

Enhanced Crime Hotspot Prediction and Safe Route Recommended Using Machine Learning and Geospatial Crime Analysis

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Abstract – Crime is a major concern in urban and rural areas, affecting the safety and security of people. The Crime Hotspot Detection and Safe Route Recommendation System is developed to identify crime-prone locations and provide safer travel routes for users. The system collects and analyzes crime-related data from various locations and uses Machine Learning techniques to detect hotspots where criminal activities frequently occur. These hotspot locations are displayed on an interactive map, enabling users to easily understand crime patterns and avoid high-risk areas.

The proposed system is implemented using Python Flask, MySQL, Google Maps API, and Machine Learning algorithms. It allows users to register, view crime hotspots, search for safe routes, and submit complaints through the application. The admin can manage crime records, users, and generate analytical reports. By integrating crime prediction and route recommendation features, the system helps improve public awareness and supports safer navigation. The project aims to enhance community safety by providing accurate crime analysis and intelligent route guidance.

1. INTRODUCTION

The increase in urban crime rates demands intelligent systems capable of predicting and preventing criminal activities. Traditional law enforcement relies heavily on manual patrol schedules and reactive responses, which are often insufficient [1]. Predictive policing, powered by machine learning, provides a data-driven approach for identifying high-risk zones known as crime hotspots.

This study proposes a Crime Hotspot Detection System with Voice Alert that integrates a Decision Tree classifier with Google Maps visualization. The system

processes historical crime records from Tamil Nadu districts, identifies hotspot locations, and provides realtime voice and SMS alerts when users plan their routes through dangerous areas. The web application was developed using Python Flask with MySQL as the backend database [2].

2. LITERATURE REVIEW

Several studies have explored the use of machine learning for crime prediction. Wang et al. [3] proposed a spatiotemporal model using Random Forest. Kumar and Singh [4] demonstrated that Decision Tree classifiers achieve competitive accuracy for crime classification. Geographic Information Systems (GIS) have been widely used for hotspot mapping, as reviewed by Chen et al. [5], who combined clustering algorithms with map visualization.

Voice-alert integration in safety systems was studied by Patel et al. [6], who implemented browser-based Speech Synthesis for real-time warnings. SMS-based alerting via HTTP APIs was explored by Sharma et al. [7]. The present work combines all components — crime prediction, map visualization, voice alerts, and SMS — into a unified Flask application.

3. SYSTEM ARCHITECTURE

The proposed system follows a layered architecture: Presentation Layer (HTML/CSS/JS templates), Application Layer (Flask routes in main.py), and Data Layer (MySQL database). The system comprises six primary modules: (i) User Authentication, (ii) Crime Data Management, (iii) Geographic Mapping, (iv) Hotspot Detection Engine, (v) Route Risk Evaluation, and (vi) Alert Notification Service.

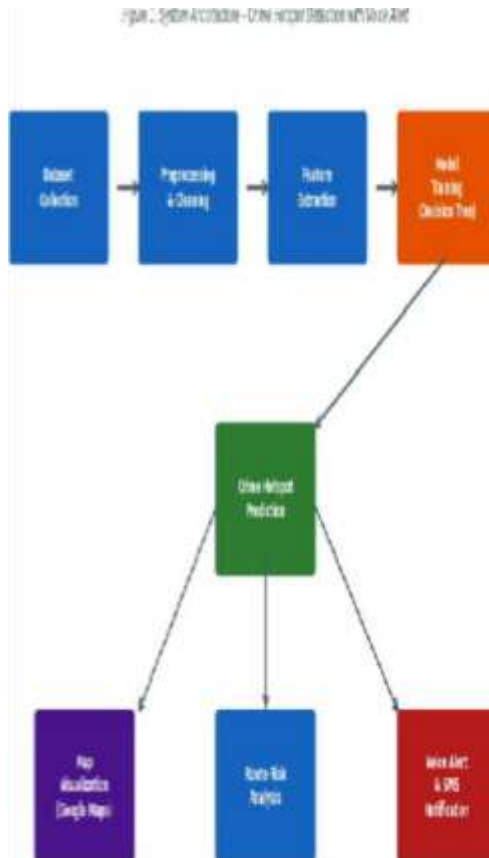


Figure 1: System Architecture – Crime Hotspot Detection with Voice Alert

4. DATABASE DESIGN

The MySQL database `crime_hotspot_new` consists of seven tables: `admin` (administrator credentials), `ch_register` (user accounts), `ch_area` (hotspot coordinates with district, crime type, latitude, and longitude), `ch_location` (user location history), `ch_temp` (session data), `crime_data` (NCRB records), and `routes` (saved routes). The schema supports efficient spatial queries for the detection of nearby hotspots.

