Optimizing Pedestrian Paths for Maximum Shadow Coverage: Balancing Efficiency and Distance

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Background

Pedestrian navigation apps typically optimize for distance but often **overlook user preferences, such as climate considerations**. Walking through cities involves more than just finding the shortest path; pedestrians also seek to maximize their well-being by, for example, walking on **shaded paths**.

However, two challenges arise:

1. **Predicting shadow locations** accurately can be difficult, as it depends on different geographical factors.
2. This often results in **routes that are either excessively long** yet shaded, **or too exposed to sunlight** when prioritizing distance.

The solution overcomes these challenges by considering pedestrian's **shade preferences**, optimizing routes based on real-time shadow availability and individual priorities.

Goals

- Generate an accurate measure for **shadow coverage** of a certain sidewalk in a given time.
- Create an algorithm that optimizes routes considering distance and shadow coverage.
- Use **spatial software (like QGIS)** to visualize the resulting routes.

Datasets

Three datasets were used regarding Downtown San Antonio:

- **Trees:** geospatial dataset containing the information of every tree in **San Antonio's Downtown**. Relevant information is height and spatial coordinates.
- **Buildings:** geospatial dataset containing the multipolygon and coordinates that represent every building in San Antonio's Downtown.
- **Sidewalks:** walkable streets from San Antonio's downtown. Obtained from open source library **OpenStreetMapNX.**

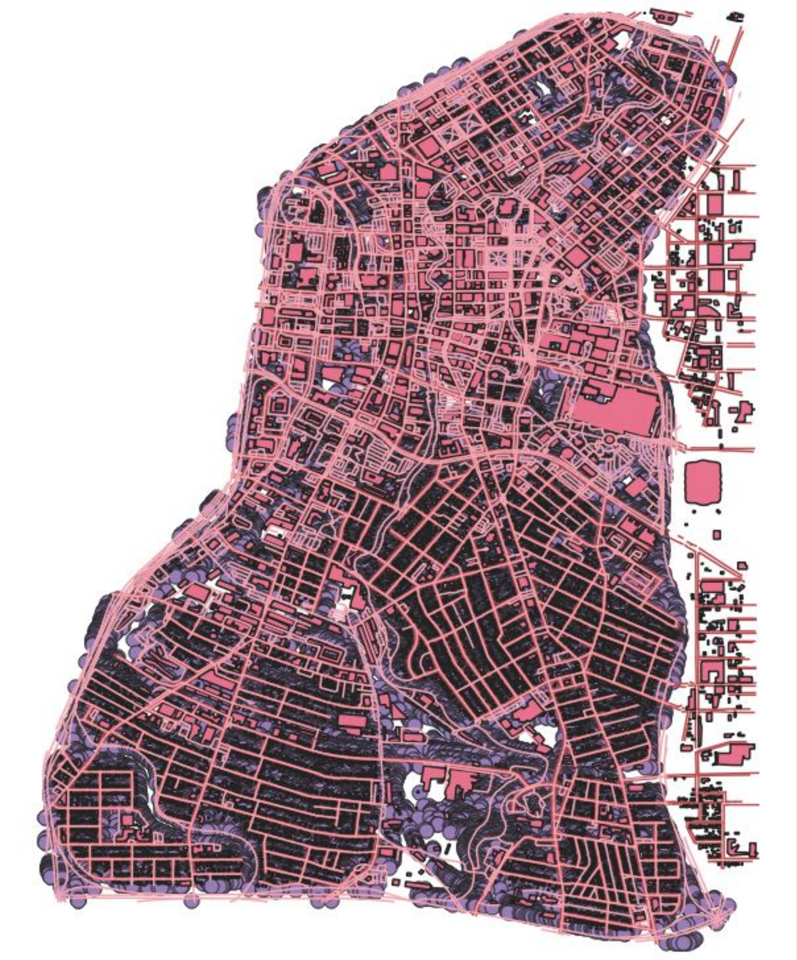

Figure 1. Downtown San Antonio spatial representation

Methods

- **Shadow projection** of trees and buildings (trees were considered as cylindrical buildings).
- Using geospatial analysis operations like intersection and union: obtain the **shaded and non-shaded** segments of **sidewalks**.
- Optimize the route using **Dijkstra**

Shaded-Distance Objective Function

$$f(x) = d(x) - \beta s(x) \quad \text{where} \quad \beta \in (0, 1)$$

Based on Melnikov et al. research the parameter β (= 0.84) represents the perceived difference of shade walking.

