Two New Pedestrian Navigation Path Options based on Semi-indoor Space

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Contents

INTRODUCTION

Vehicle navigation

Pedestrian navigation

Environments (spaces) where navigation happens

Indoor

Semi-indoor

Outdoor

Semi-outdoor

- Yan, J., Diakité, A. A., & Zlatanova, S. A generic space definition framework to support seamless indoor/outdoor navigation systems. Transactions in GIS. 2019; 23(6): 1273-1295.

Semi-indoor (sI-space)

The sI-spaces are the **hollow parts** formed by living environments that are **semi-open** to the outdoors, physically enclosed by **upper boundaries** (e.g., roof, shelter), and may have a **surrounding boundaries** (e.g., wall, fence), but is **not physically enclosed completely** like indoor.

(a) (b) (c) (d) (e)

Examples of semi-indoor environments (spaces) formed by built structures

- Yan, J., Diakité, A. A., Zlatanova, S., & Aleksandrov, M. (2019). Top-Bounded Spaces Formed by the Built Environment for Navigation Systems. ISPRS International Journal of Geo-Information, 8(5), 224.
- Yan, J., Diakite, A. A., & Zlatanova, S. (2018). AN EXTRACTION APPROACH OF THE TOP-BOUNDED SPACE FORMED BY BUILDINGS FOR PEDESTRIAN NAVIGATION. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences, 4(4).

THE TWO PATH OPTIONS

Two new navigation path options based on semi-indoor spaces:

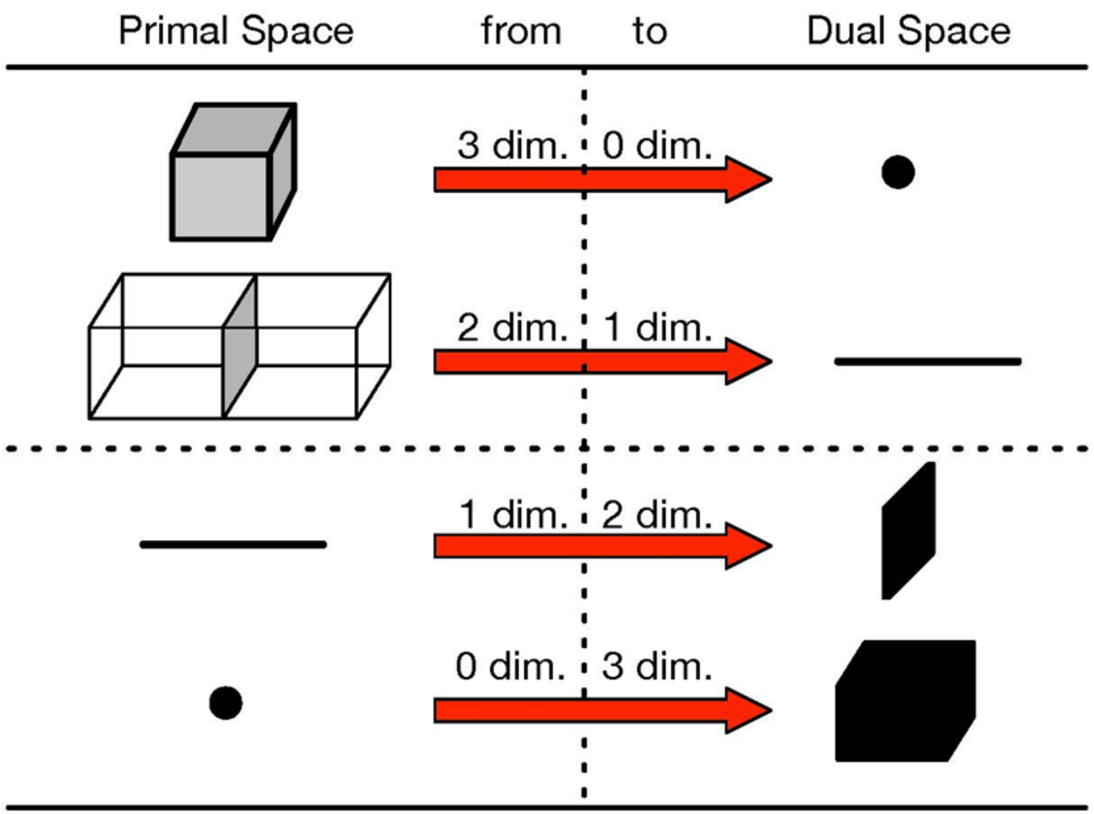
(i) the **M**ost-**T**op-**C**overed path (**MTC-path**)

