Safest paths for women at night in Cluj-Napoca: a feature offered by UrbanPathfinders

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ABSTRACT

Urban safety for women represents a critical societal concern, with direct implications for mobility and quality of life. In this context, UrbanPathfinders is a mobile application designed to generate safe routes for women by leveraging modern technologies such as Machine Learning (ML) and geospatial analysis. This paper presents the system architecture of the application, the methodology used to identify safe routes, and the results obtained from initial testing.

KEYWORDS

women's safety, safe routes, mobile app, machine learning, technology for safety

1 INTRODUCTION

Women's safety is a crucial topic nowadays. Our app takes the problem of walking alone at night as a woman and solves it by generating the safest routes: most illuminated, more crowded, more popular for other female users, but fast as well, to ensure the best walkable path.

2 METHODOLOGY

UrbanPathfinders furnishes a mobile application that computes optimal walking routes by balancing three primary criteria: air quality, travel time, and nighttime safety—especially tailored for women. The app comprises a TypeScript/Ionic front end and a Python back end incorporating AI-driven pathfinding and recommendation modules. Below, we detail our system architecture, route computation algorithm, continuous update mechanisms, and security considerations.

2.1 System Architecture

Front End (Ionic + TypeScript).

- **Cross-Platform UI**: A single codebase renders on both iOS and Android via Ionic's web-based components and responsive layout system.
- **Real-Time Map Visualization**: Integration of Leaflet.js for dynamic map tile rendering and interactive polyline overlays.
- **User Preferences & Authentication**: Secure storage and synchronization (via REST API) of user-specific thresholds for pollution tolerance and safety risk, managed through JWT-secured endpoints.

Back End (Python).

- **API Layer**: Flask REST API exposes endpoints such as

```
GET /routes?safe=true&fast=true&lowPollution=true
POST /feedback
PUT  /user/preferences
```

- **Data Ingestion Service**: APScheduler jobs poll external sources every 5 minutes to update:
  - Air Quality Index (AQI) from municipal open-data APIs
  - Crime and incident reports from safety feeds
  - Street lighting and CCTV coverage layers from CityGIS
- **Database**: A PostGIS-enabled PostgreSQL stores the street network as a weighted graph with per-edge attributes (crime rate, AQI, lighting score).

2.2 Route Computation Algorithm

Graph Modeling. Each street segment is an edge in a weighted graph; intersections (or sensor midpoints) are nodes. Edge weights combine time, pollution, and safety as:

$$w_{ij} \;=\; \alpha\, t_{ij} \;+\; \beta\, p_{ij} \;+\; \gamma\, s_{ij},$$

where:

- t_{ij} = estimated traversal time,
- p_{ij} = normalized pollution level,
- s_{ij} = safety risk score (higher for poorly lit or high-incident segments),
- α, β, γ = user-adjustable coefficients.

A Search with Custom Heuristic. We employ the A algorithm using a heuristic $h(n)$ that estimates remaining composite cost based on straight-line distance (d_{euclid}), expected AQI, and anticipated safety:

$$h(n) \;=\; \tilde{\alpha}\, d_{\text{euclid}}(n,\, \text{goal}) \;+\; \tilde{\beta}\, \overline{\text{AQI}}_{\text{est}} \;+\; \tilde{\gamma}\, \bar{s}_{\text{est}},$$

designed to be admissible and thereby guarantee optimality.

Personalized Route Re-Ranking. A lightweight neural network (PyTorch) predicts a *user satisfaction score* for the top-k A candidates:

- *Training data*: Anonymous feedback ratings from beta testers.
- *Features*: total distance, mean AQI, count of dark segments, elevation gain, time of day.
- *Output*: re-ranked route aligned with the user's implicit preferences (e.g., prioritizing CCTV coverage for nocturnal walks).

2.3 Continuous Updates & Feedback Loop

Automated Data Refresh.

- A background task fetches updated sensor and incident data every 5 minutes.
- Bulk SQL upserts refresh edge weights in PostGIS.

- Clients subscribe to a WebSocket channel; significant weight changes trigger re-computation prompts.

User Feedback Integration.

