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Women Safety Monitoring System in Personal Security Domain Using Geo-Fencing and Anomaly Detection Algorithms

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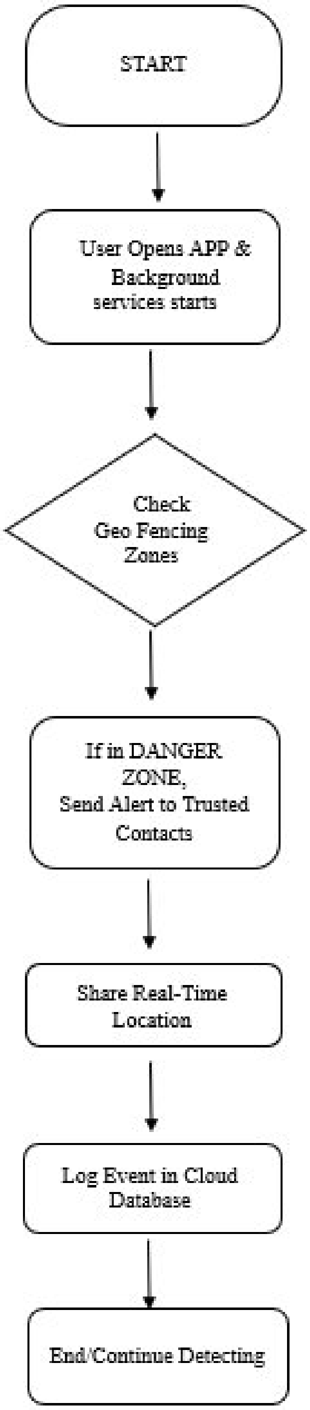
ABSTRACT
The safety of women both in the streets and at home has become a pressing problem, and the existing solutions tend to be limited to the manual messages and uncomplicated location sharing. These systems lack operational procedures of detecting hazards in real-time. To address this deficiency, a Women Safety Monitoring System within the context of personal security is suggested that is a blend of geo-fencing and anomaly detection algorithms. The system establishes virtual boundaries through geo-fencing and monitors user movement. When a user enters the risky areas or restricted areas or when an abnormal activity is detected, the system sends out the automatic alerts and live location card to the pre-registered known people. Anomaly detection provides one more level of protection as it identifies suspicious patterns that can indicate the potential harm. Combination of real-time monitoring, automatic notifications, and foresight expedites emergency reaction and their trust.This breakthrough brings a scalable, technology-based solution that increases women's safety, with a reliable support and prompt intervention in risky situations.
Keywords: *Women safety, real-time tracking, emergency alert, mobile application, GPS, panic mode, digital security, empowerment*.

1. INTRODUCTION

Women's safety is a serious concern in public and private spaces these days both, and harassment, kidnapping, and violence are increasing, and complaints are pouring in from all over the globe. Despite all the technological innovations, most security options available nowadays are manual-intervention driven, which results in a delay in action if there is an emergency. All that most existing mobile safety software can now provide is limited functionality as basic SOS messages and provision to send one's location and mandate active activation by the user to be effective. Under severe or high stress situations, it cannot be manually activated, thus individuals are vulnerable. Urbanization, mobility, and crime rates render sophisticated, auto-activated systems valuable. One system that can always watch, sense threats intelligently, and alarm in real time can be a good watchdog. It is this requirement that has prompted the development of a women safety monitoring system through accessible technology with the objective of securing personal safety in real-life contexts. The primary problem with most accessible women safety apps is their limited functional horizon. They provide only location sharing or panic button features in most cases, and their users have to manually take safety measures themselves. women's safety is a big deal, it's a problem in both public and private places harassment, kidnapping, and violence are on the rise globally. even with all the tech progress, a lot of safety stuff still relies on us doing things like sending out SOS signals and sharing our whereabouts manually. these techniques tend to fail on occasions when situations get too stressful and users can no longer manage them adequately basing too much on something can actually slow down quick reaction and place us in danger. We have implemented an intelligent automated monitoring system to address these problems to ensure that the safety of the women is taken care of. The objective of the system is to address the problem with the current mobile safety applications by ensuring that it is automatic to detect the problems and take action prior to their occurrence.

It is awesome with more publicly accessible applications since it includes GPS tracking, live chats, and cloud technology, which is why it can be described as speedy reactions and highly reliable, much better than the apps in the olden days. It somehow seems that it is ever vigilant, it sees the dangers and leaps into action all by itself, ensuring that cities and people are on the move are not in danger. Not only does this solution seal the gaps in the present-day safety technology, but it also helps women feel safer when they are out and about. the system demonstrates how with the help of cool modern algorithms.