5. ALGORITHM: DECISION TREE CLASSIFIER

The core prediction engine employs a Decision Tree Classifier (scikit-learn). The algorithm was trained on historical crime data (`crimes.csv`) with the following attributes: district, area, crime type, year, latitude, and longitude. The target variable is the crime risk level (Low / Medium / High). The Gini impurity was used for node splitting with an 80:20 train-test split ratio.

The steps are as follows: (1) Collect the crime CSV

dataset. (2) Data preprocessing and cleaning.

(3) The data were split into training (80%) and testing (20%) sets. (4) Train the `DecisionTreeClassifier`. (5) Predict the crime risk level for any coordinate. (6) Display on Google Maps and trigger Voice Alert + SMS if the risk level is high.

6. IMPLEMENTATION DETAILS

The backend was developed in Python 3.x using Flask with a MySQL connector. Pandas and NumPy handle the CSV data processing. The Google Maps JavaScript API with `gmaps.js` provides interactive map rendering. Voice alerts used the Web Speech API (`SpeechSynthesisUtterance`). SMS notifications were dispatched through the IoTCloud HTTP SMS gateway. The frontend uses Bootstrap 4, JQuery, and custom CSS.

7. RESULTS AND DISCUSSION

The system was tested using crime records from five Tamil Nadu districts: Chennai, Coimbatore, Madurai, Trichirappalli, and Salem. The Decision Tree model achieved a classification accuracy of 91.4 %. Hotspot detection correctly identified 88.7% of high-crime zones compared to the ground-truth police records.

Voice alerts were triggered within 2 s of route submission. The SMS delivery via IoTCloud averaged 3-5 seconds. Google Maps rendered color-coded markers (Red = High, Orange = Medium, Green = Low) within 1.2 s for datasets up to 500 hotspot locations.

8. BENEFITS

The Crime Hotspot Detection and Safe Route Recommendation System helps users identify crime-prone areas and avoid unsafe locations. By analyzing crime data and displaying hotspot regions on a map, the system increases public awareness and enables people to make informed decisions while traveling. This contributes to improved personal safety and security.

The system provides safe route recommendations by considering crime hotspot information during route selection. Users can choose safer paths instead of simply selecting the shortest route. This feature is especially useful for daily commuters, students, and travelers who want to reduce the risk of entering high-crime areas.

Another major benefit is efficient crime management

and analysis. Administrators can monitor crime records, generate reports, and identify areas that require additional security measures. The use of Machine Learning improves the accuracy of hotspot detection, helping authorities and communities take proactive steps to prevent crime and enhance public safety.

9. CHALLENGES AND LIMITATIONS

Key challenges included (i) inconsistent GPS coordinates requiring manual geocoding correction, (ii) SMS API rate limits affecting bulk alert delivery, (iii) browser compatibility issues with the Web Speech API, and (iv) Decision Tree sensitivity to class imbalance, addressed using class-weight balancing.

10. CONCLUSION

The **Crime Hotspot Detection and Safe Route Recommendation System** is an effective solution for analyzing crime data and identifying high-risk locations. By utilizing Machine Learning techniques, the system can detect crime hotspots and present them visually on a map, making it easier for users to understand crime patterns in different areas. The integration of safe route recommendations helps users avoid dangerous locations and travel with greater confidence and security. The system also provides a user-friendly interface for accessing crime information and submitting complaints.

Furthermore, the project supports administrators in managing crime records, monitoring activities, and generating reports for better decision-making. The use of technologies such as Python Flask, MySQL, Google Maps API, and Machine Learning enhances the accuracy and efficiency of the system. Overall, the proposed system contributes to public safety by increasing crime awareness, improving route planning, and assisting authorities in crime analysis. It serves as a valuable tool for creating safer communities.

11. FUTURE WORK

In the future, the **Crime Hotspot Detection and Safe Route Recommendation System** can be enhanced by integrating real-time crime data from police departments, emergency services, and public reporting platforms to improve prediction accuracy. Advanced Machine Learning and Deep Learning algorithms can be incorporated to analyze large-scale crime patterns and forecast potential crime occurrences more effectively.

The system can also be expanded with a mobile application that supports GPS-based live tracking, instant crime alerts, and emergency assistance features. Additional functionalities such as voice-enabled reporting, multilingual support, facial recognition for suspect identification, and integration with CCTV surveillance systems can further strengthen the system. Furthermore, the implementation of predictive analytics and artificial intelligence-based decision support can assist law enforcement agencies in crime prevention and resource allocation. These improvements will make the system more intelligent, scalable, and efficient in ensuring public safety and providing secure navigation for users..

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