Results

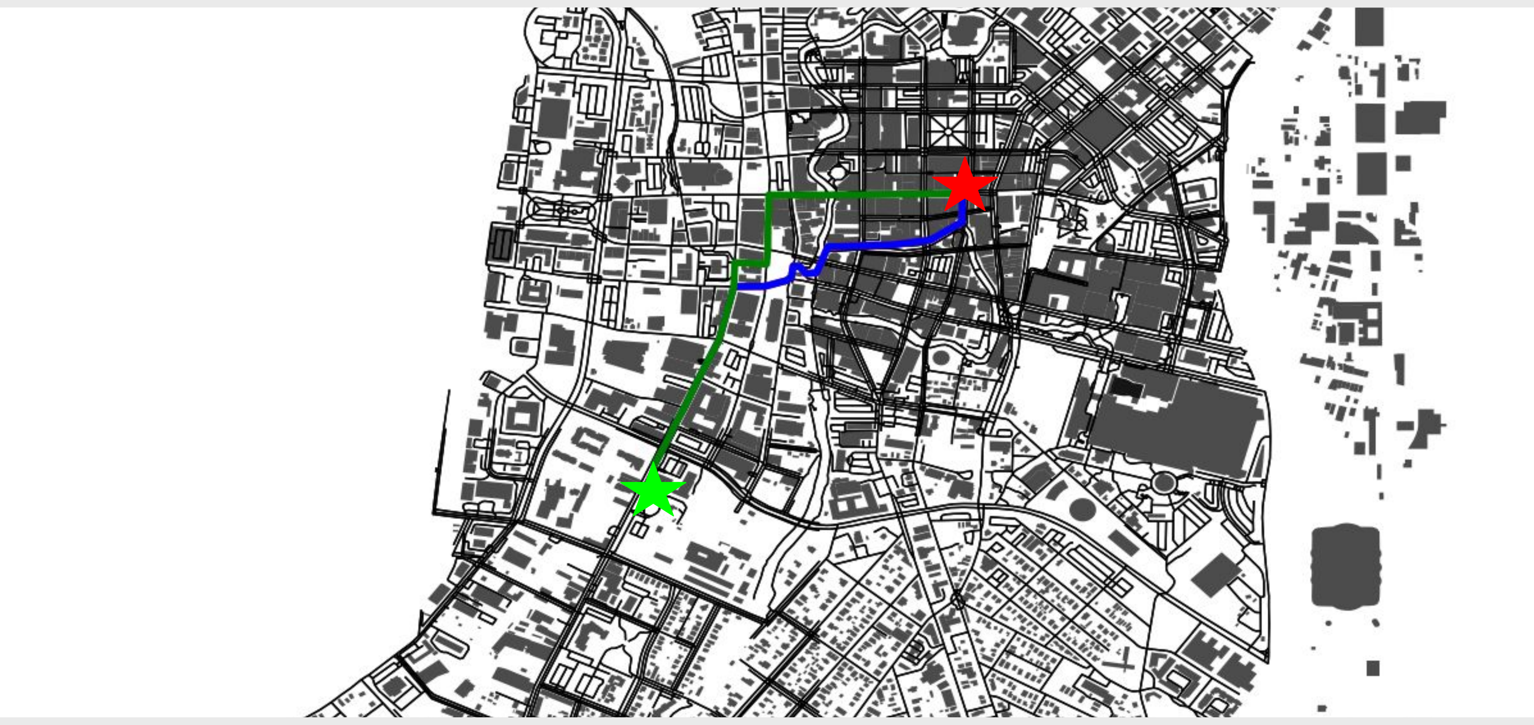

Figure 2. Resulting map of San Antonio for β = 0.5 (blue), with alternative routes for β = 0 (red) and β = 1 (green).

