VibeWalk: AI-Powered Safety Navigation System

System Design & Technical Report (Convolve 4.0 Submission)

Project Name: VibeWalk
Submission Category: Semantic Search & Vector Memory Systems
Primary Engine: Qdrant Vector Database

1. Problem Statement

1.1 Societal Issue: The Safety Gap in Navigation

Conventional navigation apps (Google Maps, Waze) optimize primarily for **speed** and **efficiency**. They calculate the shortest path from A to B, often routing pedestrians through unlit alleyways, high-crime zones, or construction sites without warning.

For vulnerable groups **women, children, and the elderly** the "fastest" route is not always the best route. "Safety" is subjective and hyper local; a street that feels safe at 2 PM might be terrifying at 10 PM.

1.2 Impact

- **Fear of Movement**: 45% of women report avoiding walking alone at night due to safety concerns.
- **Information Asymmetry**: Crime data exists (e.g., NYC Open Data), but it is buried in CSV files, not integrated into daily navigation tools.
- **Static Data Failure**: Official crime statistics are lagging indicators. They don't capture real-time temporary hazards like a broken streetlight, a gathered crowd, or harassment incidents that go unreported to police.

1.3 The Solution: VibeWalk

VibeWalk is a **"Safety-First" Semantic Navigation System**. Instead of optimizing for distance, it optimizes for **"Vibe" (Semantic Safety Score)**. It uses **Qdrant** to store and retrieve dense vector representations of the city combining hard crime stats, positive place reviews, and real-time user reports to route users through the safest, most comfortable paths.

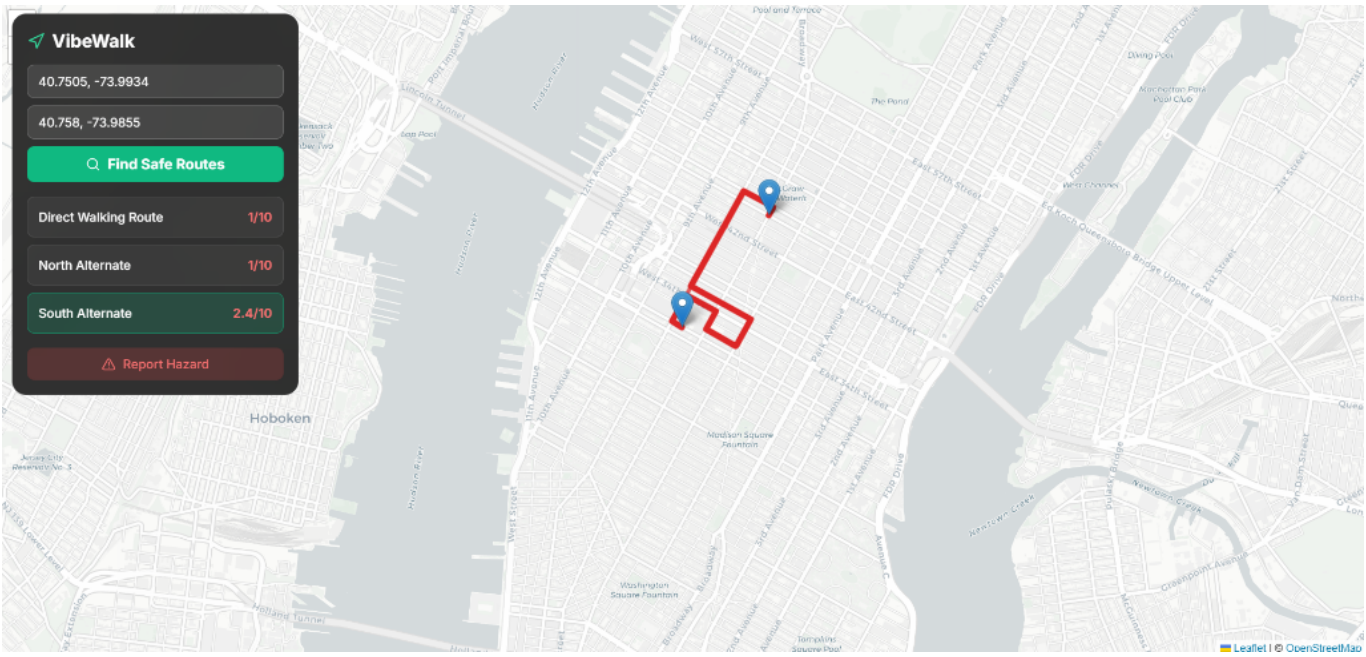

Figure 1: VibeWalk generating safe routes using semantic scoring.