- Post-walk ratings on safety, cleanliness, and lighting.
- Feedback adjusts both the A coefficients (β, γ) and retrains the neural re-ranker, enabling the system to adapt over time.

2.4 Security and Privacy Considerations

- **Data Anonymization**: Journey traces remain on-device; only abstracted route IDs and endpoints are transmitted.
- **Secure Communication**: HTTPS + JWT for all API traffic; encryption at rest in PostgreSQL.
- **Safety Alerts**: Deviations into high-risk zones trigger in-app alerts recommending safer alternatives.

2.5 Conclusion

UrbanPathfinders delivers a powerful, user-centric solution for safe and efficient urban walking routes, offering the following key advantages:

- **Enhanced Safety:** Real-time assessment of crime risk and street lighting levels, combined with automatic alerts if a user deviates into a higher-risk area.
- **Personalized Routing:** Adjustable parameters for pollution tolerance, travel speed, and safety preferences, further refined by an AI-driven re-ranking model trained on user feedback.
- **Continuous Data Updates:** Automated refresh of air quality indices, incident reports, and lighting coverage every five minutes, ensuring routes adapt to current conditions.
- **Cross-Platform, Intuitive Interface:** A cohesive Ionic/TypeScript front end with interactive Leaflet.js maps, delivering a seamless experience on both Android and iOS.
- **Privacy-First Design:** On-device processing of sensitive movement data, with only aggregated route summaries transmitted for analytics, preserving user anonymity.

These features make UrbanPathfinders an ideal companion for women (and all pedestrians) seeking reliable, comfortable, and secure navigation through the urban environment.

3 RESULTS AND EVALUATION

The app was available on the university server, making it possible for each student to test it. As a result, the app proved that its routes are safer than classical ones that don't take into consideration safety measurements. Whilst the classical apps always aimed for the faster route, thus including dark alleys in their routes, our app avoided the at any cost approach, finding an alternative in more illuminated areas. Also, the classical apps avoid crowded areas, but our app finds those particular paths more favorable for walking at night because a woman can feel that she's not alone.

Moreover, to ensure the strict access of only women to this feature in our app, we have developed a security feature that allows only women to access these routes by using an OCR algorithm for validating their sex using an ID.

4 RELATED WORK

Researchers have also explored combining smartphones with wearable IoT devices for women's safety. Gehani and Ponnusamy (2024) describe a comprehensive AI-based women's security system involving a smart wearable (e.g. a device worn like a pendant or on clothing) connected to a mobile app [5]. Their design uses sensors like a microphone, heart-rate monitor, and accelerometer to detect signs of an attack or panic, for instance, voice recognition to detect a scream, elevated pulse, or sudden movements [5]. Upon detecting danger, the system would automatically activate a built-in electric shock module to disorient the attacker (a form of immediate self-defense), while simultaneously sending the victim's location and an emergency alert to her trusted contacts and the police [5]. This study, published as a book chapter in Impact of AI on Advancing Women's Safety, illustrates the inventive ways AI and hardware can be integrated for personal protection.

While these technological innovations are promising, their effectiveness and safety in real-world use are key concerns raised by scholars. In a peer-reviewed survey of 86 personal safety apps available in the UK, Ford et al. (2022) found that many apps offer features like one-touch SOS alerts, live location tracking, and even evidence recording (audio/video) to help prosecute offenders [6]. However, analysis of user reviews revealed significant issues: users reported bugs and false alarms, worry about privacy (e.g. apps that inadvertently expose location data), and uncertainty whether the apps actually prevent violence [6]. The study, published in BMC Public Health, cautions that without oversight or standards, such apps may create a false sense of security and even introduce new risks (for example, if an app shares personal data insecurely) [6].

5 CONCLUSION AND FUTURE WORK

UrbanPathfinders contributes to enhancing the safety of women in urban environments by providing intelligently optimized routes that minimize exposure to risk factors, leveraging real-time geospatial data and machine learning technologies. By empowering users with data-driven navigation options, the application addresses both physical mobility and the psychological sense of safety. As part of our future development plans, we aim to expand the application internationally and tailor it to local safety contexts in different cities.

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