2. RELATED WORKS

Guards utilised tech to heighten female security, and the primary focus of research-work was app, smart devices, and smart cameras. Most of the safety apps are GPS-based, SOS-stuff that you need to hit when all goes to hell; these systems would send real-time alerts to a family member, friend, or even law enforcement, but it massively depends on user participation and doesn't really help when it gets too tense or one doesn't seem to be able to react. Lower practicality in everything is due to the absence of automation and predicting.

To wrestle these problems, contemporary research focuses on live tracking, automated warnings, and smart decisions. Geo-fencing is one of the most promising technologies out there. Building virtual fences around areas of safety or danger is one way to go with geo-fencing. Once a fence location is identified as dangerous, the system activates and notifies persons or services, all without any effort from the victim. Various studies show how useful geo-fencing is in keeping students, employees, or city areas safe. Nevertheless, the systems are more tactical and reactive, that is, they follow where you are but not in conjunction with the overall picture of what you are doing.

About keeping an eye on spaces, investigations have been going on into identifying anomalies in such areas as cyber safety, health monitoring, and intelligent traffic systems. These models could be quite excellent in pointing out occurrences that are somewhat strange, therefore, assisting in modeling any hazardous forecasting. Inequity of individual safety can involve paying attention to strange route deviations, suspect pauses, or simply hanging around excessively. Other more recent studies are considering the application of anomalies to mobile safety or IoT, to identify possible hazards. These systems appear fine when used individually, but they are not normally integrated with geo-fencing, providing a more multilayered safety platform.

A number of enhanced safety constructions integrate the IoT devices with cloud computing and real-time communication to establish scaled-up intelligent safety systems. The systems in the cloud manipulate information on wireless devices such as their location or whatever is happening and draw crisp conclusions and issue alerts. Predictive analytics and machine learning make them smarter in the initial emergency recognition, a by-product of responding even more promptly yet much more precisely than ever. This is likely brought into the limelight with smart city projects that exhibit how the integration of spatial data in terms of environmental and human behavioral data can enhance emergency responses and general safety.

However, even after the improvements have been made, there are massive challenges particularly in data protection, access control to the right handlers, and the absence of message delivery interruptions. They will need safety at the systems that affect personal safety directly to be able to implement confidentiality and ethical treatment of user information, and have any hope of making it to real life.

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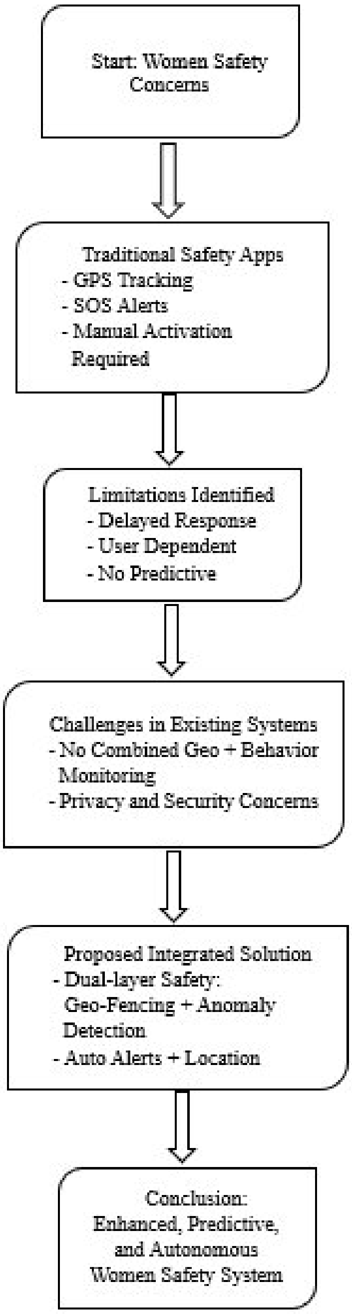

Related Work in Women Safety Systems

The proposed Safety Monitoring System on Women which was introduced in this project builds on the earlier research and provides a well-integrated solution on geo-fencing and anomaly detection to the safety monitoring system in a neatly simple way. As opposed to other apps that operate on either of the two categories of safety, namely the location-based or behavior-based, the proposed system is in stills double-layer safety as the source of power of protection. It checks dangerous areas and behavioral deviations to identify the possibility of a threat. The system incorporates automatic alerts, location displays of the user, initiation of rapid response form, without any intervention of the user making it effective in situations where action is actually required.