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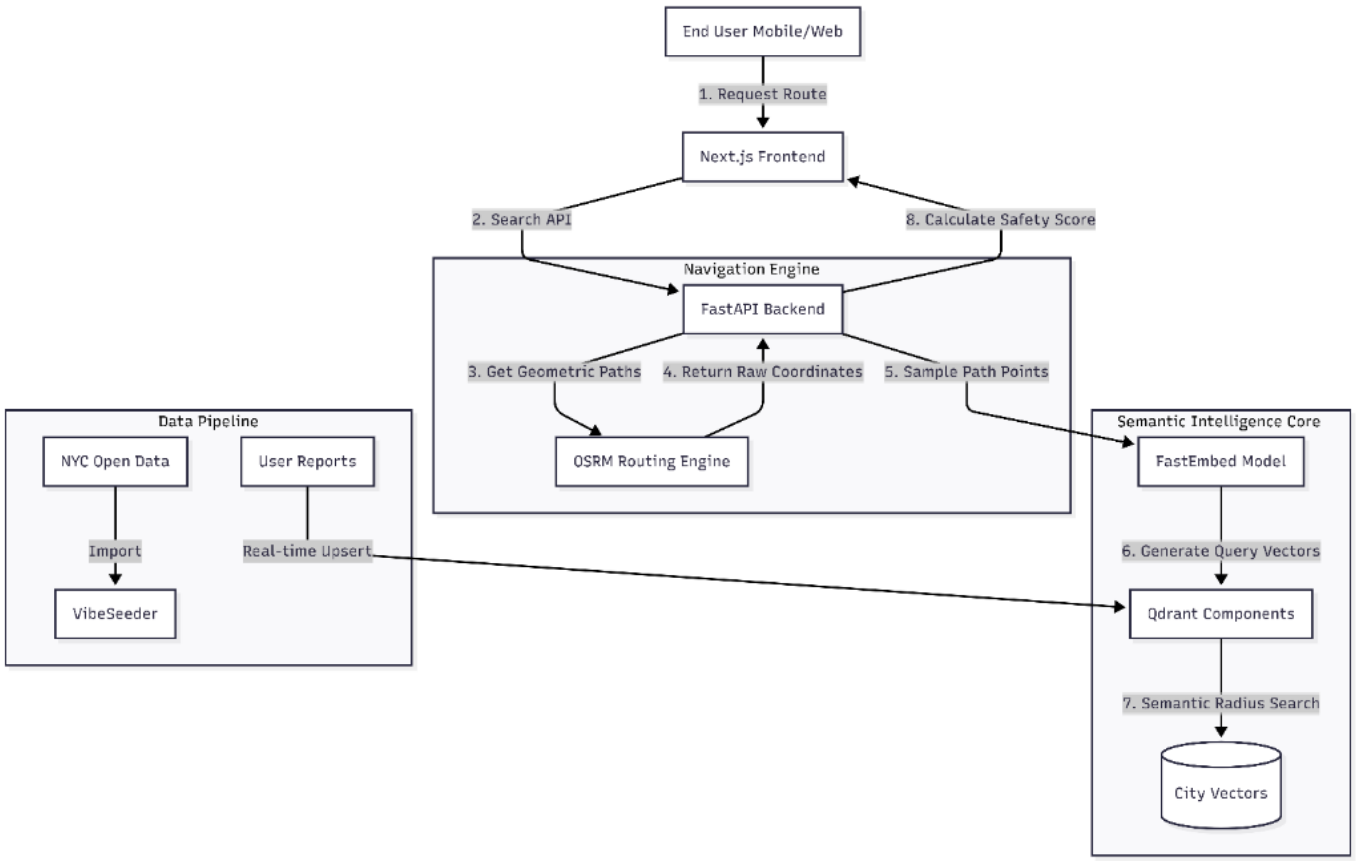
2. System Design

2.1 Architecture Overview

The system follows a modern **RAG (Retrieval-Augmented Generation)** pattern applied to Navigation.



