Godspeed

Alternative navigation system
for safer pedestrian travel.

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Godspeed

by
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Pedestrian safety in Berkeley, a growing concern post-pandemic amid increased crime, prompts the need for targeted strategies. While the city's violent crime rates remain comparatively low, specific offenses and assaults have risen. A study by Berkeley Safe Transportation Research and Education Center reveals crime on 21456 out of 24871 streets in the last two decades. Community engagement and addressing socioeconomic factors are vital for improvement. User research indicates a widespread feeling of insecurity among pedestrians, prompting a project integrating surveys, crime data, and streetlight information to create a safety-rated map. An algorithm offers alternative routes optimizing distance and safety. Despite reliance on crowdsourced data and biases, this initiative seeks to enhance collective responsibility for safer navigation. Future endeavors involve refining data systems considering social and spatial parameters for a comprehensive safety evaluation.

Pedestrian safety in Berkeley has been a concern for the last few years especially post-pandemic when the city has seen a surge in crime and unsafe activities. While the city maintains relatively low violent crime and homicide rates compared to national averages, there have been increases in certain types of crimes and assaults. According to Berkeley Safe Transportation Research and Education Center, 21456 out of 24871 streets in Berkeley have reported some form of crime in the last 20 years. Continued emphasis on community engagement, targeted crime prevention strategies, and addressing underlying socioeconomic factors is crucial in further enhancing pedestrian safety in Berkeley. User research conducted in this exploration suggests pedestrians in Berkeley do not feel safe while they walk down the street in the city of Berkeley owing to these unsafe events that occur. Based on surveys conducted by the author, these pedestrian subjects wish to navigate their way around the city feeling safe. Hence, the first part of the project explores data collection and processing where pedestrian subjects are invited to rate various points within the city based on their perception of safety. This information is combined with WarnMe crime data and streetlight data of the city to generate a safety-rated map of Berkeley. A custom algorithm is designed to provide alternative routes optimizing distance and safety to provide the user with routes for safer navigation. A limitation of this project lies in defining 'perceived safety' along with the quality of crowdsourced data and the inherent biases that accompany it. This work focuses on an implementational approach to pedestrian safety navigation that shall help users get a better understanding of the routes they take, enabling collective responsibility and safer experiences. A large part of the future work would entail building robust data collection and processing systems, taking in the context of various social and spatial parameters to evaluate the perception of safety on a more holistic level.

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by
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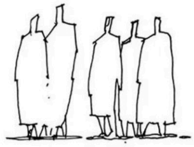

Dadun, Main, Dinna and Dadai - this is for you.

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History/Prior Art

Urbanization is a notable global trend, with cities housing more than half of the world's population [1]. While cities provide potential for economic growth and cultural interchange, they also pose considerable obstacles, particularly in terms of pedestrian safety. Pedestrian safety is especially important in heavily populated metropolitan areas. Maps and street signs, for example, typically fall short of reflecting the dynamic and complicated nature of urban settings. This study of the literature examines the current issues in pedestrian safety in urban contexts and calls for the introduction of novel navigation mediums as a critical step toward improving urban safety.

Kaplan in 'Humanscape: Environments for People' [2] posits that urbanization is a fundamental motivation behind the increasing requirement for better pedestrian system frameworks. Faster urban growth results in higher population densities which result in greater urban footfall and an increased exposure to pedestrian hazards. The result produces not only the greater likelihood of pedestrian accidents and injuries but also the rise of unsafe activities adding to the skewed definition of urban safety in today's context. The latter is well outlined in 'The Influence of Perceived Safety and Security on Walking' by Fyhri et al. [3] where they explore the relationship between a pedestrian's perception of security and safety and their walking behavior. This particular work highlights the various factors that dictate people's decisions to walk in certain situations contributing to the subjective nature of this perceptive aspect of pedestrian behavior recognising that different social and environmental factors influence an individual's perception of safety and security while walking on the streets. The fundamental idea of perceived safety being central to this research forms a foundation for an implementation-based approach to this subject - it encompasses that pedestrians inherently perceive safety influenced by a myriad of factors that are not necessarily limited to lighting conditions, visibility, crime rates, and the presence of pedestrians or other individuals.

While I discuss novel implementation navigation systems, what crosses our investigation is one of the most fundamental methods of navigation - maps; which is explored in depth by Clive Thompson [4] - where he explains how maps from the time of Ptolemy and the Roman era has transitioned from a primary source of storytelling to an instrument of spatial fact-checking. As maps were revered as symbols of power and knowledge in the past, the ubiquity of technology has put this power in the hands of most technology consumers in today's context. However, in this spatial knowledge, there still are actionable aspects that are tied to different socio-economic aspects (like urban safety or urban comfort) that can be unlocked by leveraging the same.

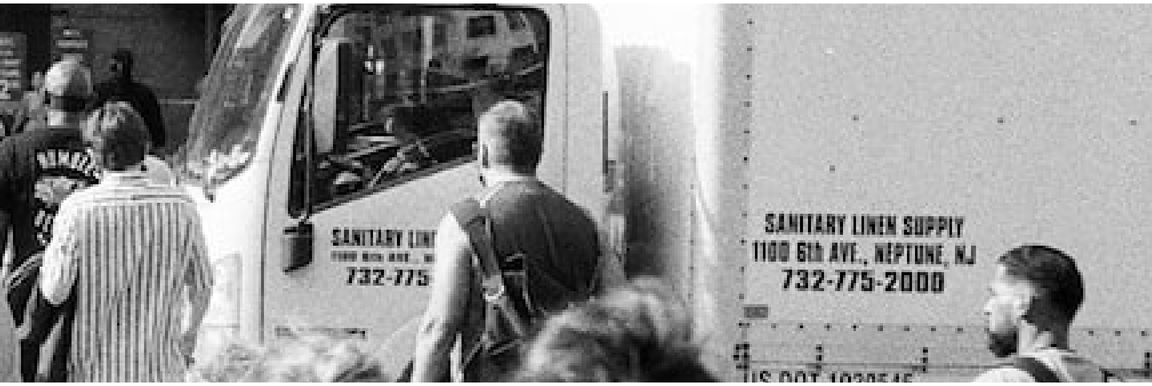
On the other hand, Greg Milner [5] posits how navigation using novel mapping technologies has transferred the burden of cognitive navigation from the user to the technology which makes me think as to what extent can this be exploited to make spatial navigation holistically better and 'seductive' as said by Milner. As I speak about the ubiquity of such technology, the economic aspect of scaling such technology must also be considered as the socio-economic conditions of certain places call for the intervention of inexpensive technology to support every social strata [6].

