



International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 2(1) (2026)



**ijerst.editor@gmail.com
editor@ijerst.com**

Research Paper

URBAN CRIME INCIDENT TYPE CLASSIFICATION USING SPATIO-TEMPORAL AND CONTEXTUAL ATTRIBUTES

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Abstract

Urban areas are increasingly facing diverse crime incidents that significantly impact public safety and urban management. Effective classification and analysis of such incidents are crucial for improving law enforcement strategies and reducing crime rates. This project, titled “Urban Crime Incident Type Classification Using Spatio-Temporal and Contextual Attributes,” aims to develop an intelligent system capable of automatically classifying crime types based on multiple influencing factors.

The proposed approach utilizes historical crime data by integrating spatial attributes (such as location, latitude, longitude, and region), temporal attributes (including time, day, and month of occurrence), and contextual attributes (such as environmental and surrounding conditions). By combining these dimensions, the system identifies meaningful patterns and relationships associated with different types of crimes.

Various machine learning algorithms are employed to train classification models that categorize crime incidents into types such as theft, robbery, assault, and burglary. Data preprocessing techniques—including data cleaning, feature extraction, and normalization—are applied to enhance data quality and improve model performance. The models are evaluated using standard metrics such as accuracy, precision, recall, and F1-score to determine the most effective approach.

I. Introduction

Crime is a major challenge faced by modern urban societies, significantly affecting public safety, economic stability, and overall quality of life. With rapid urbanization and population growth, cities are experiencing a steady increase in various types of crimes such as theft, robbery, assault, burglary, and vandalism. These incidents not only pose risks to individuals but also hinder the sustainable development and security of urban environments.

Law enforcement agencies continuously collect large volumes of crime-related data, including details such as location, time, date, and other contextual information. While this data holds valuable insights, manually analyzing such large and complex datasets is both time-consuming and inefficient. Traditional crime analysis methods, which rely mainly on basic statistical techniques, often fail to capture the complex relationships between different factors influencing crime.

In recent years, advancements in machine learning and data mining have provided powerful tools for analyzing large datasets and extracting meaningful patterns. These techniques enable automated classification and prediction by learning from historical data. In the context of crime analysis, machine learning models can be used to classify crime incidents and uncover patterns related to specific locations, time periods, and other influencing factors.

II. Literature Survey

Urban crime analysis has become a critical area of research due to the increasing complexity and frequency of criminal activities in modern cities. With rapid urbanization, traditional methods of crime analysis—such as manual reporting and basic statistical techniques—have proven insufficient in identifying hidden patterns and relationships among crime incidents. These conventional approaches often fail to effectively analyze the interactions between various factors such as location, time, and environmental conditions. As a result, there has been a growing need for data-driven techniques that can provide deeper insights and support better decision-making for law enforcement agencies.

Recent studies have highlighted the importance of spatio-temporal analysis in understanding crime patterns. Spatial attributes, including geographic location and crime hotspots, combined with temporal attributes such as time of day, day of the week, and season, help in identifying when and where crimes are most likely to occur. Researchers have applied techniques such as clustering algorithms (e.g., K-Means), hotspot analysis, and spatial autocorrelation to detect high-risk areas and analyze crime distributions across different regions and time periods.

In addition to spatio-temporal factors, contextual attributes have also been widely explored to enhance crime classification accuracy. These include socio-economic conditions, demographic information, environmental factors, and proximity to important locations such as schools, markets, and commercial areas. Studies indicate that integrating contextual information with spatial and temporal data significantly improves the performance of classification models and provides a more comprehensive understanding of crime behavior.

Machine learning and data mining techniques have played a major role in advancing crime analysis. Algorithms such as Decision Trees, Random Forest, Support Vector Machines (SVM), and Neural Networks have been widely used to classify crime types based on historical data. Among these, Random Forest models have demonstrated strong performance due to their ability to handle large datasets and capture complex relationships between features. Furthermore, several research works have focused on developing predictive models and decision support systems that can forecast crime occurrences and assist law enforcement agencies in resource allocation and strategic planning.

III. System Analysis

System analysis focuses on understanding the requirements and challenges involved in urban crime classification. The system needs to process large volumes of crime data collected from various sources. This data includes spatial, temporal, and

contextual attributes that influence crime patterns. The analysis identifies the need for automated methods instead of manual analysis. It examines how machine learning techniques can be used to classify crime incidents efficiently. Data preprocessing requirements such as cleaning and normalization are also considered. The system must ensure accuracy, scalability, and efficiency in handling datasets. Performance evaluation metrics like accuracy and recall are important in analysis. The system should provide meaningful insights for decision-making. Overall, system analysis helps in designing an effective crime classification solution.

