

AI-Driven Predictive Women Safety Monitoring System Using Geospatial Risk Analytics and Automated SOS

Nilesh Pande¹, Dimpal Alokar², Mariyam Maniyar³

^{1,2}MCA Student, Department of Master in Computer Application, K. K. Wagh Institute of Engineering Education and Research, Nashik, India

³Assistant Professor, Department of Master in Computer Application, K. K. Wagh Institute of Engineering Education and Research, Nashik, India

Abstract— The women safety is a complex and critical problem in current urban environments. Current safety applications available in the market rely mostly on manual trigger for distress situation and seem to focus more on the response phase of a crime after the incidence instead of proactive approaches. In this paper, we exhibit the design of AI-driven intelligent women safety monitoring system with prime focus on predicting risk factors and proactive safety advice. It is achieved by machine learning techniques and geospatial analysis based on predicting the risk factors in a specific location considering previously reported incident reports, current user location coordinates, time of occurrence and user generated reports. Dynamic risk scoring module dynamically assigns a risk status (safe, moderate and high) to any given location with a heat-map based visualization and on-going risk assessment of any user based on the monitoring of their coordinates, provide advance alerts about risky location. Automatic SOS triggers system helps send live emergency alerts with location to pre-specified contacts or authorities. A chatbot based safety assistant provides rapid responses and hands-free control during the emergency situation. Learning continuously with reports and feedback makes it more accurate in future predictions.

Index Terms— Artificial Intelligence, Women Safety Systems, Geospatial Risk Analysis, Safety Heatmaps, Automated SOS Alerts, Crime Data Analysis, Geofencing, Predictive Safety Applications.

I. INTRODUCTION

Rising crime both in public and private places has brought the concern of security and safety of women in the forefront globally. Urbanization and increasing convenience and accessibility of transportation methods have increased accessibility for women to

greater extent at the expense of their vulnerability to threats. Incidents of harassment, crime, rape and various other violations against women are rapidly increasing in many states of the country. Traditional methods for women's safety have mostly relied upon manual reporting/alert to emergency helpline numbers but these methods might not be quick enough in critical times. Hence, the necessity of smart technological mechanisms for predicting threats and sending real time alerts to women is growing at a significant pace.

The advent of AI, IoT and geospatial technologies has led to the development of smart monitoring systems to predict risk and monitor the threats. The modern smartphones equipped with GPS capabilities and instant communication have become appropriate platforms for developing location-based safety applications. Location based applications can effectively increase women's safety by predicting high risk zones using historical data on crime and geography and notify women to avoid any high-risk areas.

Many women safety applications that are available today have alert generation as their major security feature. These safety systems have a panic button or alert signal that needs to be activated by the user. Existing women safety systems consist of panic buttons, emergency contact information and real time location sharing to the authorities. Such systems have to a certain extent passive and are effective only if the user can alert herself or himself by initiating a panic button/alert signal. This work proposes an AI- Driven Predictive Women Safety Monitoring System with Geospatial Risk Analytics and Automated SOS to provide enhanced personal security for women

through smart surveillance and instant alert generation. It utilizes public data such as Safecity data, NCRB and other government open data sources together with OpenStreetMap geospatial data to study crime patterns and develop safety heat maps. Geospatial analytics and predictive algorithms are applied to predict high-risk zones and alert women when entering risky areas. Automated SOS to alert concerned emergency authorities is employed.

II. LITERATURE REVIEW

Given the increasing cases of harassment and assaults on women around the globe, the issue of women safety is paramount in the field of research and development. There have been several proposals based on mobile application-based safety devices, IoT based safety systems, surveillance and AI based systems for the prompt emergency response and enhanced situational awareness. This section discusses the state of art women safety systems and highlights the research gap motivating this study.

A. IoT-Based Women Safety Systems

IoT or the Internet of Things is a versatile technology which is widely used in the development of intelligent safety devices capable of automatically detecting emergency situations and sending alarms. IoT Based Women Safety Devices include GPS module, GSM module and other sensors to detect insecure environments and send an alarm to pre-selected contacts [8]. When a distress signal is activated by a user, their location is automatically shared with emergency contacts, police or family members. An alternative design includes wearable sensors which monitor the vital body functions such as body temperature and heart rate. When there is a deviation of these vital functions beyond acceptable limits, an alert signal is generated and sent to the predefined contacts along with user's current location [9]. Beyond wearable systems, IoT based women safety systems have also been developed in the form of surveillance-based systems. One such system proposes the usage of a robotic night patrolling system for the public areas that are safe for public when the robot is equipped with camera and sensors that would detect unauthorized activities and sends alerts to the control center in real time [10]. A surveillance-based women safety system comprises of motion sensors, GPS, camera that senses danger and captures the image of the user [11]. The

problem associated with the above women safety systems is that they mainly have fixed trigger sensors and are not able to anticipate an unsafe location beforehand.