2.2 Why Qdrant is Critical

Qdrant is not just a database for VibeWalk; it is the **Decision Engine**.

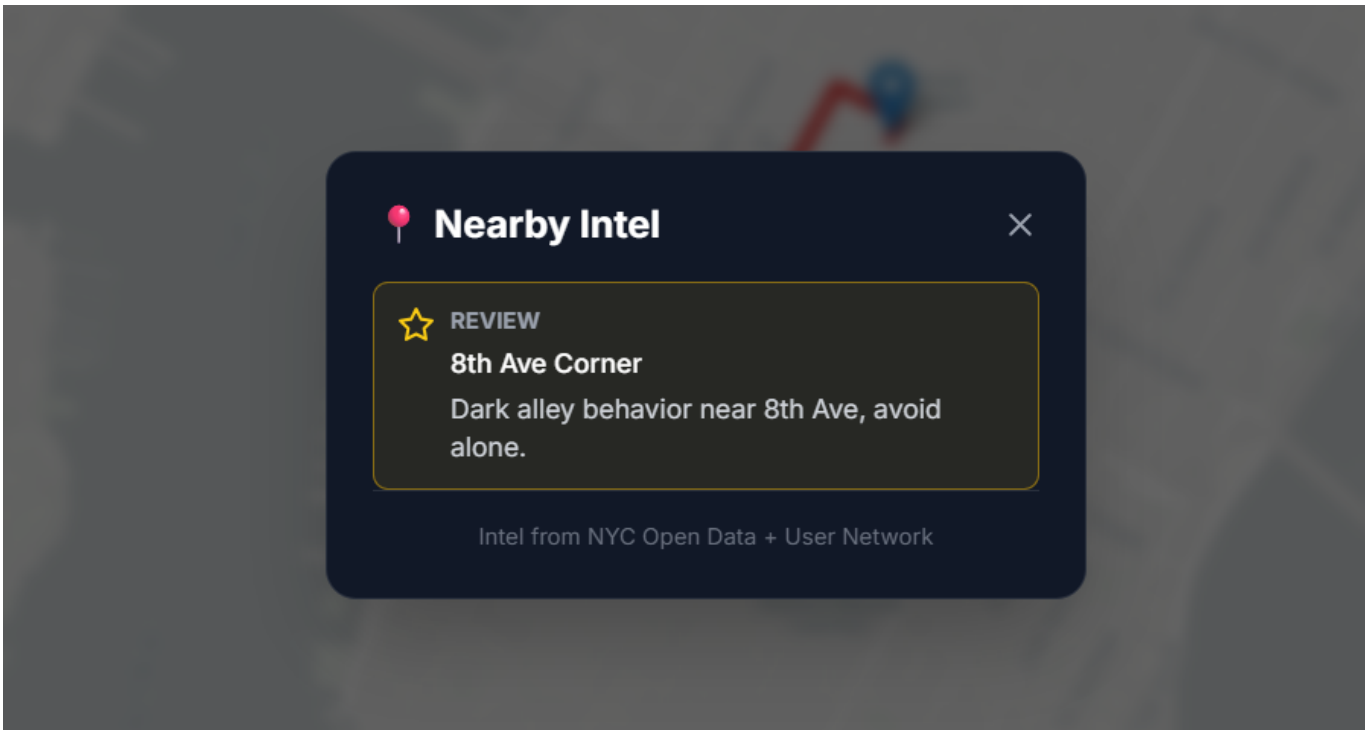


Figure 2: Qdrant retrieving "Semantic Intel" (Reviews) near a user.

