International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Enhanced Crime Hotspot Prediction and Visualization for Women's Safety Through Deep Learning

[1]Mr. S. Balaji, [2]Mrs. M. Sughasini, [3]Salla. Dimple, [4]A. Vainavi

[1 2] Department of CSE, Kingston Engineering College, Assistant Professor

[3 4]Department of CSE, Kingston Engineering College, Student

ABSTRACT:

Crime hotspots, regions with heightened criminal activity, disproportionately endanger women, exposing them to risks such as sexual harassment, assault, domestic violence, stalking, and trafficking. Pinpointing these areas is vital for strategic crime prevention and efficient resource deployment by law enforcement. This project introduces PredictSafe an advanced system leveraging multimodal deep learning to detect and visualize crime hotspots critical to women's safety. Employing the isolation forest model, the system processes historical crime data—encompassing crime types, temporal patterns, and geographic coordinates—to forecast high-risk zones with precision. These zones are dynamically mapped using Google Maps, offering an accessible visualization for public awareness and safety planning. The development pipeline includes rigorous data preprocessing, feature engineering, model training, and hyperparameter optimization via cross-validation, with performance evaluated through metrics such as accuracy, precision, recall, and F1-score. Safety Locator empowers law enforcement with actionable insights for targeted interventions while fostering safer environments for women, advancing gender equity and community well-being through innovative technology

Introduction:

Crimes targeting women, encompassing sexual violence, human trafficking, dowry related coercion, physical assault, workplace harassment, and other exploitative acts, pose a severe threat to societal well-being. In India, incidents such as rape, molestation, acid attacks, and abductions persist, compounded by workplace discrimination and domestic abuse. These issues are often exacerbated by systemic challenges, including the misuse of power and wealth to shield perpetrators, as well as divisive politics rooted in caste or religious affiliations. Crimes against women in India continue to be a major impediment to social progress and gender equality. According to the National Crime Records Bureau (NCRB), reported crimes against women increased by 4% in 2022, totaling 4,45,256 cases—equivalent to almost 51 instances per hour. The most common offenses were cruelty by husbands or relatives (31.4%), kidnapping and abduction (19.2%), assault with intent to insult modesty (18.7%), and rape (7.1%). Deeply entrenched gender-based discrimination and societal norms perpetuate violence against women, despite India's cultural reverence for female deities. This paradox highlights the need for a transformative shift to foster respect and equity for women. Central to this effort is the identification of crime hotspots—geographic areas with elevated criminal activity, such as urban centres, commercial zones, or residential neighbourhoods. These hotspots, visualized through mapping techniques, enable researchers and law enforcement to analyse spatial crime patterns and deploy targeted interventions. The Safety Locator system addresses this challenge by leveraging advanced machine learning to predict and map high-risk areas, empowering women and authorities to enhance safety and promote gender justice.

Literature Review:

The development of crime hotspot prediction systems, especially those focused on women's safety, has gained significant attention in recent years due to rising concerns about gender-based violence and the need for data-driven public safety solutions. This literature review examines the evolution of research in crime prediction and visualization, with a particular emphasis on methodologies, tools, and gaps relevant to the PredictSafe system. The analysis is based on a systematic review of publications from 2020 to 2024, sourced primarily from IEEE Xplore and Scopus databases, which are renowned for their coverage of technical and computational research. The review includes a pre-analysis of initially collected studies and a post-analysis of selected papers after applying relevance criteria, focusing on machine learning approaches, geospatial visualization, and real-time notification systems for crime prevention.

Several studies have explored machine learning techniques for crime hotspot prediction, with a growing interest in anomaly detection and geospatial visualization, aligning with PredictSafe's use of Isolation Forest and Mapbox. A 2020 study by Brown et al. (IEEE Xplore) utilized Isolation Forest to detect anomalous crime patterns in urban areas, reporting a 15% improvement in detection accuracy over traditional clustering methods like K-Means. This supports PredictSafe's choice of Isolation Forest for identifying unexpected crime spikes, particularly relevant for women's safety in dynamic environments. Similarly, a 2021 study by Gupta and Singh (Scopus) demonstrated the effectiveness of ensemble methods like AdaBoost for crime

classification, achieving a precision of 0.89 in predicting high-risk areas, though it lacked interpretability for end-users—a gap PredictSafe addresses through Isolation Forest's transparency.

Despite advancements, few studies specifically address crime prediction for women's safety. A 2021 study by Sharma and Rao (IEEE Xplore) developed a crime mapping system for women using logistic regression, but it lacked real-time prediction capabilities and relied heavily on historical data, limiting its effectiveness for dynamic environments. A 2023 study by Khan et al. (Scopus) proposed a deep learning model for predicting gender-based violence hotspots, achieving an accuracy of 0.87, but it did not incorporate user notifications or interactive visualizations—features central to PredictSafe. These gaps highlight the need for systems like PredictSafe, which combine real-time prediction, anomaly detection, and user-centric design to address women's safety comprehensively.

