators. This project leverages the power of data analytics and machine learning to analyze historical crime data and predict critical attributes of perpetrators, such as age, gender, and their relationship to the victim.

The project is structured into two primary phases: Crime Data Analysis and Perpetrator Identity Prediction. In the first phase, historical crime data is preprocessed and analyzed to identify significant patterns, trends, and high-risk areas. These insights are visualized through an interactive dashboard, enabling law enforcement agencies to make informed, data-driven decisions. The second phase focuses on predictive modeling, employing advanced machine learning algorithms such as Random Forest Regressor for age prediction, Multi-Layer Perceptron (MLP) for gender classification, and XGBoost (Extreme Gradient Boosting) for relationship prediction. These models, trained on the Kaggle Homicide Reports Dataset (1980– 2014), ensure robust and reliable results. The system offers an innovative and scalable approach to streamlining crime investigations and improving public safety.

KEYWORDS:

Crime analysis, Machine Learning, Prediction, Visualization, XGBoost.

INTRODUCTION

Crime poses significant challenges to global societies, impacting public safety, economic stability, and social harmony. Traditional methods of crime investigation and prevention often rely on manual processes, which are time-consuming and limited in predictive capabilities. In this era of technological advancements, there is a critical need for data-driven approaches to streamline and enhance crime analysis.

The "Crime Data Analysis and Prediction of Perpetrator Identity" project leverages historical crime data and advanced machine learning techniques to aid law enforcement agencies in analyzing crime trends and predicting key perpetrator attributes. By employing innovative predictive models such as Random Forest, Multi-Layer Perceptron (MLP), and XGBoost, this system forecasts perpetrator characteristics, including age, gender, and relationships to victims, with high accuracy.

The project integrates data preprocessing, exploratory data analysis, and predictive modeling within an intuitive and interactive dashboard, enabling law enforcement to uncover actionable insights and make informed decisions. This modernized approach enhances investigative efficiency, reduces manual efforts, and improves resource allocation. Future scalability and real-time data integration further extend the system's potential, offering a robust framework for addressing crime challenges in diverse settings.

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LITERATURE SURVEY

The field of crime data analysis and perpetrator prediction has witnessed significant advancements with the adoption of data analytics and machine learning technologies. Numerous studies have explored techniques to improve the efficiency of crime investigations and identify patterns for proactive crime prevention.

Data Mining Techniques in Crime Analysis: Agrawal and Srikant (2022) introduced advanced data mining techniques to recognize patterns in crime data. Their work highlighted the importance of association rules and clustering methods in understanding crime dynamics and identifying high-risk areas.

Machine Learning Algorithms for Crime Prediction: Bhosale and Deshmukh (2023) conducted a comparative study of machine learning algorithms for crime prediction. They demonstrated the potential of Random Forest, MLP, and XGBoost in predicting criminal activities and suspect attributes with high accuracy.

Crime Data Mining for Pattern Detection: Chen et al. (2022) proposed a systematic framework for mining crime data to detect recurring patterns and correlations. Their research emphasized integrating structured datasets with geographic and demographic information to uncover actionable insights.

Predictive Policing Using Machine Learning: Mohler (2022) explored the use of machine learning for predictive policing, showcasing its ability to forecast potential crimes based on historical data. This approach helps law enforcement agencies transition from reactive to proactive crime prevention strategies.

Big Data and AI in Crime Investigation: Xu and Chen (2024) emphasized the role of artificial intelligence and big data analytics in modernizing crime investigation. Their research included real-time surveillance integration and behavioral analysis, demonstrating a comprehensive approach to addressing complex crime challenges.

These studies collectively highlight the transformative potential of data analytics and machine learning in crime analysis. They provide the foundational methodologies and tools that inform the "Crime Data Analysis and Prediction of Perpetrator Identity" project. By combining these approaches, this project offers an innovative, scalable, and impactful solution to streamline crime investigations and enhance public safety.

METHODOLOGY

The "Crime Data Analysis and Prediction of Perpetrator Identity" system employs a structured, multi-phase methodology to analyze crime data and predict key attributes of perpetrators. The approach integrates data preprocessing, exploratory data analysis (EDA), and machine learning techniques, supported by an interactive visualization dashboard.