(ii) path to the **N**earest **sI**-space from departure (**NSI-path**)

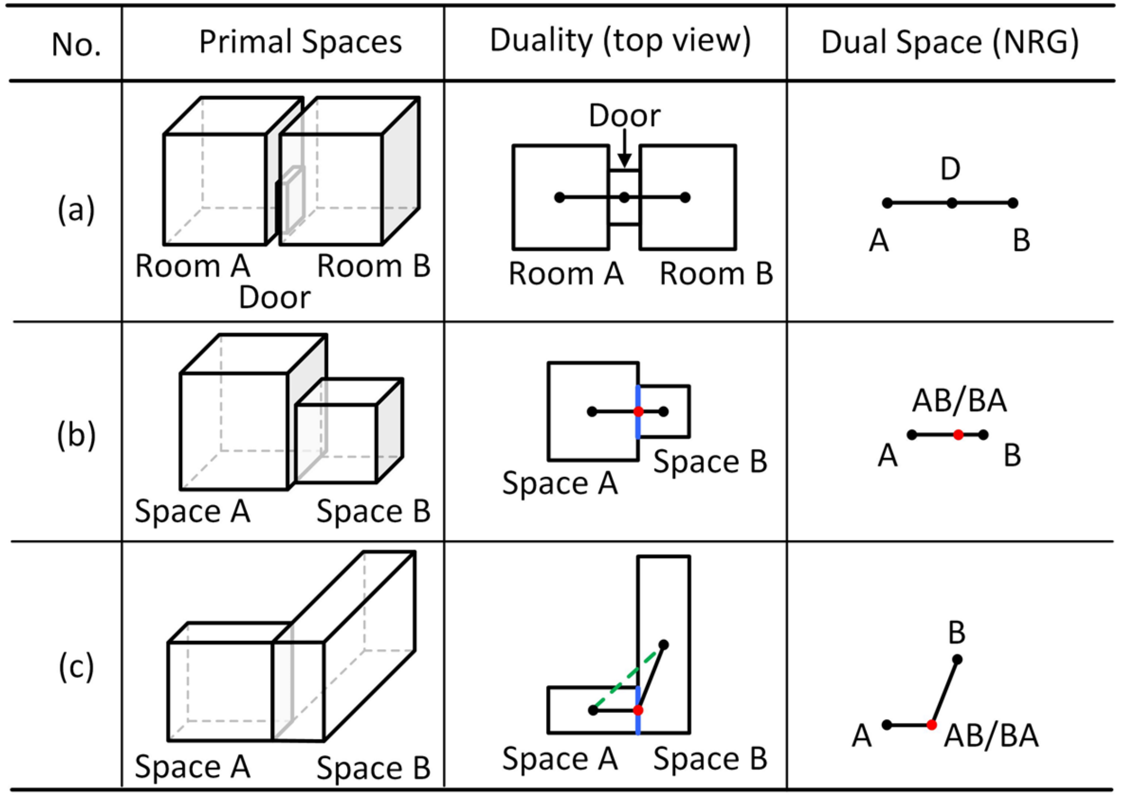
Escape from rains

Escape from sun

Duality used for navigation network derivation



Poincaré duality



The duality used in this paper

Parameters for Navigation Model

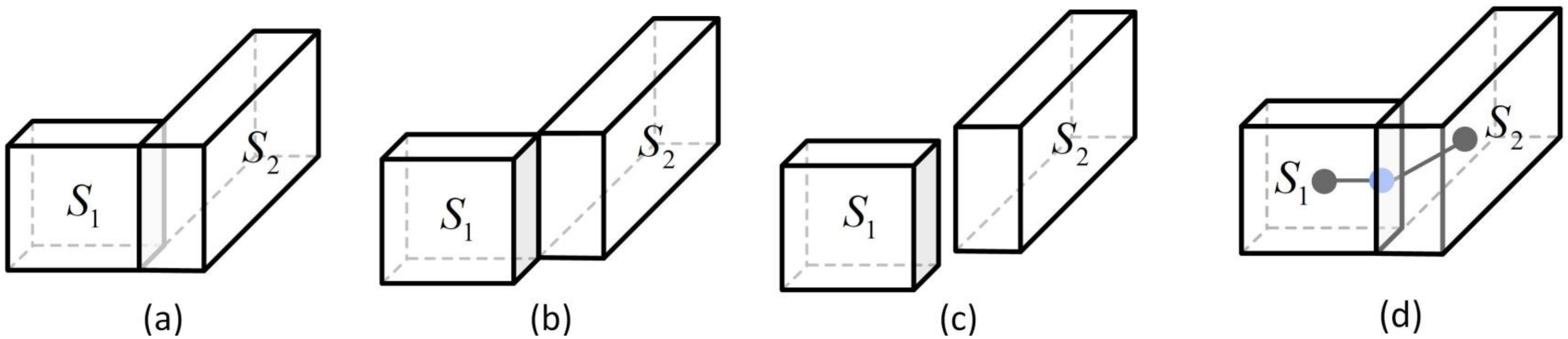


Illustration of connected spaces

- The distance between two connected spaces ($D_{S_{ij}}$)
- Original weights ($W'_{S_{ij}}$) ⟹ $W'_{S_{ij}} = \dfrac{D_{S_{ij}} - D_{S_{ij}}(min)}{D_{S_{ij}}(max) - D_{S_{ij}}(min)}$
- Covered ($D_{cS_{ij}}$), & uncovered ($D_{ucS_{ij}}$) distance
- Uncovered ratio ($\lambda_{S_{ij}}$) ⟹ $\lambda_{S_{ij}} = D_{ucS_{ij}} / D_{S_{ij}}$