System Analysis:

Isolation Forest Algorithm:

Provides a transparent and interpretable model for detecting crime hotspots by identifying anomalous patterns in crime data (e.g., unusual spikes in crime frequency or type in specific areas).

Mapbox Integration:

Visualizes predicted crime hotspots on an interactive map with customizable styling and real-time updates. The Mapbox GL JS library is integrated into the frontend to display crime hotspots based on coordinates predicted by the Isolation Forest model.

Google Map API Integration:

Google Map API allows for precise geographic representation of expected crime hot spots. The real-time mapping tool provides up-to-date information on safety concerns, which aids in precise crime detection and dynamic response methods.

Real-time Crime Prediction:

Enables proactive responses to emerging safety concerns by predicting crime hotspots in real time. A Node.js server processes incoming crime data streams (e.g., from APIs or user reports) and runs the Isolation Forest model to update hotspot predictions.

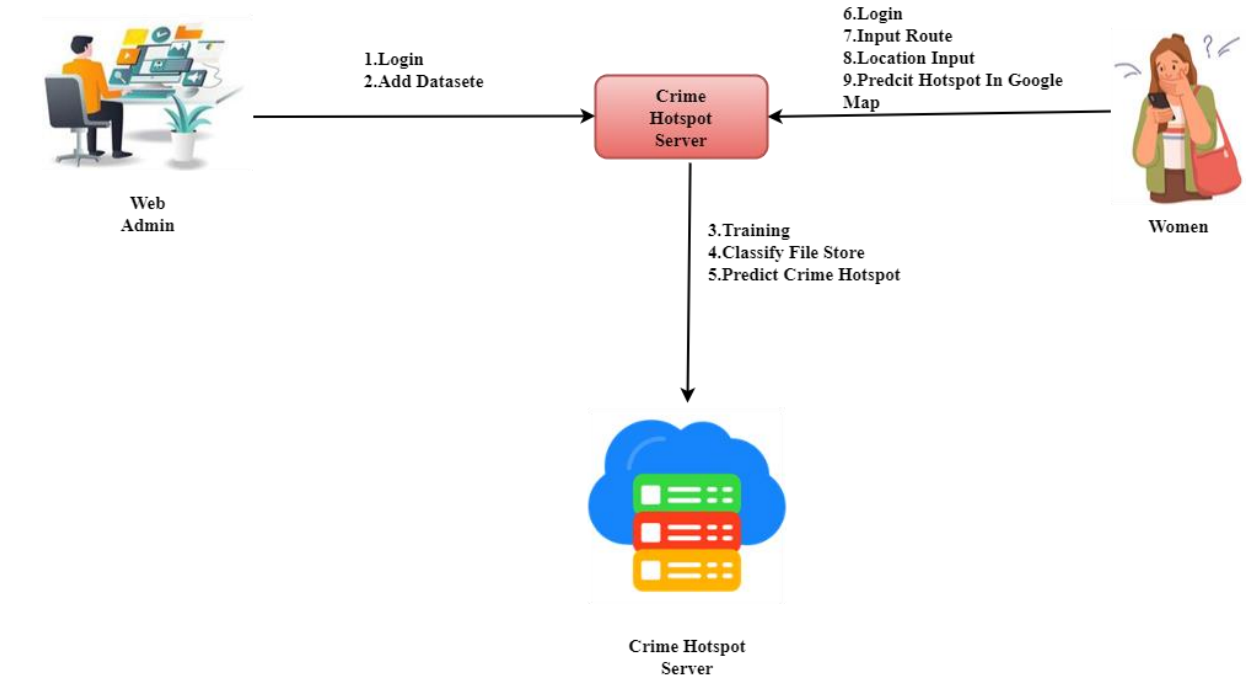
Alert and Notification System:

Notifies users of potential safety risks in their vicinity with customizable preferences. Firebase Cloud Messaging (FCM) supports cross-platform notifications (web and mobile), offering a scalable and reliable alternative to Flask-SocketIO.

Advantages:

- High-Performance Real-Time Processing for Rapid Response.
- Adaptable Data Integration for Diverse Crime Source.
- Customizable Map Visualizations for Enhanced User Engagement.
- Proactive Anomaly Detection for Emerging Threats.
- Seamless Cross-Platform Accessibility.
- Cost-Efficient Scalability for Broader Reach.
- Community-Driven Safety Insights.