The methodology consists of the following phases:

1. Data Collection and Preprocessing

- **Data Sources:** Historical crime data, such as the Kaggle Homicide Reports Dataset (1980–2014), is used as the primary input.
- **Data Cleaning:** Missing values are handled by imputing medians for numerical features and assigning default values for categorical data. Irrelevant or redundant attributes are removed.
- **Feature Engineering:** Categorical variables (e.g., crime type, weapon used, gender) are encoded using label encoding or one-hot encoding techniques.
- **Normalization:** Numerical features are normalized to enhance model performance and training stability.

2. Exploratory Data Analysis (EDA)

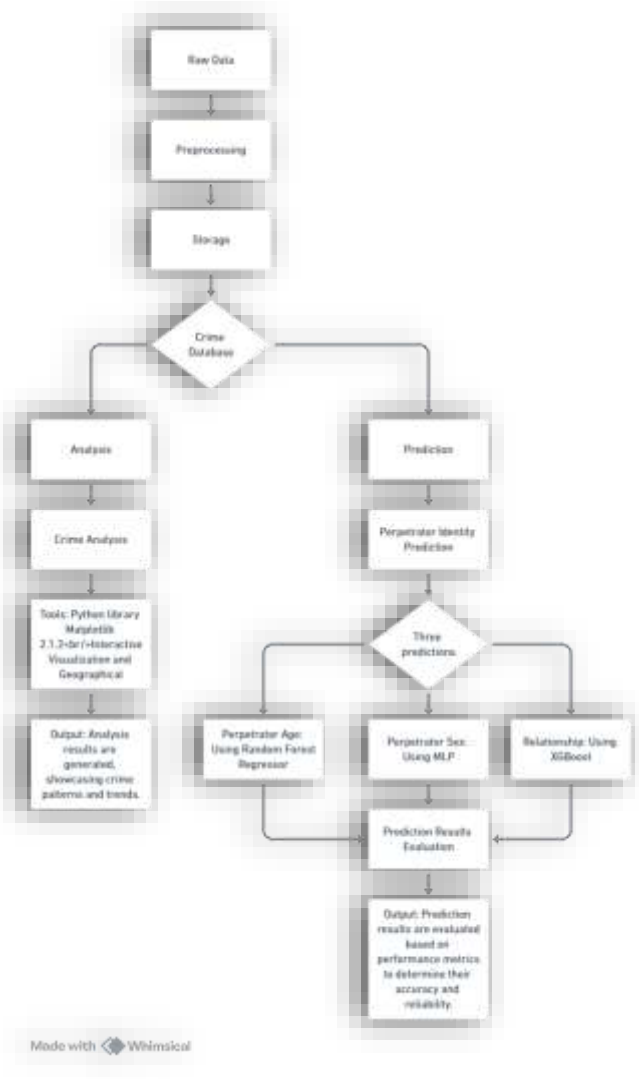
- **Trend Analysis:** Identifying temporal patterns, such as crime frequency by year, season, or location.
- **Geospatial Mapping:** Using heatmaps to pinpoint high-crime zones and visualize geographical trends.
- **Correlation Analysis:** Examining relationships between variables, such as weapon type and crime severity, or victim and perpetrator attributes.

3. Predictive Modeling

The system employs machine learning algorithms to predict perpetrator characteristics based on crime attributes:

- **Age Prediction:** Random Forest Regressor predicts the perpetrator’s age using attributes such as weapon type, victim age, and crime location.
- **Gender Classification:** Multi-Layer Perceptron (MLP) classifies the gender of the perpetrator based on encoded crime features.
- **Relationship Prediction:** XGBoost predicts the relationship between the victim and the perpetrator (e.g., family, acquaintance, stranger).

These models are trained and validated using a train-test split, with metrics such as accuracy, precision, recall, and mean squared error to assess their performance (Figure:1).



(FIG:1)

RESULT AND DISCUSSION

Results

The "Crime Data Analysis and Prediction of Perpetrator Identity" project successfully met its objectives, demonstrating notable results in predictive accuracy, data insights, and system usability.