- Modified weights ($W''_{S_{ij}}$) ⟹ $W''_{S_{ij}} = \xi W'_{S_{ij}} + (1-\xi)\lambda_{S_{ij}}$

ξ (coefficient)

GRID

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Parameters for Navigation Path

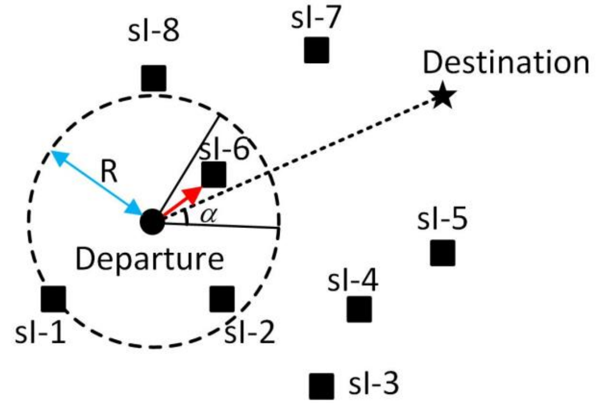
- Path length (P_l) $\Longrightarrow$ $P_l = \sum D_{S_{ij}}$
- Covered/Uncovered length of a path (P_{l_c} / $P_{l_{uc}}$) $\Longrightarrow$ $P_{l_c} = \sum D_{cS_{ij}}$ $P_{l_{uc}} = \sum D_{ucS_{ij}}$
- Top-coverage-ratio of a path (P_{c_r}) $\Longrightarrow$ $P_{c_r} = P_{l_c}/P_l$
- Weight-based path length (W_p) $\Longrightarrow$ $W_p = \sum W_{S_{ij}}$

Steps of path computation

MTC-path (Most-Top-Covered path)

- Select semi-indoor spaces.
- Compute the original and modified weights.
- Compute the MTC-path.