Existing System

The existing system for crime analysis mainly relies on traditional methods and manual data interpretation. Law enforcement agencies use basic statistical techniques to analyze crime data. Crime reports are often studied individually without automation. These systems primarily focus on simple data visualization and reporting. Most approaches consider limited attributes such as location or time separately. There is minimal use of advanced machine learning algorithms. Data processing is often slow and inefficient due to manual involvement. Existing systems lack the ability to handle large-scale datasets effectively. They do not provide accurate classification of crime types. As a result, decision-making is often based on incomplete or less reliable information.

Disadvantages of Existing System

- Relies heavily on manual processing
- Time-consuming and prone to human errors
- Traditional statistical methods fail to capture complex relationships
- Does not effectively integrate spatial, temporal, and contextual data
- Lacks automation in data analysis
- Not scalable for handling large datasets
- Low accuracy in crime prediction and classification
- No support for real-time analysis or insights

Proposed System

The proposed system introduces a machine learning-based approach for crime classification. It uses spatio-temporal and contextual attributes to analyze crime data effectively. The system collects and preprocesses historical crime datasets for better performance. Techniques such as data cleaning, feature extraction, and normalization are applied. Machine learning algorithms like Logistic Regression are used for classification. The system can automatically classify crime types such as theft, robbery, and assault. It analyzes patterns across different locations and time periods. Performance is evaluated using metrics like accuracy, precision, recall, and F1-score. The system is designed to handle large datasets efficiently. It supports data-driven decision-making for law enforcement agencies.

Advantages of Proposed System

- Automates the crime classification process
- Reduces manual effort and saves time

- Improves accuracy using machine learning techniques
- Integrates spatial, temporal, and contextual attributes effectively
- Efficiently processes large datasets
- Identifies hidden patterns and trends in crime data
- Provides better insights for decision-making
- Supports real-time or near real-time analysis

IV. Methodology

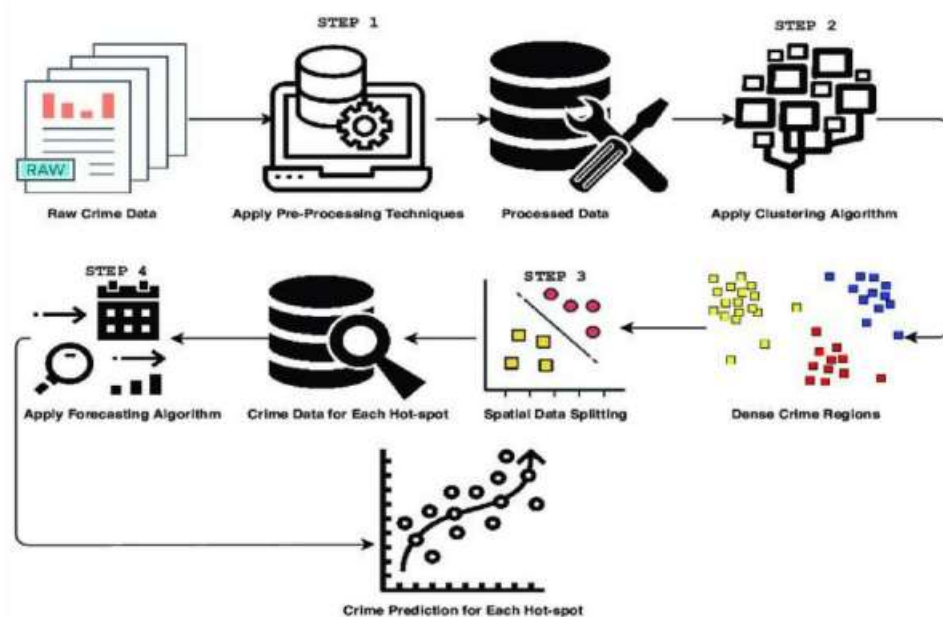
The methodology of the proposed system focuses on developing an efficient machine learning model to classify urban crime incidents using spatio-temporal and contextual attributes. The process begins with data collection, where historical crime datasets are gathered from reliable sources containing information such as location, time, and crime type.