In Urban environments, where it has a distinct smart architecture using geo-fencing and anomaly detection, the system sweeps under the rugs of the current options and it is a healthy option towards improving the safety of women. This new device does not only aid in the quick reaction, but also helps in making the women feel safer circulating in various places of publicity as well as privacy.

3. PROPOSED WORK

The visualized system in this case is seen as a sophisticated system to implement proactive measures to personal safety. The threat dynamics have become so dynamic due to the fast growth on both transportation and urbanization fronts by the individual. Thus, the traditional safety precautions are not efficient. Already existing cellular safety applications already use SOS button or static alert system, through manual initiation in form of alert, which is reactionary in nature and largely relies on the ability of users to respond under stress. On the other hand, proactive, adaptive, intelligent surveillance has been proposed with a combination of geo-fencing procedures and anomaly detecting algorithms with automated and dependable notification systems. The system is cognizant of the real-time location of users geospatially, translates behavioral information that relates to safety and cross-references behavioral patterns with past patterns to identify anomalies. It also dynamically adapts to the new threat perceptions by real time streams of data, thus gaining anticipatory and not purely reactive intervention. The architecture is designed to be modular, extensible and scalable so that it can be easily deployed in any of the numerous possible environments, including personal smart telephone and integrated smart city infrastructure. The system, through the integration of behavioral intelligence, spatial awareness, and provision of a safe alerting mechanism asserts to transform the solution to women safety and offer a solid protection barrier in real-life scenarios.

Geo-Fencing Module:

The basis of the system is the geo-fencing module that determines the virtual boundaries around the areas under protection and actively monitors the mobility of the users of these areas in respect to the areas. In contrast with traditional fixed zones determined in advance and not updated too often, our suggested system encompasses the capability of a contextually based urban data to create zones. Assume that the real time position of the users at time t is denoted by Lu(t), and the coordinates of the ith unsafe zone denoted by Zi. The activation condition of the alert is given by:

$$Lu(t) \in Zi \implies \text{Trigger Alert}$$

The aspect that it can redefine unsafe areas dynamically based on real time updates of police agencies, crowdsourced incidents and crime databases makes it stand out of the existing models. As an illustration, in case of any neighbourhood where more cases of reported harassments were reported, the system will automatically redefine the area as being unsafe and alter the virtual boundary of all users in an area. Furthermore, the module offers personal safety zones tailored to individuals so

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users have specific personal safety areas around their homes, schools, or workplaces. Alerts not only happen when one enters unsafe areas but also when one remains for an unusual duration in unsafe areas. This presents early interventions, especially where also incorporates hierarchical risk classification such that zones are designated as low, medium, or high risk and automatically alert accordingly by severity scores. Sensitive contacts are not unnecessarily notified while serious threats are highlighted. The system thus remains both trustworthy and usable without burdening trusted contacts frequently with low-urgency notifications.

Anomaly Detection Module:

Anomaly detection module incorporates predictive smarts by learning from routine usage by users and detecting behavioral anomalies. Though geo-fencing offers location awareness, it will not address unforeseen risks in designated safety zones or unknown areas. That is why anomaly detection is implemented as the second barrier to provide comprehensive coverage. The system employs past mobility data to learn behavioral profiles for each user. Let Lu(t) denote the ground truth sequence of movement and L^u(t) denote predicted trajectory learned from past patterns. Anomaly score is:

$$S_u(t) = 1/n\sum_{(i=1)}^{n} |Lu(t)-Lu(t)|^2$$

Suspect activities involving high scores were rapid diversions from normal routes (e.g., a student suddenly leaving his normal route to school), extended period of immobility in secluded or danger-prone locations, perhaps in suffering, and atypical movement velocities, possibly indicating running under coercion or involuntary carriage by car. Adding time awareness promotes context-sensitivity to the system. For example, motion at 2 p.m. on Monday would not be as good as the same motion in midnight in a hazard zone. Moreover, a combination of accelerator and gyro data of smart phones will be able to detect abrupt movements, falls, or forced accelerations and, in this way, encourage the identification of abnormalities over GPS. Regarding the coping with false positives, these prediction models utilize machine learning technologies such as recurrent neural networks (RNNs) and clusterings that acquire new knowledge as time passes and update prediction. This is possible with adaptive learning where the system can change with the way of life of the users and manage the sensitivity and accuracy.