NSI-path (path to the Nearest Semi-Indoor space from departure)



Example of NSI-path planning from departure to destination.

- Select semi-indoor spaces.
- Create a straight line by linking the departure and destination.
- Set time (t) and searching angle (α).
- Find potential nearest sI-spaces.
- Determine the nearest sI-space and NSI-path

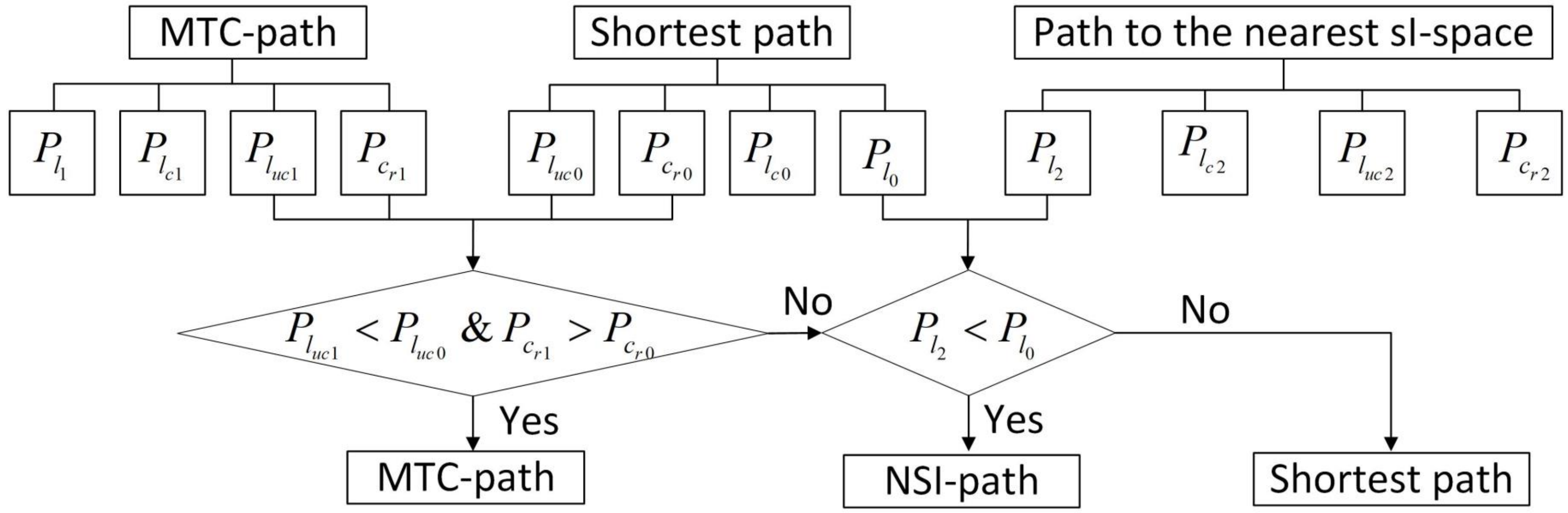
A Path Selection Strategy

- **MTC-path**
- **NSI-path**
- **The traditional shortest path**

Condition 1: Uncovered length of a MTC-path ($P_{l_{uc1}}$) is **shorter** than that of the Shortest path ($P_{l_{uc0}}$)