Over the years different algorithms have taken shape referencing different crevices of mathematics that contributed to accurate mapping of space and navigation in general. One of the most ubiquitously used algorithms for navigation is Dijkstra's algorithm [7] to find the shortest path in a graph. For many years, researchers have been studying the shortest path problem. The shortest path problem is concerned with determining the shortest distance or pathway between nodes or vertices in a graph (in this case, a road network). There are numerous variations of the algorithm. The original Dijkstra algorithm discovered the shortest path between two given nodes, but a more frequent form fixes a single node as the "source" node and finds the shortest pathways from the source to all other nodes in the network, yielding a shortest-path tree [8]. This particular variation is leveraged in this research exploration where another factor (perceived safety) is introduced to appropriately optimize between the shortest distance and safety perception rating of each node. Because of its completeness, optimality, and optimal efficiency, another algorithm called the A* algorithm is used which is basically a graph traversal and path search method that is employed in many domains of computer science [9]. One significant practical disadvantage is that it has greater space complexity because it saves all created nodes in memory. Thus, it is often outpaced in actual travel-routing systems by algorithms that can pre-process the graph to achieve higher performance, as well as memory-bounded techniques; yet, A* is still the best answer in many circumstances [10]. In contrast to Dijkstra's method, the A* algorithm only determines the shortest path from a given source to a given goal, rather than the shortest path tree from a given source to all potential goals. This is an unavoidable cost of employing a goal-directed heuristic. Since the entire shortest-path tree is constructed by Dijkstra's method, every node represents a goal, and there can be no specific goal-directed heuristic.

Applying these algorithms has been a common practice in the domain of spatial navigation. One particular place of inspiration is MIT's Senseable City Lab's 'Pointiest Path' project which serves as a point of reference in implementation-based mapping algorithms and how custom use cases can be generated by using computational tools for an application like urban safety [11]. The project mentions that human path planning can be near-optimal while exhibiting significant systematic divergences in the calculated shortest path - these divergences come from a certain mental computational mechanism that this project models in quantitatively precise terms to generalize across different urban environments.

The formal computational definition of such mechanisms can definitely inform the design of custom spatial navigation tools that can account for different subjective aspects like safety and comfort. My research exploration aims to couple human and machine intelligence, bringing the subjective and the objective to spatial navigation.

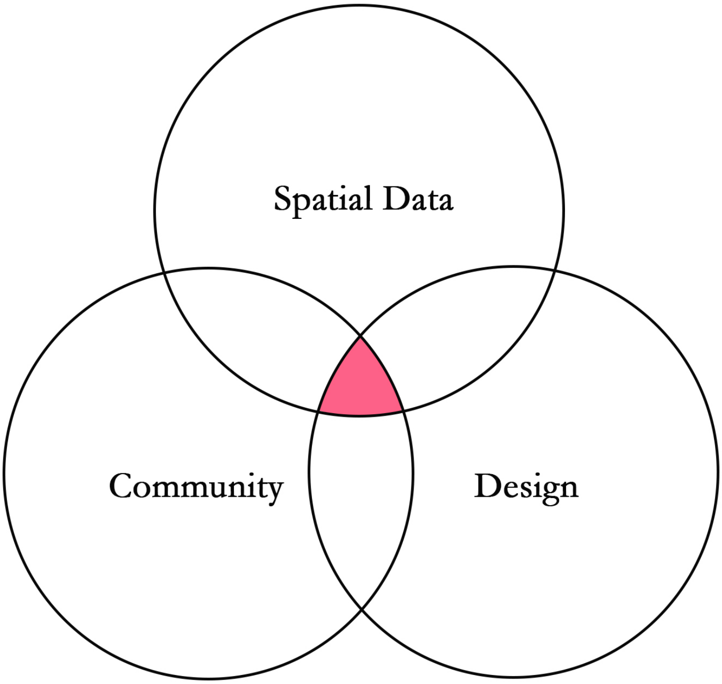
I understand my contribution as a continuation of research in novel spatial navigation intelligence in the field of urban design and space planning. For this particular work, I want to test out an implementational navigation system that can account for subjective perception-based parameters like safety and produce alternative routes based on optimization.

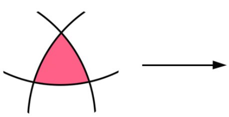


Motivation

The primary motivation for this project stems from the rising crime rates in the city of Berkeley post-pandemic [12]. Berkeley being a college town, sees a large influx of migratory students and personnel associated with the academic ecosystem of the city. It is important to understand how unsafe events/circumstances can hamper the development of a healthy and functional pedestrian commute system in any city - especially in a city like Berkeley where the population mostly comprises young adults [13]. With this premise in mind, the need to build systems that promote the idea of a safe commute becomes paramount.