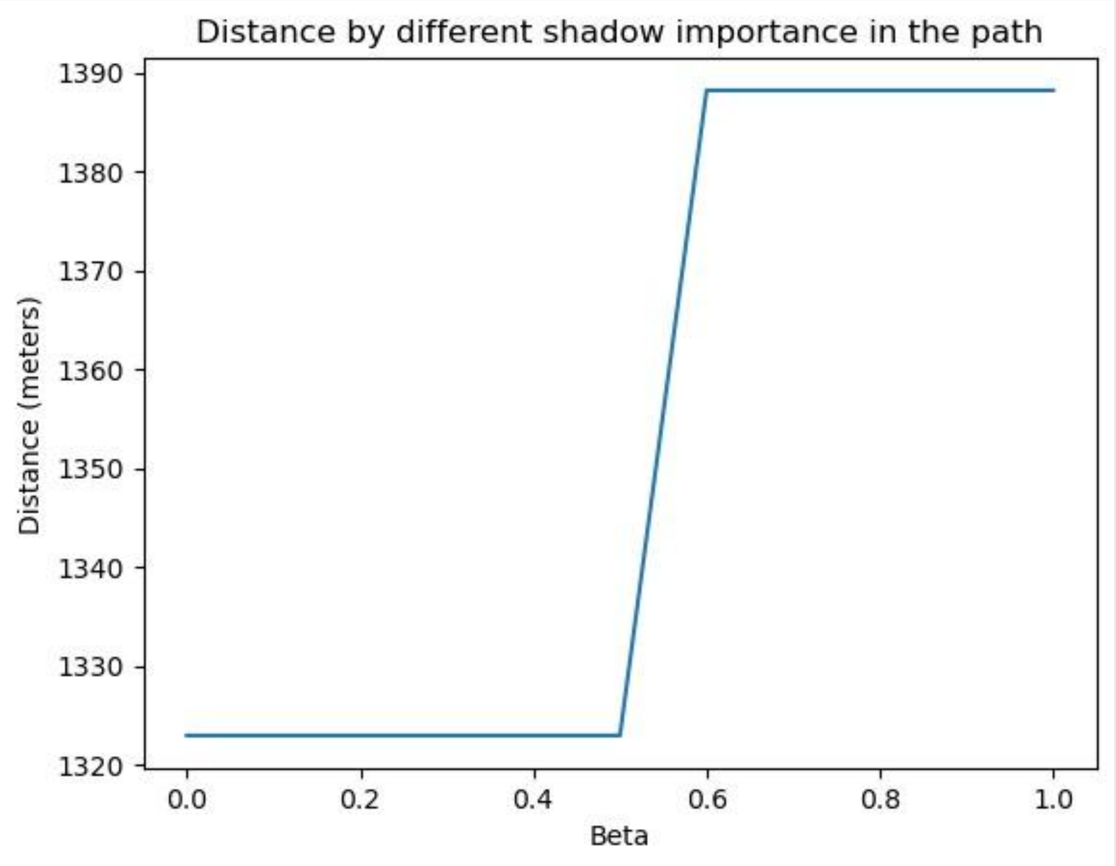

Figure 3. Travel distance in meters with different shadow importance, for a very simple route.

Conclusions and future work

Conclusions:

- It has been demonstrated the usage of a method to optimize routes for maximum shade coverage, while only **sacrificing as much time and distance in proportion to the pedestrian's perceived value of shade** over distance.
- An **interactive application** was developed, allowing **pedestrians** to **optimize their routes** and evaluate alternative paths.
- As shown in **Figure 2 and 3,** the goal of finding optimal walking routes in San Antonio was accomplished, **balancing the trade-off between distance and shade.**