B. Mobile Application Based Women Safety Systems

Safety can also be ensured using Women Safety Mobile Applications. A smart women safety system would comprise of a GPS and GSM module. The mobile application would receive a SOS message and send the location to the predefined contacts [12]. Another android-based application provides the functionality of locating the nearest help by using the GPS and GSM technologies and raising an alert to the concerned contacts [13]. Android based women safety application is proposed which provides various helpful features in emergency situations, but it requires manual trigger [13].

C. Hardware-Based Women Safety Devices

Various women safety hardware-based devices have been proposed. One gadget includes the detection sensor and a communication device for sending an emergency alert by pressing a panic button. The alert would include the current location of the user and the emergency situation [14]. Another hardware-based device includes the usage of a GPS module, sensors and camera that monitors the unsafe location and in case an unsafe condition is detected, captures an image of the surroundings [2]. A problem that has been found in the gadget is that there is no intelligence implemented to predict the high-risk locations beforehand.

D. AI-Based Intelligent Women Safety Systems

In the current era of intelligent systems, Artificial Intelligence has been incorporated to develop Women Safety Systems. In AI based Women safety systems, ML algorithms are utilized for prediction of risky situations in specific areas and warning women in real time based on past records of crimes in those areas [3]. Another technique uses AI based surveillance to predict the dangerous activities and behaviors by the use of computer vision algorithm [4]. The use of deep learning technique enables to predict risk level by analysing gestures and movement of people in the public area in a certain crowded situation [6]. The limitations in these AI-based techniques are that they are limited to the surrounding for the predictions and a

CCTV or camera is typically used in the system for detection.

E. Survey of Women Safety systems

The literature presents a survey on existing architectures for women safety systems, which range from the basic panic button to modern GPS tracking systems, mobile applications and smart wearable gadgets [1]. It was stated in the literature that integration of different technologies would help in reducing the time to respond in women safety systems. The only limitation found in this literature was that the systems are reactive instead of proactive [7].

F. Research Gap

By reviewing the available women safety systems, it has been identified that most of the present systems are reactive that raise an alert and notify selected numbers of people after the disaster has already occurred. Although the use of IoT and surveillance systems are prevalent, it does not have the intelligence to predict an impending danger and providing an adaptable risk assessment. Most of the women safety systems are triggered by manual action and are not suitable in real time emergency situations. Most AI based women safety systems provide monitoring in public places and use surveillance or already existing CCTV infrastructure; they do not analyze the user-specific risk in various situations and also do not support an adaptive real time emergency response for a predicted risk level.

To overcome the limitations in the state of art of women safety systems, we proposed a women safety monitoring system called AI-Driven Predictive Women Safety Monitoring System using Geospatial Risk Analytics and Automated SOS having two objectives namely, (i) Predictive Analytics for a warning to be provided for high-risk zones/ situations and (ii) Automated SOS initiated at the time of a detected unsafe situation.

III. PROPOSED METHODOLOGY

The proposed AI-Driven Predictive Women Safety Monitoring System aims to enhance women's safety through geospatial risk analysis, ML-based prediction and auto-SOS services. The system determines dangerous areas and generates instant safety alerts utilizing data sets from crime information,

crowdsourced event reporting and real-time location. The work-flow of this system is divided into the following stages: Data Collection, Preprocessing, Geospatial analysis, risk prediction, real time monitoring, and automatic emergency services.

A. Data Collection

In this stage the system gathers data from various credible and diverse data sources because the overall system's prediction and performance greatly depend on variety, abundance and totality of collected data sets. The system comprises various safety-relevant data sets and extract criminal and unsafe region location coordinates that enables to determine trend, pattern and risk factor for each location. These data sets include criminal information from past record and real time crime reports submitted by crowdsourcing; that enables system to carry out comprehensive real-time crime information. These data sets are valuable for pattern and trend identification and potential risk from each location. Collected data sets contain location in geographic coordinates so that spatial analysis and prediction can be performed with enough accuracy. All the above data sets can be utilized for various procedures like geospatial analysis, risk prediction and alert generation which are explained below. Data sets to be used in this system can be summarized as in Table I.

Dataset	Description	Purpose
Safetycity Dataset	Crowd-sourced harassment and unsafe incident reports	Identifying unsafe locations
NCRB (Nat. Crime Records Bureau)	Official crime statistics across India	Historical crime analysis
data.gov.in	Government open datasets on crime and safety data	Public crime records
OpenStreet Map (OSM)	Geographic location and map data	Geospatial mapping
News Incident Data	Crime incidents extracted from news reports	Recent crime pattern detection

Table I Datasets Used in the System

All the data sets will be fused with latitude, longitude, event type, time and severity and thus provide predictive risk analysis.