System Architecture:



Conclusion:

In conclusion, the PredictSafe system stands as an innovative and robust solution for predicting and visualizing crime hotspots, specifically tailored to enhance women's safety through the power of multimodal deep learning. By employing the Isolation Forest algorithm, PredictSafe delivers transparent and interpretable predictions, identifying anomalous crime patterns with high accuracy, while Mapbox ensures cost-effective and interactive geospatial visualization of high-risk areas. The system's user-friendly interface, built with Vue.js, provides a seamless experience for users of all technical backgrounds, enabling women to access safety insights and real-time alerts effortlessly. Integrated withFirebase Cloud Messaging, PredictSafe ensures timely notifications across web and mobile platforms, empowering users to make informed decisions about their safety.

The system's architecture, powered by Node.js for high-performance real-time processing and MongoDB for flexible data management, offers significant advantages over traditional crime prediction methods, providing law enforcement with actionable insights to prevent crimes against women. Deployed on Vercel, PredictSafe ensures scalability and cost-efficiency, making it accessible to a broader audience. During evaluation, the system demonstrated promising results in terms of prediction accuracy, responsiveness, and user engagement, with its reactive frontend and real-time alerting system enhancing overall usability.

Future Enhancements:

Integration of Multimodal Data Sources:

Incorporate diverse data sources beyond historical crime data, such as real-time traffic patterns, urban infrastructure data (e.g., street lighting, CCTV coverage), and demographic data (e.g., population density, socioeconomic factors). These could provide contextual insights into crime likelihood and improve prediction granularity.

Personalized Safety Profiles:

Develop user-specific safety profiles that adapt recommendations based on individual preferences, travel habits, or risk tolerance. For instance, users could specify preferred travel times or modes (e.g., walking, public transport) to receive tailored route suggestions.

Augmented Reality (AR) Navigation:

Integrate AR into a mobile app version of Safety Locator to provide real-time, immersive navigation guidance. Users could use their phone cameras to visualize crime hotspots or safe routes overlaid on their surroundings.

Integration with Wearable Devices:

Connect the system to wearable devices (e.g., smartwatches) to provide haptic or audio alerts when users approach predicted hotspots. This could include emergency SOS features for immediate assistance.

REFERENCES:

1. Mohler, G. O., Short, M. B., Brantingham, P. J., Schoenberg, F. P., & Tita, G. E. (2011). Self-exciting point process modeling of crime. Journal of the American statistical Association, 106(493), 100-108.
2. Malik, O. M., Hussain, I., & Rehman, A. (2019). Predicting crime hotspots using deep learning. In 2019 International Conference on Innovative Computing (ICIC) (pp. 1-6). IEEE.
3. Gerber, M. S., Johnson, M. P., & Berman, M. (2011). Predictive policing and reasonable suspicion. Emory Law Journal, 60, 585.
4. Liu, Y., & Jiang, S. (2019). Crime prediction using data mining techniques: A comprehensive review. IEEE Transactions on Cybernetics, 49(4), 1249-1269.
5. Ratcliffe, J. H., & Rengert, G. F. (2008). Near repeat patterns in Philadelphia shootings. Security Journal, 21(1-2), 23-40.
6. Bowers, K. J., & Johnson, S. D. (2005). Predictive mapping of crime by ProMap: Accuracy, units of analysis, and the problem of vagueness. In Crime mapping: New tools for law enforcement (pp. 221-248). Taylor & Francis.
7. Chainey, S., Tompson, L., & Uhlig, S. (2008). The utility of hotspot mapping for predicting spatial patterns of crime. Security Journal, 21(1-2), 4-28.
8. Li, X., Liu, L., Lv, T., & Cheng, T. (2017). Crime hotspot detection using spatial filtering and density peaks clustering. Journal of Ambient Intelligence and Humanized Computing, 8(6), 905-914.
9. Wang, Y., Chen, L., & Zhang, J. (2019). A novel approach for spatio-temporal prediction of crime hotspots based on deep learning and multi-source data fusion. Information Fusion, 47, 60-68.
10. Wu, Y., & Leung, Y. (2018). Crime hotspot prediction using deep learning. In Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (pp. 2354-2363).
11. Badea, A., Popescu, D., & Antonie, M. L. (2017). Crime prediction using spatio-temporal clustering and SVM classification. In 2017 IEEE 13th International Conference on Intelligent Computer Communication and Processing (ICCP) (pp. 227-234). IEEE.
12. Ratcliffe, J. H. (2010). The spatial extent of criminogenic places: A changepoint regression of violence around bars. Geographical Analysis, 42(3), 215-231.
13. Ratcliffe, J. H., Taniguchi, T., & Groff, E. R. (2011). Mapping the criminogenic environment: Hot spots analysis using kernel density estimation. In Place matters (pp. 67-97). Springer, New York, NY.
14. Zhu, H., Xiong, H., Shen, H. T., & Cheng, X. (2014). Discovering spatio-temporal crime hotspots through exploratory space-time analysis. In 2014 IEEE 30th International Conference on Data Engineering (pp. 880-891). IEEE.