The secondary motivation to build this system pertains to the indirect contributions that unsafe circumstances extend toward pedestrians in Berkeley. Among them the most important aspect is how increased unsafe activities in the city have contributed to pedestrians reducing their work hours to walk home/ to their destinations safely avoiding unsolicited interventions while they travel - this affects students the most [14]. A survey of 41 students at UC Berkeley reflected this occurrence among 58% of the responders. The second aspect pertains to the increased cost of transportation incurred to ensure one's safety [15] - 83% of pedestrians in Berkeley surveyed for this study reported that they frequently take rental cabs (Uber, Lyft) as a way to reach a destination safely. From a walkability perspective, this is less favorable given the social and climatic effects of such pedestrian habits. Lastly, another aspect that this project tries to touch upon - is the impending mental health crisis that unsafe events contribute to [16]. 4 out of 7 interviewees mentioned that such events leave a lasting impression on their memory even if they are witnesses to an event let alone be the victim of it. These surveys and interviews reflected the need for pedestrians to 'feel' and be safe from such events/circumstances irrespective of the circumstances prevailing in the city





Godspeed

Method/Approach

The research methodology for this project is bound by the principles of human-centric design which started with the 31 user interviews of pedestrians ranging from the age of 19 to 53 in Berkeley [17]. They were subjected to surveys detailing their walking experiences in the city at different times of the day and subjective and objective evaluations of different aspects of walkability in the context of pedestrian safety. One of the fundamental insights gathered from primary research was that our respondents were mostly concerned about 'feeling' safe while they walked the streets of Berkeley, especially after 7 pm. Even if the locations these people were traversing did not necessarily have spots for recent unsafe activities, the 'unsafe feeling' still hampered their walking experiences. This insight helped to pivot the direction of the project toward the idea of 'perceived safety'. Further research was primarily conducted to understand the factors that contributed to the respondents' perception of safety.

Through our interviews, I found that one of the most answered aspects to parametrize the perception of safety was that pedestrians have a fixed route to follow while walking to known destinations but have qualms regarding how safe it is on a day-to-day basis. On this note, another thought that was mentioned by our respondents - "Are other people trusting the route or following a similar route during odd hours of the day?". Lastly, one extremely objective aspect that contributed to one's perception of safety was "Whether the route is well lit?". These questions helped us to conclude that potential users are eyeing safer routes or routes that do not have unsafe events occurring around them. These routes have to be well lit abiding by certain rules and regulations to contribute positively to the perception or feeling of safety [18]. The aspect of lighting is explored further in the final design part of the project.

The requirement of safer routes or routes that demarcate a certain level of safety raises the question: how might I design routes that can help people feel safer as they walk? The answer to this lies in the type of data that needs to dictate the definition of safety [19]. Given I are primarily working with the 'perception' of safety - subjective ratings of respondents about how safe they feel about walking is one of the fundamental data points that can guide route creation [20]. From an objective point of view - locational data regarding unsafe events occurring in Berkeley forms the backbone of the route generation process given this reported data is not only computational but also the foundation for this project's motivation. Lastly, data regarding street illumination is considered another objective parameter in defining the definition of perception of safety[21]. The sources of data that are selected for the respective processes are detailed in the final design section.