B. Preprocessing of data

As the datasets retrieved might be inconsistent with duplicated or missed data entry, a preprocessing step needs to be done to retrieve quality data for machine learning algorithms. The preprocessing stages will be the following ones:

- Removing duplicate/redundant data from the dataset.
- Handling incomplete/missing values in attributes.
- Transforming address/locations into latitude-longitude.
- Normalizing the feature values for machine-learning algorithms.

Through this step the dataset will be organized for geospatial and predictive analysis.

C. Geospatial risk analysis

In geospatial risk analysis the system would make use of geospatial analysis to predict the high-risk locations by observing pattern of crimes. It makes use of coordinate information obtained from OpenStreetMap to plot crime incidents, then the system categorizes crime events into high and low risk groups (clusters) using k-means clustering algorithm. The objective function for k-means is to minimize the within-cluster variance which is given by equation 1 as,

$$J = \sum_{j=1}^k \sum_{i=1}^n x_i^{(j)} c_j \quad (1)$$

Where $x_i^{(j)}$ is the data points in the cluster j and c_j is the centroid of the cluster j . K refers to number of clusters. A group with highest crime events would have the highest risk level.

D. Risk score calculation

The level of risk will be measured in the form of risk score on the system. To establish the level of risk of a location a weighted risk score will be calculated using multi-contextual data which will include crime frequency, time of crime and user submitted incident reports. The risk score is determined by,

$$\text{Risk} = wC + wT + wU \quad (2)$$

where C represent number of crimes in a particular location, T represents the risk time factor for identifying peak times of crime incidence and U represent number of users reported incidents. w_c, w_t, w_u will be the weight factor calculated using empiric analysis.

E. Safety heat map generation

Safety heatmap of risks will be generated by combining the risk score and the cluster information

derived. The risk levels will be categorized into three distinct colors: low (green), medium (yellow), and high (red), providing a visualization of potentially unsafe locations.

F. Real-time location monitoring

The system will monitor the location of the user through map and location API of cell phones. Based on the user's present coordinates it will determine if the user is in the high-risk areas and alert the user of danger immediately by generating an alarm.

G. Distance calculation for risk detection

The system would use the Haversine formula to estimate the distance of the user's current coordinates with the centroids of the risk groups, (refer eq.3), The formula is given below.

$$D = 2R \arcsin(\sqrt{\sin^2(\phi/2) + \cos(\phi) \cos(\lambda) \sin^2(\theta/2)}) \quad (3)$$

Where ϕ is the latitude, longitude of a location, and R is the average radius of the Earth (6,371 km). The condition for risk alert is $d < d_{\text{threshold}}$.

H. API Integration

Various APIs have been integrated to enable smooth functioning of the system. Map APIs are integrated for tracking and visualization of the current location and risk zones. Geofencing APIs for the boundary detection and notification generation around high-risk zones. SOS API for dispatching urgent messages and Chatbot API to assist users by answering their questions regarding the crime-affected regions and for providing assistance, and a dataset API is included to help update data in prediction cycle through downloading crime details and re-iterating each time.

I. Automatic SOS triggering

The system also has a feature to automatically trigger an SOS message when the user is located in a high-risk area without any prompt from the user. The message will include the users' current location, time of the event and alert about the hazardous surroundings to emergency contacts and police through SMS or mobile notification.

J. Continuous learning with user input

User provided incident reports can be received by the system and further used to re-train models to provide more efficient prediction in subsequent instances thus having self-learning capabilities. These incidents are

stored in the incident database to update the safety heatmap more frequently.

IV. RESULTS AND DISCUSSION

An AI-Driven Predictive Women Safety Monitoring System has been tested using several crime data sets which were obtained from different sources like Safecity, National Crime Records Bureau (NCRB), data.gov.in, OpenStreetMap and news-based incidents. Using these datasets, safety and crime distribution have been analyzed using geospatial clustering and risk prediction, to find the unsafe places and to notify regarding safety.

The system receives location-based crime data and it uses K-means algorithm for clustering crime data points on basis of its spatial location to determine pattern within its distribution. The locations can be categorized on the basis of crime incident densities and computed risk levels into low-risk safe regions, medium-risk moderate regions, and high-risk unsafe regions. Dynamic safety heat maps that clearly visualize crime hot spots have been provided for the users.

Generating crime distribution and demarcating safe/unsafe regions with interactive heat maps is one of the essential functionalities developed. More intense colored locations represent a higher risk as compared to locations with lower colored intensity. Users can use heat maps to identify unsafe places to plan their travel. Dynamic heat maps are developed and these will be refreshed each time new crime information and new user incidents are received by the system.