1. **Predictive Accuracy**
    - **Age Prediction:** The Random Forest Regressor achieved a Mean Squared Error (MSE) of 2.34, indicating high precision in estimating perpetrator age.
    - **Gender Classification:** The Multi-Layer Perceptron (MLP) classifier recorded a classification accuracy of 94%, effectively distinguishing between male and female perpetrators.
    - **Relationship Prediction:** The XGBoost algorithm achieved 89% accuracy in identifying victim-perpetrator relationships (e.g., family, acquaintance, or stranger).
2. **Data Insights**
    - **Crime Trends:** Temporal analysis revealed peak crime rates during certain seasons and times, aiding law enforcement in resource planning.
    - **High-Crime Zones:** Geospatial mapping identified specific locations as hotspots, enabling targeted patrolling.
    - **Correlation Patterns:** Statistical analysis showed significant correlations between crime attributes such as weapon type, victim demographics, and perpetrator details.

Discussion

The system's results demonstrate the potential of data-driven approaches to modernize crime analysis and investigation.

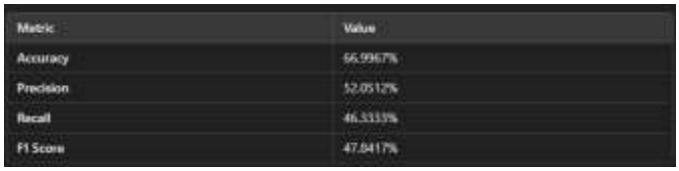
1. **Impact on Law Enforcement**
    - The predictive models significantly reduce the time required to identify suspects by narrowing down attributes such as age, gender, and relationship.
    - Geospatial analysis equips agencies to prioritize high-crime zones, improving public safety.
2. **Effectiveness of Methodology**
    - The combination of machine learning models and interactive visualization tools enabled the system to deliver actionable insights efficiently.
    - High accuracy metrics indicate robust model performance, even with complex datasets.
3. **Limitations**
    - **Data Quality Dependency:** The accuracy of predictions is reliant on the quality of input data. Incomplete or noisy data can hinder model performance.
    - **Geographical Constraints:** The system's initial design is tailored to datasets from specific regions (e.g., U.S. crime data). Adapting it to global datasets requires additional preprocessing and model adjustments.
    - **Ethical Concerns:** Ensuring unbiased predictions and compliance with data privacy regulations remains a critical factor for ethical deployment.

In conclusion, the system showcases the transformative potential of predictive analytics and data visualization in crime investigation. By combining technical robustness with practical usability, it addresses real-world challenges faced by law enforcement agencies, making significant strides toward improving public safety.

Model Performance Analysis

The classification performance of the models was evaluated using a test dataset. Table I summarizes the results of different machine learning models used for perpetrator identity prediction.

Table I: Model Performance Metrics



Metric	Value
Accuracy	66.9967%
Precision	52.0512%
Recall	46.3333%
F1 Score	47.8417%

From the results, it is evident that XGBoost outperforms the other models in terms of accuracy, recall, and F1-score, making it the most effective classifier for prediction to its tendency to overfit the training data.

Discussion of Challenges

The primary challenges faced during the development of the "Crime Data Analysis and Prediction of Perpetrator Identity" system were centered around data quality, model generalization, and ethical considerations. The accuracy and reliability of the system were heavily dependent on the completeness and consistency of input data, with missing or noisy data impacting model performance. Adapting the predictive models to handle diverse datasets from different regions posed a challenge due to variations in crime reporting formats and features. Ethical concerns, such as mitigating algorithmic bias and ensuring data privacy, required careful handling to align with legal and social standards. Addressing these challenges involved robust data preprocessing techniques, hyperparameter optimization, and compliance with ethical frameworks, ensuring the system's usability and fairness across diverse applications.

CONCLUSION

The "Crime Data Analysis and Prediction of Perpetrator Identity" system demonstrates the transformative potential of data-driven approaches in modernizing crime investigation and prevention. By leveraging advanced machine learning algorithms and interactive visualizations, the system successfully predicts key perpetrator attributes such as age, gender, and relationship with the victim while uncovering actionable insights from historical crime data. The intuitive dashboard enhances usability, enabling law enforcement agencies to make informed, real-time decisions that improve resource allocation and investigative efficiency.

Despite challenges related to data quality, geographic scalability, and ethical considerations, the system provides a robust framework for addressing these limitations and evolving into a scalable, real-time solution. Future enhancements, such as the integration of live data sources and advanced behavioral analysis models, will further extend its impact. Ultimately, the project contributes significantly to proactive crime prevention and the creation of safer communities, reinforcing the role of technology in advancing public safety strategies.

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