Next, data preprocessing is performed to improve data quality. This includes handling missing values, removing duplicates, encoding categorical variables, and normalizing the data. Clean and well-structured data is essential for accurate model performance.

After preprocessing, feature selection and extraction are carried out. Relevant features such as latitude, longitude, time, day, month, and contextual factors are selected to represent the dataset effectively. This step helps in reducing complexity and improving model efficiency.

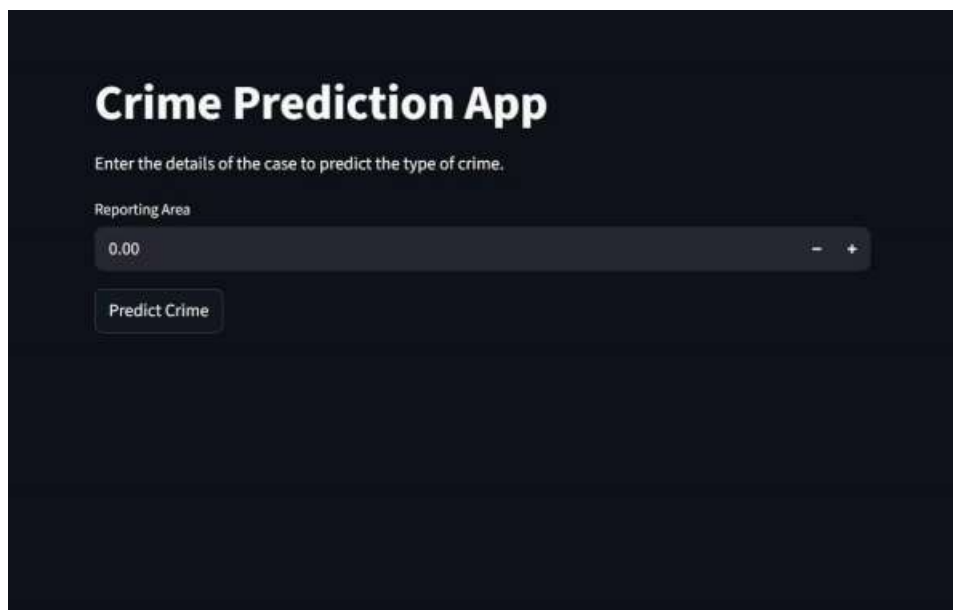
The next stage involves model selection and training, where machine learning algorithms such as Logistic Regression (or Random Forest if used) are applied. The dataset is divided into training and testing sets, and the model is trained using historical data.

System Architecture



The system architecture for urban crime incident classification is designed as a multi-layered structure that efficiently processes and analyzes crime data using machine learning techniques. The architecture begins with the data source layer, where historical crime data is collected, including spatial attributes (location, latitude, longitude), temporal attributes (time, day, month), and contextual information. This data is then passed to the data preprocessing layer, where it is cleaned, normalized, and transformed into a suitable format by handling missing values and removing inconsistencies. Next, the feature engineering layer extracts and selects relevant attributes to improve model performance and reduce complexity. The processed data is then fed into the machine learning layer, where classification algorithms such as Logistic Regression are applied to train the model and predict crime types. After training, the evaluation layer assesses the model's performance using metrics like accuracy, precision, recall, and F1-score to ensure reliability. Finally, the prediction and output layer generates classified results and presents them through reports or visual dashboards. An optional user interface layer allows users, such as law enforcement agencies, to interact with the system and gain insights for better decision-making.

V. Result and Output



VI. Conclusion

This project presents an effective approach for classifying urban crime incidents using spatio-temporal and contextual attributes combined with machine learning techniques. By integrating location-based, time-based, and environmental factors, the system is able to identify meaningful patterns and relationships within crime data. The use of data preprocessing, feature engineering, and classification algorithms improves the overall accuracy and efficiency of crime analysis compared to traditional methods.

The developed model successfully classifies different types of crimes such as theft, robbery, and assault, and evaluates performance using standard metrics like accuracy, precision, recall, and F1-score. The results demonstrate that incorporating multiple

attributes leads to better prediction and understanding of crime patterns across different regions and time periods.

This system can assist law enforcement agencies and city administrators in making data-driven decisions, optimizing resource allocation, and implementing proactive crime prevention strategies. Furthermore, it contributes to the development of smart city solutions aimed at improving public safety and urban management. Future enhancements can include the use of advanced deep learning models, real-time data integration, and larger datasets to further improve system performance and scalability.

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