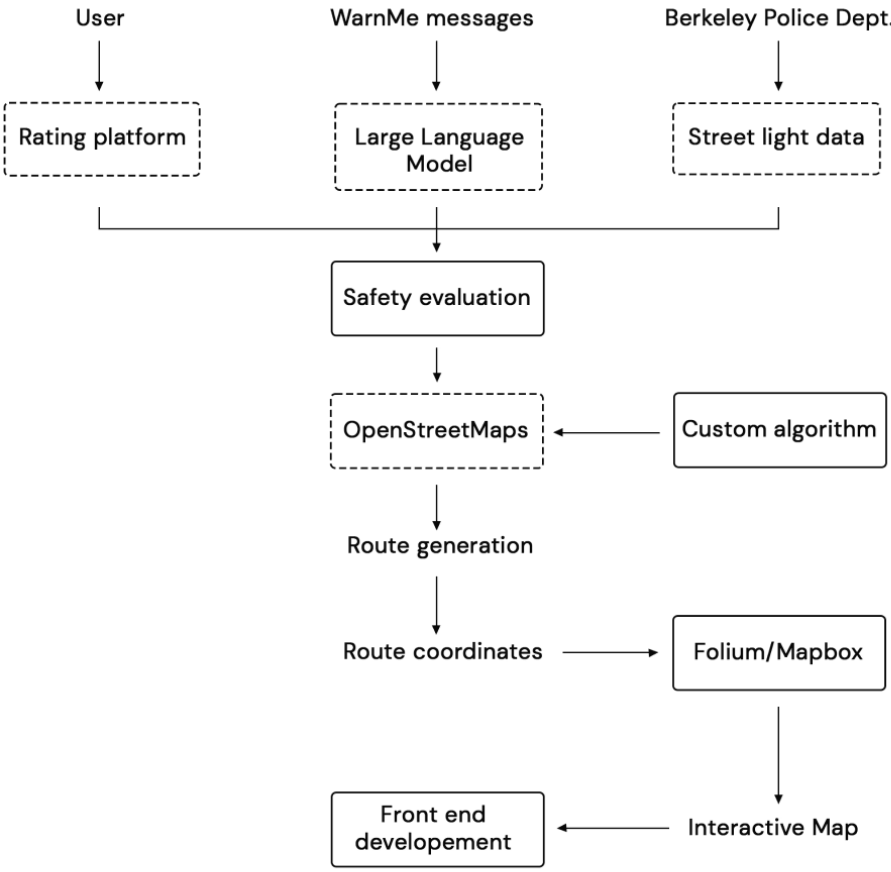


Figure 1: System map

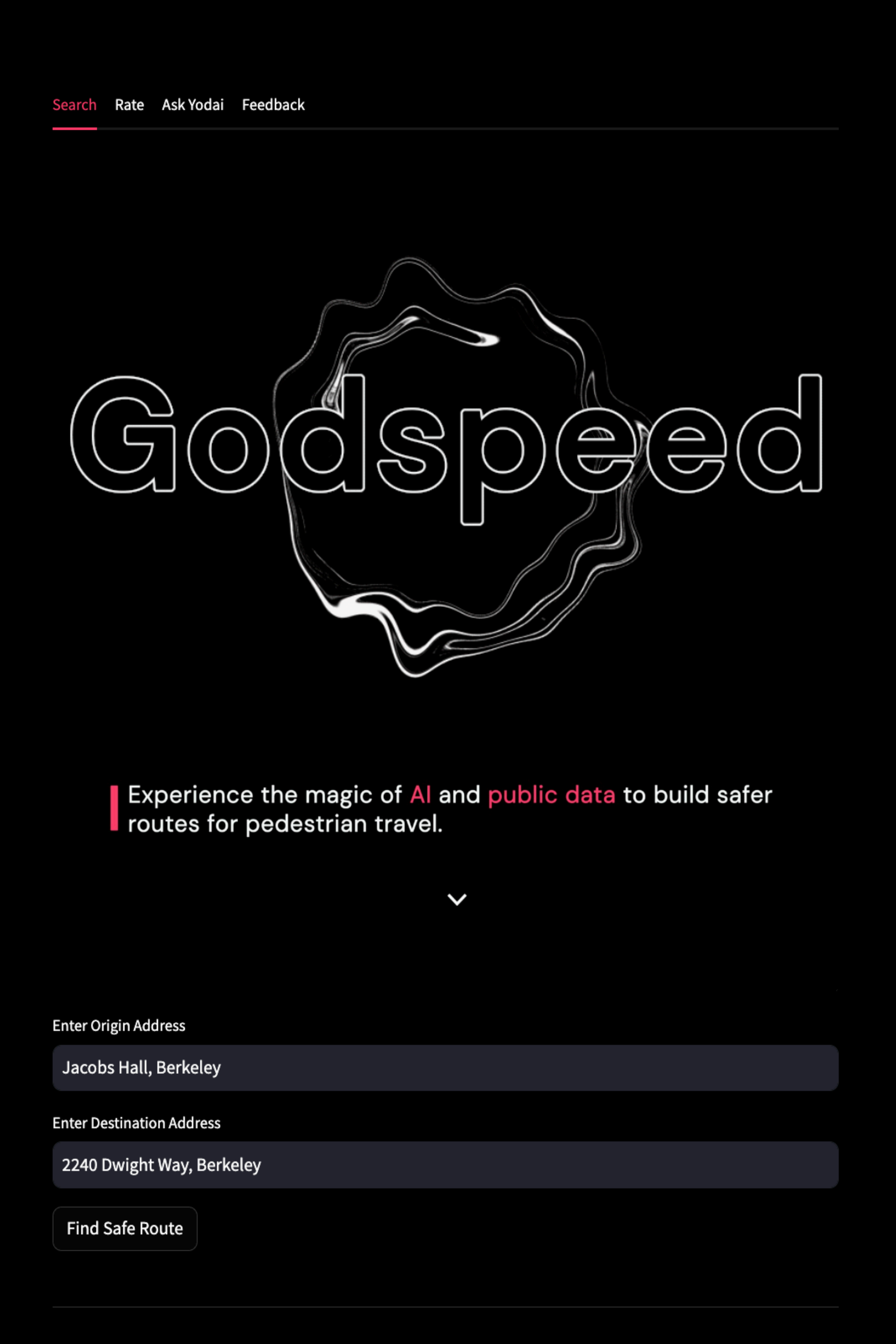
A comparison between the shortest (red) and the safer route (yellow) produced by Godspeed.

A route generation algorithm was designed inspired by Dijkstra's shortest path algorithm [22] that would parse through the road network of Berkeley as a graph and generate safer routes. This algorithm is a novel attempt at redesigning how conventional route generation algorithms work, where I aim to optimize perceived pedestrian safety and distance at the same time. Research was conducted concerning the different tools that could be used to build this algorithm. A variety of options are present in terms of altering routes based on a custom set of coordinates on platforms like Mapbox with their API [23], Google Maps with their Navigations SDK and Directions API [24] and lastly, I have Open Street Map [25]s.

Furthermore, I started working on the different iterations of the final form factor of the navigation system. Historically a common release strategy for such tools has been in the form of mobile applications [26]. However, as a form of a pilot I wanted to first test it out as a website for two reasons - first, to overcome trust issues [27] concerning downloading an app and second, to facilitate navigational assistance both on a desktop/laptop and on a mobile device. Lastly, I carried out iterations concerning how much data to show and what is the appropriate visual language for representing the same. The details are further elaborated in the final design section.

Final Design

The final design can be divided into 3 parts - data collection, the safer route generation algorithm and lastly encapsulating everything under a single web app (creating an interface).


Search
Rate
Ask Yodai
Feedback
Godspeed
Experience the magic of AI and public data to build safer routes for pedestrian travel.
Enter Origin Address
Jacobs Hall, Berkeley
Enter Destination Address
2240 Dwight Way, Berkeley
Find Safe Route

Data Collection and Processing

The data collection happens in three stages - first, a rating platform is created containing a simple form asking for the respondent's name, the address of the location they wish to rate, and their rating on a Likert scale of 1-10 [28]. Once the rating is recorded, it is reflected on a map on the same screen that shows all the ratings that other users have given to places in Berkeley. All of this is done anonymously when it comes to showing the data to the users. This method was preceded by a simple Google form during the pilot stage where respondents had to input the same set of information but without the interactive visualization aspect. Once the data is collected, the addresses are converted to latitudes and longitudes to find the nearest node associated with that location. The 'safety rating' is then attributed to this particular node. Since multiple people rate the same place differently, I process the data by simply taking an average of the ratings inputted. This 'safety rating' is called the 'safety_score'. One fundamental aspect to be aware of in this context is taking a simple mean might not be the best approach to consolidate the ratings into one value - primarily due to the different biases and demographic factors that prevent neutrality [29] from being achieved by employing a simple mean. This caveat is further explored in the final design section of the project.