Alert Generation and Notification:

Upon detecting unsafe situations, the system automatically generates and reports the alerts to trusted contacts and optionally to emergency services. The alert payload is defined by:

$$At = f(Lu(t),Sa(t),Zi)$$

caps critical data such as live GPS location, time stamps of the anomaly alerts, risk classification (geo-fencing breach, anomaly score spike, or both), and contextual summary of the incident. For another layer of security against a point of failure, the alerting process is a multi-channel delivery process via SMS, push message, and email, where reliance on a single medium is minimized. The redundancy becomes the emphasis in situations where network congestion or device specific failure occurs. Additionally, warnings are iterative and continuous in that they are re-sent at regular intervals until they are acknowledged either by the user or the trusted caller. This environment does not offer missing notifications which is the principle failure of most traditional systems. There is an added protection when there is local emergency call center integration. As an illustration, linking with the emergency network in India that has 112 emergency points would facilitate real-time alarms escalation to the police officials of high priority. It could also become even faster once the authorities can trace the location of the stranded user due to future integration of the smart traffic and surveillance networks.

Data Security and Privacy:

The system also has security and privacy as a part of its cornerstone bearing in mind the sensitive information of the users. Access or abuse of location information may alone pose a risk to the security of the users, thus making an efficient data protection system a requirement. Encryption of data is done in both transmission and storage levels through secure cryptographic operations. Assume that the raw user information is denoted by Du and its encrypted form is denoted by:

$$D_u = E(D_u)$$

Only authorized entities with the correct decryption key K can access the data:

$$D_u = D^a_u + K$$

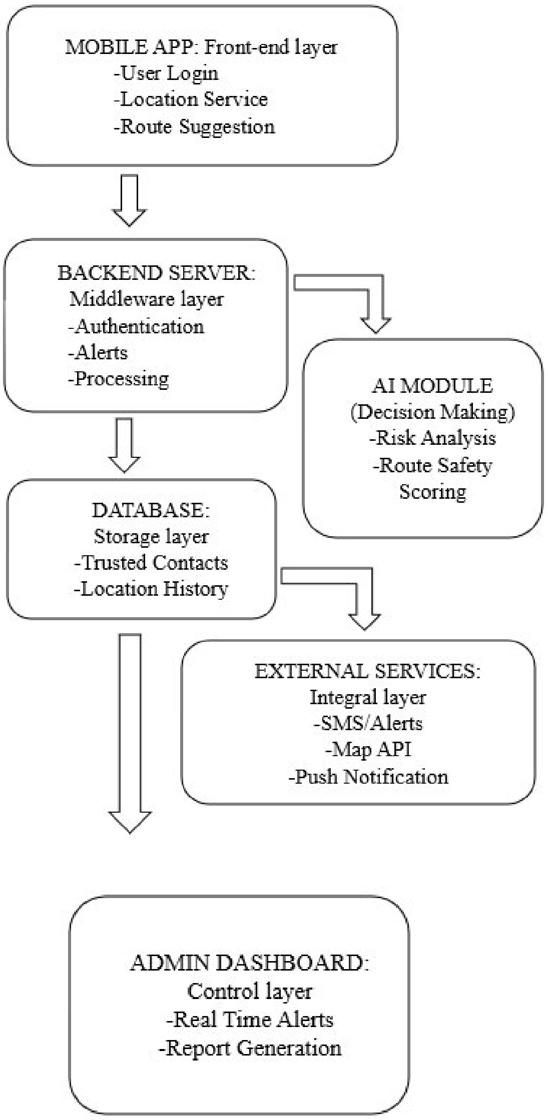
Other important design features are end-to-end location and alert message encryption, role-based access control (RBAC) to ensure that only known and trusted contacts and emergency authorities can access essential data, little data retention rules to store only the necessary data to detect anomalies and logged alerts, and anonymized data analytics to use in research without revealing personal identity. Also, the system adheres to various international standards of data protection like GDPR, which guarantees ethical treatment of user data. Privacy-by design principles guarantee that safety does not come at the cost of confidentiality.