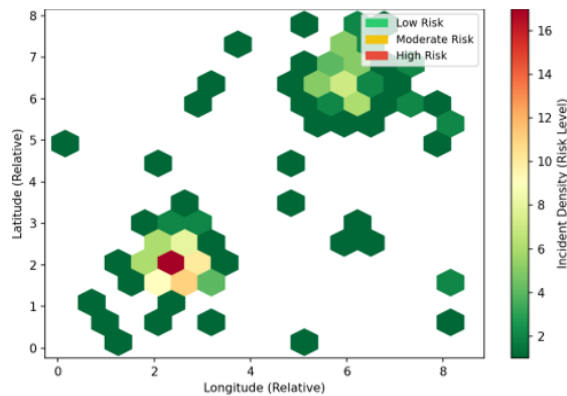


Fig. 1. Safety Heatmap Showing Crime Density and Risk Zones

B. Risk Zone Detection

This method involves the use of location tracking APIs to continuously track the user's location. User's location is compared against pre-defined risky regions using geofencing techniques. When user reaches or enters any risky region, then risk is identified by calculation of Haversine distance between user's location and the centroid of the risky region identified. When distance is less than pre-defined distance, location is declared insecure and warning message is provided earlier to the user so that effective measures can be

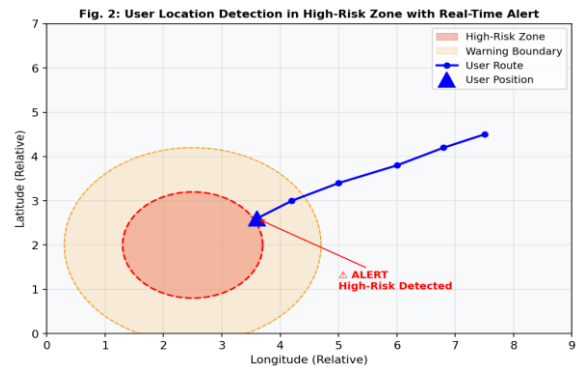


Fig. 2. Detection of User Location in High-Risk Zone with Real-Time Alert

C. Automated SOS Trigger Mechanism

An eye-catching feature of the system is the SOS alert system, which activates itself the moment the user steps into any hazardous zone. This is a totally automated SOS alert and there is no manual action involved on user's part. Once triggered, the SOS alert will be generated along with user's current location, the timestamp of the alert and the emergency alert message and will be broadcast to the registered emergency contacts, the local law enforcing agency, the emergency service using communication API.

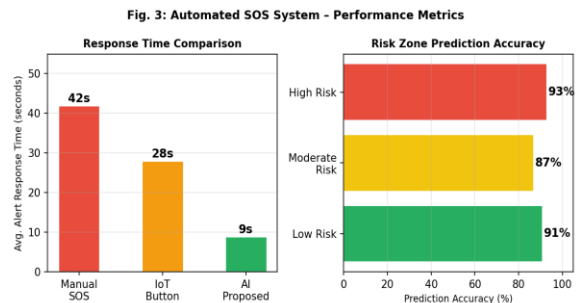


Fig. 3. Automated SOS Alert Interface Triggered in High-Risk Zone

D. System Performance and Benefits

By integrating with different sources of information (crime reports from the past and crowd reports), the efficiency of predicting the risk area is also amplified. Combining the geocustering and constant monitoring features allow it to newly predict and identify high risk areas automatically. The system we propose can:

- Dynamically generate safety heatmaps based on geocustering accurately.
- Dynamically identify high risk areas by integrating the multi-source of crime data.
- Inform real time alerts based on continuous user monitoring.
- Automatically call for SOS in case of emergencies without human involvement.
- Keep on improving the prediction by having self-learning functions.

V. CONCLUSION AND FUTURE WORK

The system of AI-Driven Predictive Women Safety Monitoring system that incorporates geospatial risk analytics and automatic SOS mechanism for women safety was built using intelligent monitoring and risk prediction techniques for women. The system integrates crime data, geospatial map, machine learning algorithms, real time location service for the risk zones and predicts the warning messages to ensure safety.

The system takes crime data (Safecity, NCRB, Govt open data) and spatial data (OpenStreetMap) and generates heatmaps indicating risk zones from analysis of criminal reports. The system is enabled with the concept of geofencing, when the user enters into any high-risk zone, it will immediately generate a safety warning in the real time. In emergency situation, SOS alert comprising of live locations of user was triggered automatically and sent to contacts and police force for timely response.

The system can successfully predict risk zones, monitors user location in real time and send automatic warning message in critical situation and help increase the situation awareness and response time. It overcomes the problem of manual SOS trigger in existing safety applications by providing the safety warning based on prediction.

The main constraints in the present system are the availability of crime data and reliable GPS service.

More advanced features and services to be incorporated with advanced prediction accuracy by using machine and deep learning models. Crowd-sourced report can be used to update real time incidents and events. Computer vision technologies can be used for identifying any suspicious activity with the help of video analysis. Also, interaction with smart city services, wearable device, police force can further develop the safety features.

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