Once I have the safety rating from the respondents, I move to the second phase of the data collection process: UC Berkeley WarnMe messages [30] - these are emergency notifications that are sent upon confirmation of a significant emergency or dangerous situation that involves an immediate threat to the health or safety of students or employees. A Python script was written to parse through the author's UC Berkeley-affiliated email to download every message sent by UC Berkeley WarnMe. This raw text data is compiled as a PDF document with appropriate time stamps for those emails. Now I perform a process called Retrieval Augmented Generation (RAG) [31] using a Large Language Model (LLM) [32]- GPT 3.5 turbo from OpenAI [33] in this case. The LLM is trained locally by injecting contextual information - in this case, the WarnMe messages to learn from that information on top of the array of data it possesses. Pre-trained Large Language Models can produce state-of-the-art outputs if fine-tuned on downstream natural language processing tasks along with the factual knowledge that is stored in their parameters [34]. However, they have limited ability when it comes to accessing and precisely processing/manipulating knowledge, therefore behind task-specific architectures, their performances have shortcomings. For this reason, a general fine-tuning technique called retrieval augmented generation is utilized. It has the ability to combine pre-trained parametric and non-parametric memory for an array of language generation use cases.

One of the use cases is for structuring unstructured data - as I see crime data present in the WarnMe messages are in the form of plain text and any actionable data analysis or data handling is difficult, but LLMs with RAG abilities can extract specific knowledge from plain text to output data in a form that can be used with natural language prompts.

With this process, I get a list of addresses with their coordinates, and their nearest nodes (if they don't exist on a node), and count for the number of incidents that have taken place in the last 48 hours. The 'number of incidents' counter serves as the 'incident_score'. The cut-off has been kept to 48 hours for two reasons - first, incidents get reported by WarnMe within 24 hours, if not 48 hours, and second - since the data is updated on a daily basis, keeping a log of outdated data can lead to the spread of misinformation [35].

One interesting aspect of this project that was revealed through different user interviews was the importance of street lighting as a metric to understand perceived safety - respondents were more likely to feel safe in a well-lit neighborhood than in a neighborhood devoid of appropriate lighting conditions. Secondary research on this aspect has also corroborated the fact that street illuminance levels play a fundamental role in deciding the 'Feeling of Safety'. It is a common misconception that there is a universally accepted principle for such illumination requirements; however, research suggests that illumination anywhere between 5-10 Lux within a stretch of 10-20 meters can be adequate to contribute positively to the 'Feeling of Safety' [36]. Illuminance beyond this range has seen minor rises in the 'Feeling of Safety' and might result in economic consequences in terms of public governance.

This insight brings us to the last form of data that I collect - street light data: 'City of Berkeley Open Data' has open-source resources to download and use data regarding street lights in Berkeley [37]. The labels for such data are mainly facility id, installation details, wattage, coordinates, current condition, and mechanical details. Out of these labels, our project mostly deals with the current condition of the street lights and their coordinates. Research suggests that it takes 5-10 Lux of illumination from streetlights to have a positive impact on a pedestrian's feeling of safety [38]. The data from the City of Berkeley's website suggest that the wattage of these street lights varies within a range of 100-150 Watts and given the area it covers, the illuminance of two lies beyond 10 Lux - so with the question of illuminance resolved, I have to see if a node has street light presence/ are they functional? or is the area dark? A Python script is created that associates every node in Berkeley with the number of street lights in a radius of 10 meters. If a node has only one streetlight is flagged as a -1 and the ones with more than one streetlight are marked '1'. I call this the 'streetlight_score'.

The final safety score is a function of all these three scores combined. Mathematically, the final safety score (final_safety_score) is generated by subtracting the 'incident_score' and adding the 'streetlight_score'. Given the individual relationships between these scores are a topic for deeper urban design and planning research, the formulation to arrive at a final safety score can be more complex and nuanced based on consideration of other on-ground factors [39]. Keeping in mind the scope of the project which deals with designing an alternative navigation system this formulation was adopted for the final design.


How
safe do
you feel?

Safer Route Generation Algorithm

Now coming to the Safer Route Generation Algorithm (S.R.G.A) - The first step involves using the OpenStreetMaps (OSM) library in Python to generate a road network of Berkeley in the form of a graph comprising 8236 nodes and 24390 edges. A node represents a point in the network and edges are lines that connect the points [40]. The different safety scores collected from the data collection process have addresses associated with them. A simple Python script is written to find the adjacent node to these addresses. With nodes correlating to their respective safety scores, I have a network with a certain value for each point connecting the city.

The second step involves using OSM's shortest route generation method which is based on a variation of Dijkstra's shortest route algorithm [41]. Two locations are randomly selected for this experiment where the shortest distance between these two locations is mapped out by the method. This shortest route generation between points A and B (say) is done for reference purposes only. Along with the route, other route attributes like distance, the list of nodes it touches upon, and the time needed to walk are recorded for comparison purposes.

Next, for the node from the first point of the route (origin node) with a safety score, I find its neighboring nodes. Now here I employ a few checks to make sure our route generation process is not interrupted. The first check I employ is one for dead ends in the road network- I find the neighboring nodes of the initially generated neighboring nodes and find whether the origin node is found in the second generation of neighboring nodes. If it is found then the node from the initial node generation list is removed because that node represents a dead-end point. The second check I employ is for loop detection - if any road network results in a loop then our code shall go into an infinite iterative state. So I check for repetitive nodes in both the neighboring nodes list and remove any parent node that has repetitive neighboring nodes because these results in looped routes.