1. **Semantic Flexibility**: We don't just filter by "crime_count > 5". We compare the *semantic meaning* of reports. A report of "loud music" implies a different safety profile than "armed robbery". Vector search understands this nuance.
2. **Geo-Spatial Vector Search**: Qdrant's unique ability to combine **Dense Vector Search** (semantic similarity) with **Geo-Radius Filtering** in a single query is the backbone of our scoring algorithm.
3. **Real-Time "Evolving Memory"**: User reports are immediately vectorized and upserted. Qdrant's speed allows these new memories to influence route scores instantly (within milliseconds).

2.3 Database Structure (Payload Schema)

Each "Vibe Node" in Qdrant represents a semantic data point in the city.

Field	Type	Description	Example
`id`	UUID	Unique Identifier	`550e8400-e29b...`
`vector`	`float[384]`	BGE-Small-EN Embedding	`[0.02, -0.15, ...]`
`payload.text`	String	Description of event/place	"Dark alley, saw a fight."
`payload.type`	String	Source Category	`crime`, `review`, `user_report`
`payload.location`	GeoPoint	Lat/Lng	`{ lat: 40.75, lon: -73.99 }`
`payload.timestamp`	ISO8601	Time relevance	`2023-10-27T10:00:00Z`
`payload.severity`	String	Impact Level	`high`, `medium`, `low`

3. Multimodal Strategy

VibeWalk treats the city as a "Multimodal Text". We convert distinct signals into a unified vector space.

3.1 Data Types & Sources

1. **Structured Government Data (Textual)**: NYC Socrata Crime API.
    - *Raw*: "PD Code 101, Assault 3"
    - *Vectorized*: "Violent assault crime report"
2. **Unstructured Social Proof (Textual)**: Place Reviews.
    - *Raw*: "Lovely park with security guards visible."
    - *Vectorized*: "Safe, monitored, family friendly location."
3. **Real-Time Crowd Intelligence (User inputs)**:
    - *Raw*: "Street light broken here, very dark."
    - *Vectorized*: "Low visibility, potential hazard, fear."

3.2 Embedding Strategy

We use **FastEmbed (`BAAI/bge-small-en-v1.5`)** running locally on the backend. This model is optimized for semantic retrieval.

- **Concept Anchors**: We pre-compute "Concept Vectors" for *Safety* and *Danger*.
    - `DANGER_CONCEPT` = Embedding("Crime, assault, robbery, darkness, fear")
    - `SAFE_CONCEPT` = Embedding("Happy, families, well-lit, security, police")

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4. Search, Memory, & Recommendation Logic

4.1 Search: The "Route Scoring" Algorithm

How do we turn vectors into a "7/10 Safety Score"?

1. **Path Generation**: Fetch 3 diverse physical paths from OSRM (Direct, North-Alt, South-Alt).
2. **Sampling**: We sample equidistant points (e.g., every 50 meters) along each path.
3. **Semantic Probe**: For each point, we query Qdrant:

```
# Pseudocode
hits = qdrant.search(
    collection="nyc_vibes",
    query_vector=DANGER_CONCEPT,
    filter=GeoRadius(center=point, radius=100m)
)
```

4. **Scoring**:
    - If `similarity_score > 0.60` (High Relevance Match):
    - Apply **Penalty**: `Score -= Hit.Score * 4.0`
    - The penalty is *semantic*: A match for "murder" (Similarity 0.85) penalizes more than "littering" (Similarity 0.40).

4.2 Memory: Evolving Safety Map

When a user reports a hazard, the system "remembers":

1. **Ingest**: `POST /report` receives text ("Creepy van parked here").
2. **Vectorize**: Convert text to vector.
3. **Upsert**: Store in Qdrant with `source="user_report"` and `timestamp=NOW`.