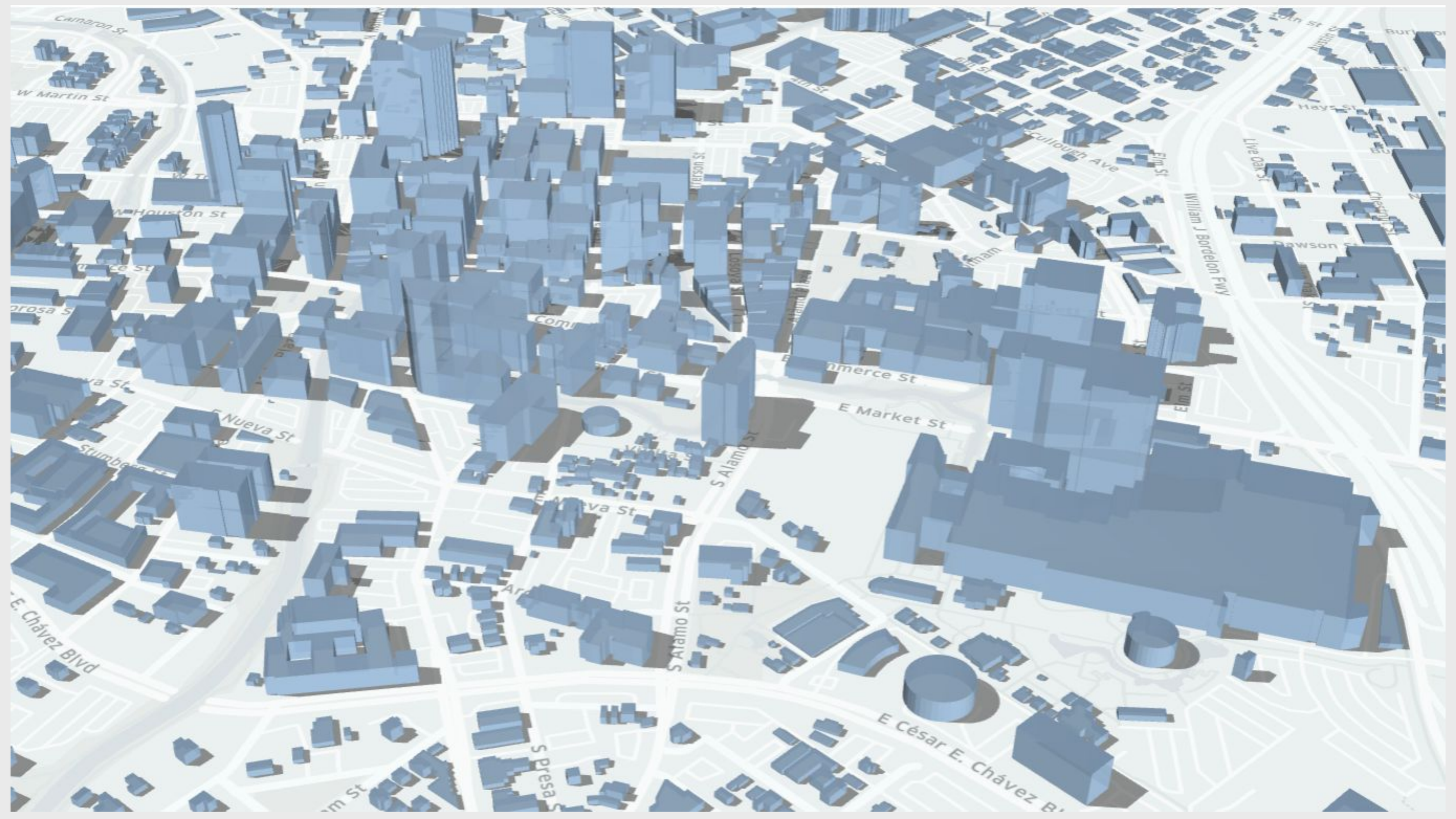

Figure 4. 3D model representation of shadow projection

Future Work

- Add other constraints to the path optimization such as time and/or temperature of sidewalk's material (via CV).
- Add information on strength of shadow, either by accounting for tree canopies and/or overlapping shadows from various entities.

References

Melnikov, V. R., Christopoulos, G. I., Krzhizhanovskaya, V. V., Lees, M. H., & Sloot, P. M. A. (2022). **Behavioural thermal regulation explains pedestrian path choices in hot urban environ ments.** Scientific Reports, 12(1), 2441. https://doi.org/10.1038/s41598-022-06383-5

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