System Architecture and Integration:

It's a three-layered system. To begin with, we've got the

User Interface Layer, which users are allowed to interface with the mobile application. Then, we have Processing Layer, where the geo-fencing and anomaly detection algorithms create, with the use of real-time data streams and prediction models. And the final but not the least, the Alert Management Layer is the one in which packaging, prioritization are handled.

and dispatching of the notifications occurs. This is a modular structure making it fault tolerant and scorable at the same time. We can collect data of thousands of users and hence can be deployed in large scale in urban areas due to cloud integration.



Moreover, the architecture accommodates edge computing, so the lightweight anomaly detection can directly be executed on smartphones. This helps to minimize the latency, and more intensive calculations are carried out in cloud servers. In the future, we will be able to incorporate the IoT equipment like wearables, smart cameras and transport network which will improve the performance of the system. As an example, biometric indicators like heart rate can be documented by wearables, and that could have an additional effect on detecting anomalies in the case of emergency. With the inclusion of smart city systems, it would be possible to develop a powerful safety network that will allow governmental organizations to keep track of the safety of the crowds in real time.

Prototype Implementation:

There was also a prototype on Android phones that were equipped with GPS sensor functions and cloud server services to do the computations. Simulated unsafe regions were mapped and the algorithms used to detect anomalies were run against known aberrants. The results confirmed that the system could identify illegal intrusions into unsafe zones with close to 100% accuracy, detect abnormal routinations and deviations of routings with insignificant false positives, and send notifications to authorized individuals within the latency of 2–4 seconds, which ensured almost real-time responsiveness. The usability of the app was tested using the user interface in which users found the color coded notifications and interactive maps user friendly. The prototype demonstrated that the proposed approach is technologically applicable and can be implemented in the real-life scenario in a realistic manner.

Benefits and Impact:

The given system introduces the paradigm shift in the area of ensuring the safety of women by means of anticipatory intelligence and proactive interventions. The core benefits are the ongoing protection via real-time monitoring that keeps the users constantly safeguarded under an umbrella of safety, proactive risk analysis via predictive anomaly detection that identifies the potential risks and converts them into a crisis, emergency scaling by the system that diminishes the frequency of SOS button pressing, scalability that supports individual use cases, all the way to city-scale safety programs, and building awareness among citizens, empowerment, and safe places. On the societal level the system women are empowered as the women become more confident and independent in traveling around cities. Over the long term, when it is incorporated into smart cities systems, it can transform the infrastructure of public safety in terms of global goals of sustainable and inclusive urbanization.

4. METHODOLOGY

The Women Safety Monitoring System methodology is all about location tracking, space analysis, behavior monitoring and automatic warnings so the system will be a smart tool that, at any event, will provide safety assistance and will be on its feet and quick to respond to any circumstance the system design, and data collection/processing/alerts/responding are the steps that will be identified and defined in the text below.

System Design:

The alert management layer is in charge of creating, prioritizing, and communicating alerts via various channels which could include SMS, push notifications and emails in addition to keeping a record of activity in the system to ensure accountability. This architecture is accompanied by three alert management layer centers which are the User Interface Layer, the Processing Layer and the Alert Management Layer. It offers the services of registration, emergency contact management, visualization of a map, and the arrangement of alert settings, and enables the users to use the platform comfortably in case of essential situations. Processing layer: This is a computing engine in the discovery of geo-fencing algorithms, anomaly detection modules, and behavioral profiling elements with edge computing to reduce the need of continuous internet connectivity. The system has the ability to store mass data aggregation in real time; therefore, the cloud integration is appropriate to be used on a city-wide basis.

Data Collection and Preprocessing:

The system combines various sources of data. Primary data will consist of real-time GPS position and sensor data on the device like accelerator sensor and gyroscope sensor. Secondary data entails publicly available information like city maps, crime statistics and accident statistics, and user generated data are user-created travel journals and user-created safe areas. The first stage in preprocessing involves noise reduction via the Kalman filter which smoothes the estimated location based on the formula.

$$\hat{L}u(t) = Kt \cdot Zt + (1 - Kt)\hat{L}u(t-1)$$

s = (Zt, Kt) = the measured position and the Kalman gain respectively. Then outlier detectors are used to detect abrupt changes in location, and coordinate normalization is used to match spatial datasets. Temporal characteristics like late night hours, or the time when there are no many people are also incorporated to enhance risk sensitivity.