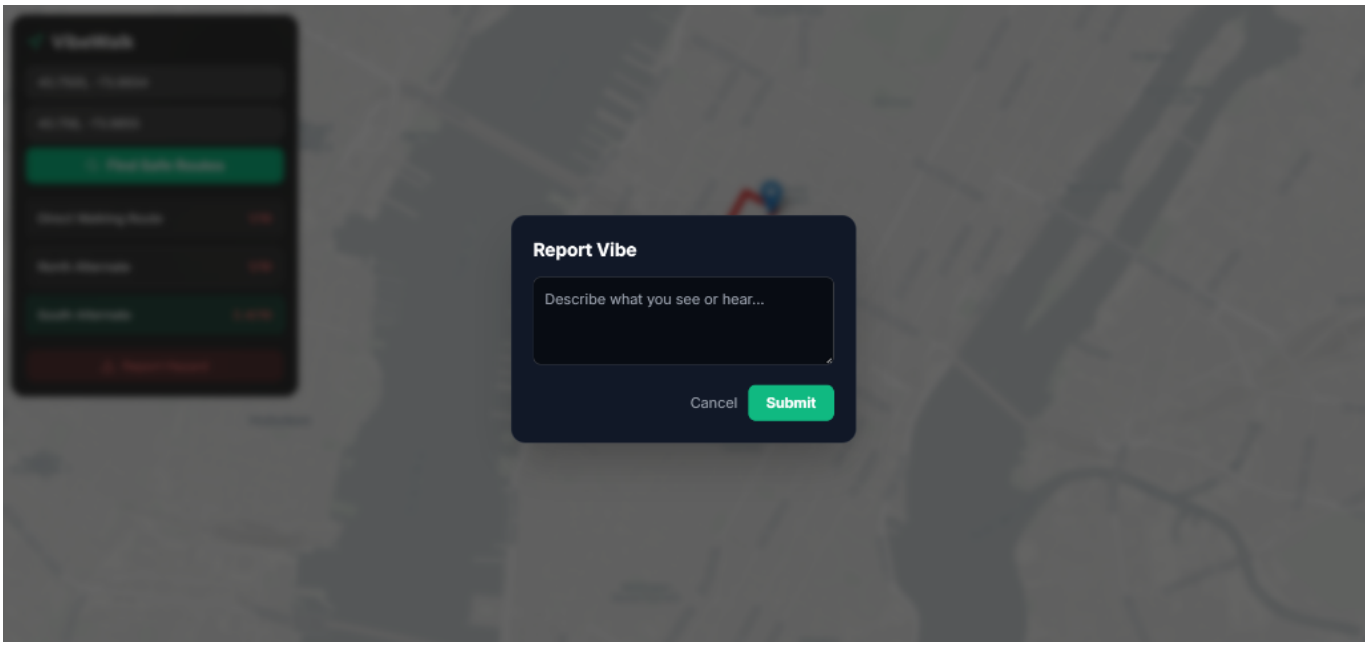

Figure 3: User reporting a hazard, which becomes a permanent vector memory. 4. **Recall**: The *very next* route search query will include this new vector in its search radius.