After all such unwarranted nodes are removed, I get a set of neighboring nodes which are probably the next destination(s) from the origin point. Next, I find the network distance between the neighboring nodes and the final destination node. Now for each neighboring node, I have two values - their distances to the final destination and their associated safety score. These values are passed through a cost optimization function that maximizes the safety score and minimizes the distance [42]. Different weights are assigned to route length and safety score to achieve a cost-optimized value. These values are then compared to each other to find which value is the greatest. The node with the greatest value is then selected as the next node after the origin node.

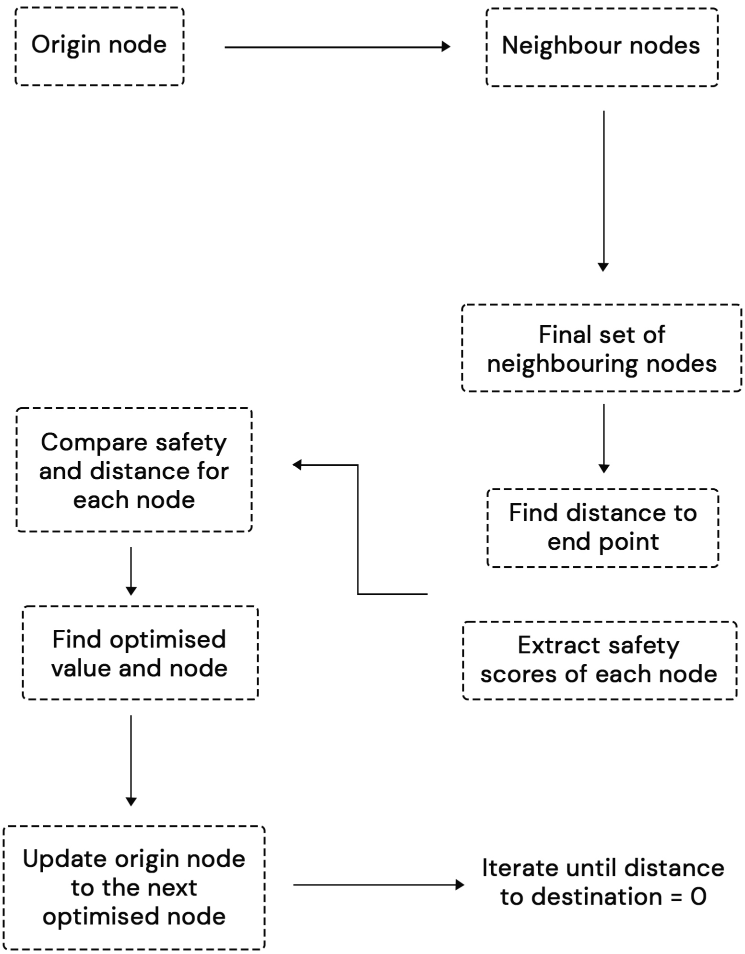


Figure 3: Safe Route Generation Algorithm workflow

After the algorithm has deciphered the next node after the origin node, it keeps repeating this process until it successfully reaches the node nearest to the destination point. An iterative function is used to achieve this where it stops once a specific destination node is detected. One caveat to this process is that often the destination point does not directly lie on the route connecting the origin node and the destination node. In this case, I see that the algorithm misses out on the right destination node and proceeds forward entering an iterative loop. To prevent that another check is introduced at the beginning to verify if the neighboring nodes of any generated node are the actual destination node. If so, the loop stops iterating and the final list of nodes ends there. With this being done, I get a list of nodes in Berkeley that are optimized based on their proximity to the destination point and their relative safety scores. These nodes are then converted to latitudes and longitudes for a mapping library like Leaflet or Folium to interpret [43].

The final step involves using Folium- a Python library that helps process locational data and create maps using Leaflet.js, where the generated coordinates are used to map a polyline on an interactive map of Berkeley [44]. This output is what users interact with. Location markers are placed at the starting and destination points to demarcate the same.