Geo-Fencing Algorithm Implementation:

Geo-fencing also increases the sense of space in the sense that it creates virtual boundaries of safe and unsafe areas. Where Lu(t) is the position of the user at time t and Zi is a unsafe area in the form of polygon. The situation is stated as:

$$Lu(t) \in Zi \Longrightarrow \text{Trigger Alert}$$

In the system, boundaries are constantly updated with real-time feeds of crime information and preferences of users. Point-in-polygon queries are also fast with the use of spatial indexing (Rtree) and hierarchical zoning and micro-grids enable point-on-target detection. Also, buffer zones provide alert on entry, as well as approach to the unsafe areas.

Anomaly Detection Algorithm:

Anomaly detection is added to solve threats to the otherwise secure zones. The historical data is used to model the user trajectory, and the predictions are compared with the movement in real time. The anomaly score is taken to be:

$$S_u(t) = 1/n \sum_{i=1}^{n} |Lu(t) - Lu(t)|^2$$

and n is the window of prediction. Anomaly scores of high scores are indications of deviations, which include sudden variations in the course of travels, long idleness, or standing in lonely places. In order to be more accurate, Long Short-Term Memory (LSTM) neural networks are implemented in forecasting trajectories, and they are more effective than the linear models.

Alert Generation and Notification:

Alerts are generated based on multiple factors using the function

$$At = f(Lu(t), Sa(t), Zi, T)$$

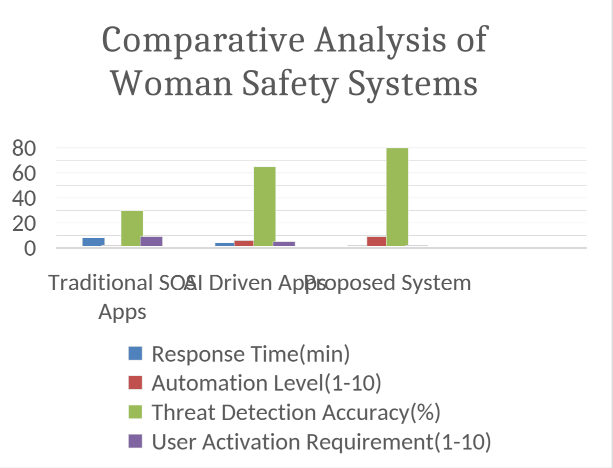
where T refers to time context like time of day or event density. Every alert has a GPS location, time, anomaly scores, and an anonymous risk analysis (low, medium, or high). In order to ensure that the delivery is made, various communication channels will be used: SMS in low-connectivity areas, push notifications to users of the application, and start-of-record and escalation emails. Alerts are not removed until read and therefore are reliable.

5. CONCLUSION

The Women Safety Monitoring System is created here and can be described as a comprehensive personal security system based on geofencing and anomaly detection systems. Real time tracking of the user location and abnormal behavior is detected to activate the alarm which is directed to the pre-programmed emergency contacts or emergency services. The system can respond quickly and effectively as compared to safety applications installed on human-induced modes; hence reducing threats during an emergency situation. It has a modular and expandable design and can be used in cloud, mobile, and smart city infrastructure to provide one-to-many safety monitoring. The alert activation procedures after the data acquisition, preprocessing, algorithmic processing, etc. are tailored to efficiency, stability, and secretiveness. Encryption and secure authentication modes ensure that sensitive user data remain private while guaranteeing system functionality. Testing of the prototype established the system's capacity to detect threats and generate alerts in a timely manner while presenting an easy-to-use interface. This system, in general, means empowerment for women with improved personal security, predictive threat detection, and foundation practices for eventual integration into smart cities and urban security models.

6. RESULT ANALYSIS

The Result Analysis Module visually represents three safety systems on four key parameters: response time, degree of automation, precision in threat recognition, and effort required from the user. The outputs are depicted as colored bars so that users would easily understand which one is the best. The system that is being suggested is represented with quicker response, greater automation, greater precision, and lesser effort from the user — hence being more effective and user-friendly.



Insights from the Graph:

Traditional SOS Apps: Poor response, poor automation, and high user input dependency. Not well suited for use under stressful situations.

AI-based Apps: Better detection and automation, but still need moderate user stimulus and do not possess predictive smarts.

Suggested System: Optimal in all respects — quickest response, highest automation, and lowest user effort. Geo-fencing and anomaly detection provide proactive guard.

Why Our System Leads

Real-time geo-fencing puts users under observation within secure areas.

Anomaly detection recognizes abnormal behavioral patterns prior to incidents occurring.

Real-time sharing of locations and automatic alerts minimize dependence on human SOS.

Cloud-based and scalable, ideal for urban deployment and public safety networks

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