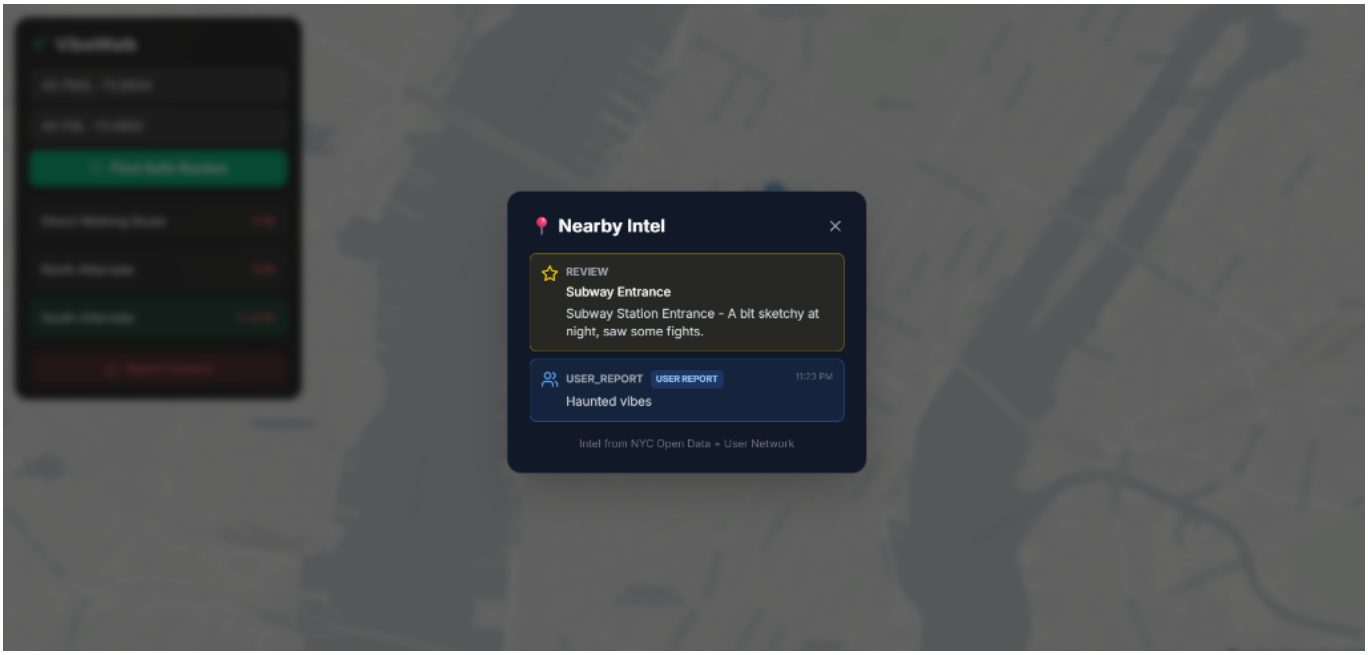

Figure 4: The system recalling a user report as part of its nearby intelligence.

If semantically dangerous, it immediately lowers the safety score of that road segment for *all other users*.

4.3 Recommendation Logic

We don't just warn; we guide.

- **Safe Havens**: We query for `SAFE_CONCEPT` (Reviews, Open Businesses).
- **Contextual Display**: If a route is dangerous, the frontend suggests "Safe Havens" (e.g., "Starbucks (Open)", "Police Station") along the path as waypoints.

5. Limitations & Ethics

5.1 Algorithmic Bias

- **Risk**: If "crime" data is historically biased against certain neighborhoods, the AI might flag minority neighborhoods as "unsafe" unfairly.
- **Mitigation**: We mix in **Positive Reviews** (Social Proof) to counterbalance raw crime stats. A busy street in a "rough" neighborhood might be safer than a deserted street in a "rich" one due to "eyes on the street" (Jacobs' efficiency).

5.2 Failure Modes

- **Sparse Data**: In areas with no reports or reviews, the system defaults to "Safe" (10/10), which is a false negative risk.
- **Adversarial Attacks**: Bad actors could spam false "danger" reports to reroute traffic.
  - *Future Fix*: Reputation systems and outlier detection using clustering mechanisms in Qdrant.

5.3 Privacy

- User location data is transient (sent for routing) and not stored.
- User reports are anonymized before vectorization.

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6. Future Roadmap

6.1 Visual Evidence & Photo Verification

Currently, VibeWalk relies on text. Future versions will allow users to **attach photos** to their reports (e.g., specific images of broken infrastructure or dangerous conditions).

- **Multimodal Learning**: We will integrate **CLIP-based models** to "read" these images. If a user uploads a photo of a dark alley, the system will automatically extract vector concepts like `darkness`, `isolation`, and `decay` without the user needing to type a description.
- **Trust & Verification**: Photos provide a "proof of work" to combat fake reviews. A report of "graffiti" accompanied by a verified photo is weighted higher than text alone.

6.2 Advanced Safety Features

- **IoT Integration**: Connecting with smart city APIs to ingest real-time data from connected streetlights and noise sensors.
- **SOS & Emergency Mode**: A "Panic Mode" that instantly shares the user's location with trusted contacts and routes them to the nearest "High Safety Score" safe haven (e.g., Police Station, 24/7 Store).
- **User Reputation System**: A gamified trust score for reporters. Users with a history of verified, helpful reports will have their inputs weighted more heavily in the safety algorithm.

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7. Conclusion

VibeWalk demonstrates that **Vector Search** is more than just a "Create-Read-Update-Delete" (CRUD) tool. It is a logical reasoning engine. By encoding the *qualitative* feeling of safety into high-dimensional space, we

provide a tool that protects the most vulnerable members of society, translating "Vibes" into actionable, life saving navigation decisions.