check n-n

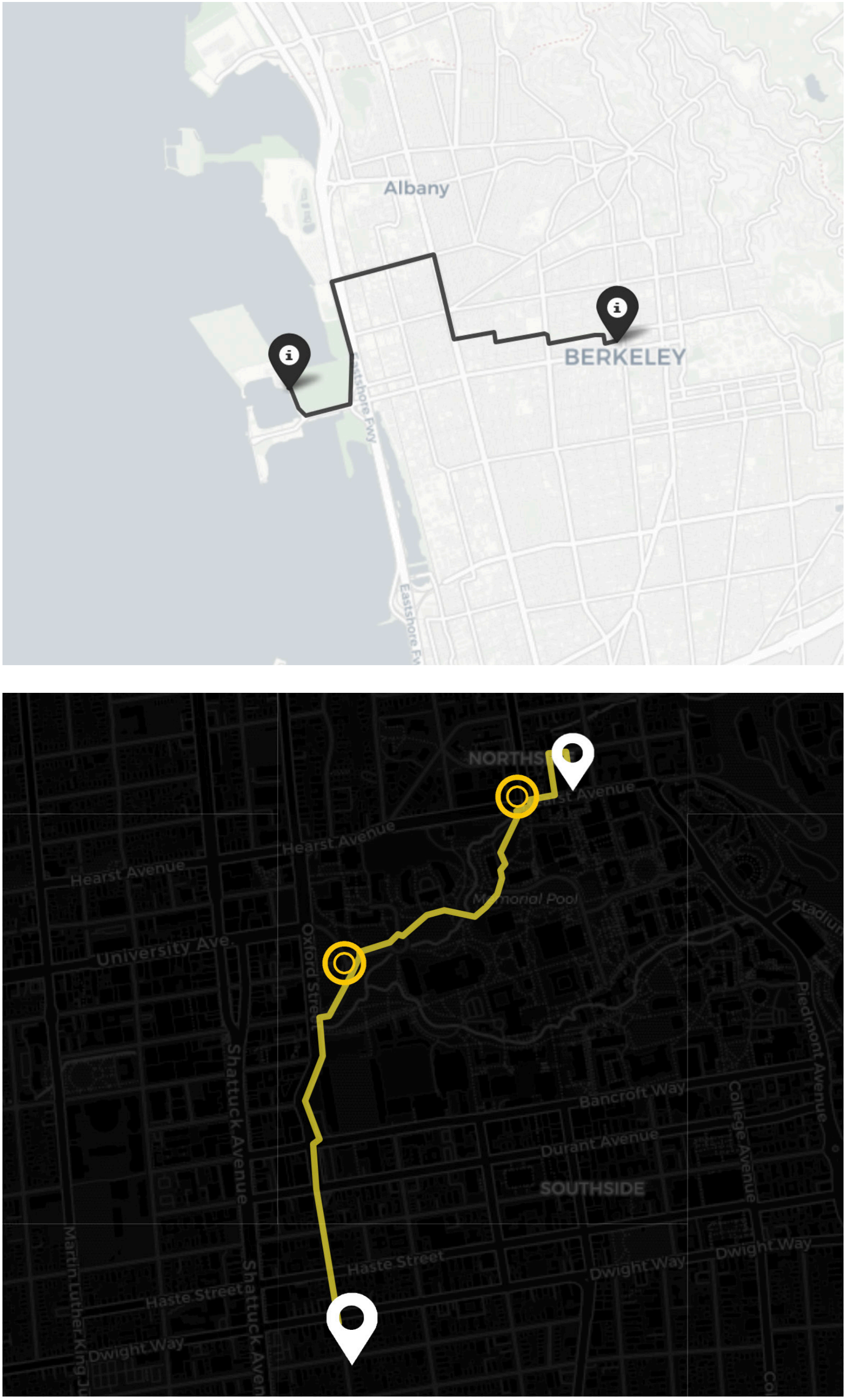


Figure 4 & 5: Light (top) and dark (bottom) mode for interactive maps

Streamlit Web app

The previous two phases deal with the backend architecture of Godspeed where I process data through the Safer Route Generation Algorithm to generate a route that is judged considered 'safer' than all other route permutations. I encapsulate this entire backend process in a Streamlit application. Streamlit is an open-source app framework in the Python language that is adept at creating deployable web apps for mainly data science and machine learning purposes. Streamlit as a platform is useful for quick deployment since there are no callbacks involved as the different widgets are treated as standalone variables [45]. Along with this, additional capabilities like data caching speed up computation-intensive workflows like in this particular case. The front-end of the web app has some simple features - the ability to generate routes based on user-inputted current and destination addresses, to be able to receive feedback on the output from the user, rate places on the web app itself, and general information displayed about how this project works in terms of data collection and route generation. The aspects to be displayed are deduced from the insights generated from various primary user surveys and user interviews.

When it comes to UX, the primary flow to generate safe routes has been kept simple. It is inspired by Google Maps given the user base that uses Google Maps are potential users for Godspeed too [46]. The user opens the platform on their phone, navigates to the search sections to enter their addresses, and presses the 'generate safer route' button, and the alternative route is generated. This familiar navigational flow lowers the barrier to entry when it comes to learning to use a new navigational tool [47].

Yodai

Most of the interaction in Godspeed happens in the form of either maps or text. In order to make the user experience more intuitive and fluid when it comes to navigational communication, one aspect that Godspeed needed to include was conversations. So a conversational AI agent was designed to be injected with the existing data garnered by Godspeed (using R.A.G) along with immaculate access to the internet. This was made possible with the Langchain development framework for AI agents. The primary purpose of Yodai is to access UCPD crime logs to update data information with respect to the current safety scenario. This would eventually help answer basic safety-related queries like " Is it safe to travel through a certain location right now?". Currently, Yodai has access to basic tools like a calculator and clock to execute basic computations asked by the user. In the future Yodai is envisaged to be equipped with advanced tools like multimodal document search and real-time automation without any human internvention.

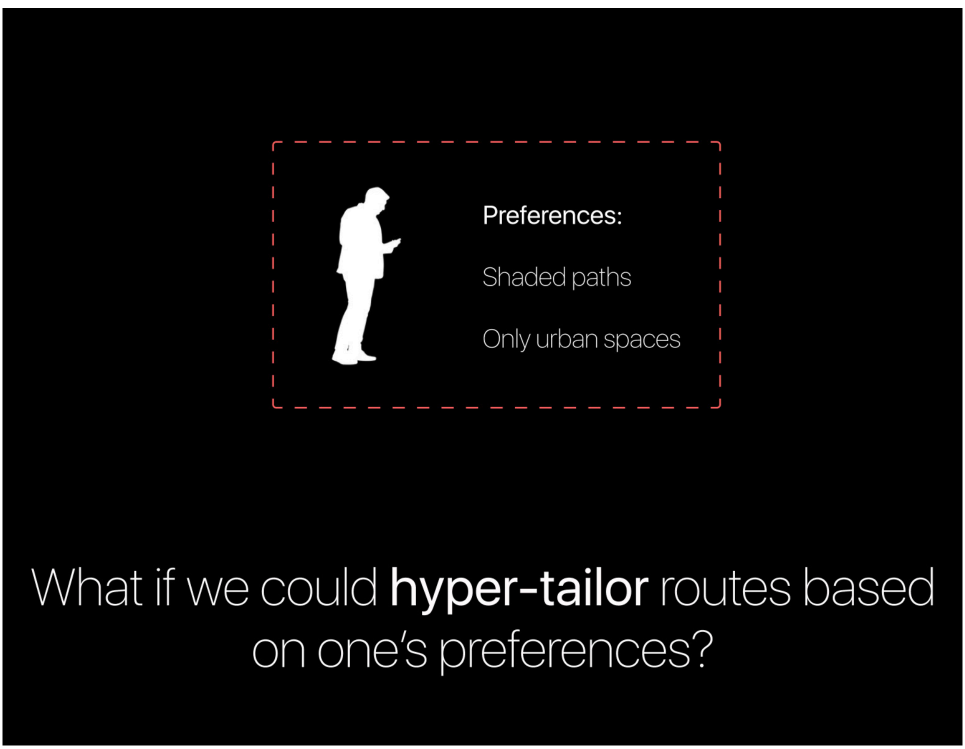
Figure 6: Conversational interface of Yodai

Discussion

This project has a few fundamental constraints that should be addressed to open doors for further exploration. The first such constraint lies in the definition of a pedestrian's perception of safety (PoS). The idea of PoS has been explored by different researchers in a fragmented manner where the focus has been on a particular aspect of walkability- that could be how the built environment contributes to PoS, or objective factors like public lighting to broader topics like modern urban planning's attempt to improve PoS [48]. However, there isn't a unified definition that parameterizes an individual's perception of safety and how to quantify it. In general, this topic falls under core sociology and urban planning research [49] and is considered out of scope but the effects of the definition echo through this project too.
Before I settled down on the present way to quantify PoS, there were a few possibilities that were explored in the research phase. The first possibility questioned what if I could build a navigation system that would be hyper-tailored to one's preferences when it comes to safety. The definition of that person's perception of safety was shaped by only their opinions and every user would definitively have a singularly unique mathematical outcome of their perception of safety. The second possibility explored a similar definition of PoS to what I have now but to achieve greater neutrality, a simple average was replaced by a weighted mean where weights were assigned to rating scores based on the respondents' ethnicities and personal backgrounds. This process is definitely nuanced and thorough but the question arises on the basis on which these weights are assigned [50]. I feel it is academically incorrect to make such assumptions or hold authority over assigning 'weights' based on ethnic biases without supporting research and reasoning. The third iteration was a variation of the combination of the different explorations where I exposed the user to the definition of PoS. In this case, I tell the users that the ethnic population they belong to has rated certain places in a particular fashion.

There are many ethical and academic issues in executing these possibilities. On one hand, I know that an improved definition of PoS needs to be derived beyond a simple mean but the other possibilities explored do not do justice to this cause.
Another topic for discussion revolves around the final output of the algorithm - Is it justified to show a particular route as the safest? I do not claim that the route generated is the safest option for pedestrians, there are multiple factors apart from the ones considered to determine the 'safest' option, however, the aim has been to generate relatively 'safer' options in terms of routes to follow. One iteration conducted in this regard was to generate multiple safer options for the user to choose from - however, it exposes the possibility of scrutiny of the places avoided by these routes in relation to each other. This can not only lead to confusion but also lead to route comparisons on different social aspects where I mathematically claim that there can be only one optimized route.


$w^1 * 0.8$
$w^2 * 0.9$
$w^3 * 0.4$
$w^4 * 0.7$
What if we could assign **weights** to peoples' safety opinions?


Preferences:
Shaded paths
Only urban spaces
What if we could **hyper-tailor** routes based on one's preferences?


Walk home,
safer
with
Godspeed.

Future Work

One integral component of navigation systems lies in their ability to track the position of the user relative to the route they are following using global positioning systems (GPS). This alternative navigation tool can be augmented with GPS support just the way the majority of navigational tools in the market work [51]. It will make the platform more actionable from a user experience perspective. There is definitive scope for improvement when it comes to the overall user experience, in terms of additional features to explore as our users embark on a particular path. One of them is data visualization of unsafe event occurrences on a map for visibility. This gives users a bird's eye view of what is happening through a map visualization. From a data processing perspective, there is great scope for further advances in parameterizing a pedestrian's perception of safety where complex socio-economic factors like racial biases and ethnocentric opinions revolving around personal safety are taken into consideration to make the rating system more holistic and sensitive from a social standpoint.

Conclusion

In closing, this research introduces a new way of providing walking directions that take personal safety into account. It gathers input on locations' perceived safety from local users as well as crime stats and streetlight data. By quantifying a "safety score", the method can then suggest alternative pedestrian routes that balance safety and trip length. This novel approach signifies progress toward navigation apps that reflect the real-life factors people consider beyond just distance or time when walking. However, accurately measuring something as subjective as perceived safety across many users remains tricky. There are also ethical questions about displaying specific crime occurrences hence it refrains from traversing that particular direction. Still, the research lays the groundwork for advancing this kind of customized, safety-conscious routing. The next steps could involve fine-tuning the safety ratings using additional community insights, as well as integrating GPS to track positioning. In the long run, features catered to users' safety and comfort could give pedestrians peace of mind and make cities more walkable.

On a broad level, this project highlights the importance of human-focused design principles. When engineers grasp subtle influences on navigation choices and build tools accordingly, the end products align better with peoples' on-the-ground priorities - not just technical efficiency. By blending urban policy, sociological, data science, and design perspectives, this cross-disciplinary effort also demonstrates the power of weaving together expertise to spur forward innovative solutions.

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Disclaimer: GenAI tools like ChatGPT were used for formatting and grammar purposes. Any research-based content has neither been produced nor plagiarized from any GenAI tool to the best of the author's knowledge.

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