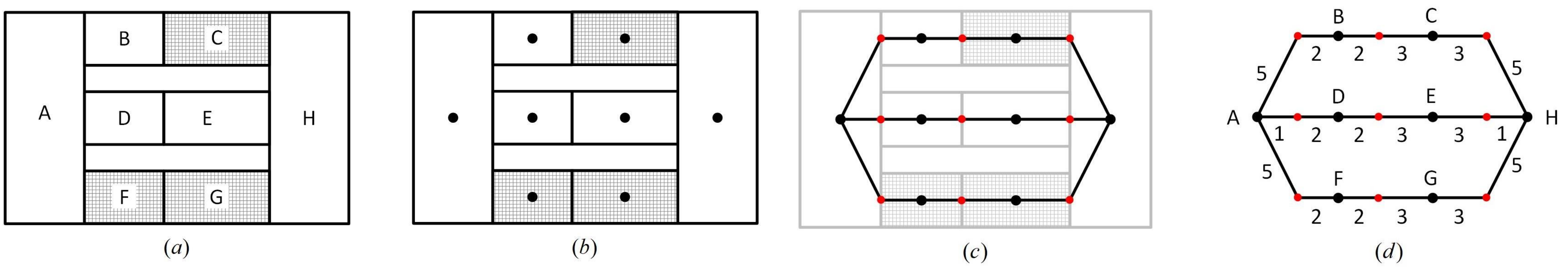
Condition 2: Top-coverage-ratio of a MTC-path ($P_{c_{r1}}$) is **larger** than that of the Shortest path ($P_{c_{r0}}$)

Condition 3: Path length of NSI-path (P_{l_2}) is **shorter** than that of the Shortest path (P_{l_0})



The path selection strategy

ILLUSTRATION OF THE TWO PATH OPTIONS



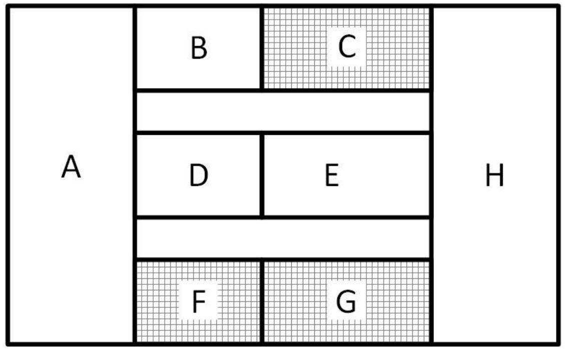
A navigation example, in which C, F and G are three sI-spaces.

(a) All spaces.

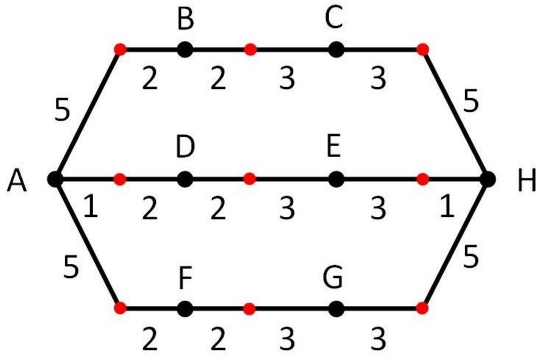
(b) Nodes extracted from spaces;

(c) Navigation graph derived from spaces based on duality theory;

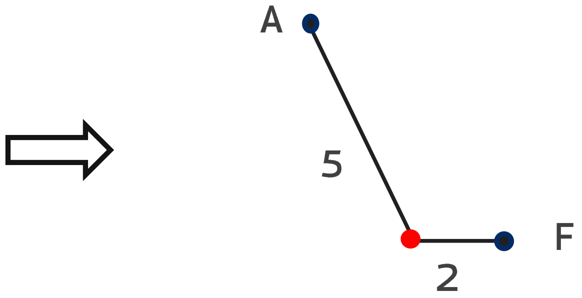
(d) Navigation graph with distance.



(a)



(d)



$$D_{S_{AF}} = 5 + 2 = 7$$

$$D_{S_{ij}} = \{D_{S_{AB}}, D_{S_{BC}}, D_{S_{CH}}, D_{S_{AD}}, D_{S_{DE}}, D_{S_{EH}}, D_{S_{AF}}, D_{S_{FG}}, D_{S_{GH}}\}$$
$$= \{7,5,8,3,5,4,7,5,8\}$$

$$D_{S_{ij}}(min) = 3$$

$$D_{S_{ij}}(max) = 8$$

Original weight

$$W'_{S_{AF}} = \frac{D_{S_{AF}} - D_{S_{ij}}(min)}{D_{S_{ij}}(max) - D_{S_{ij}}(min)} = \frac{7-3}{8-3} = 0.8$$

Covered distance

$$D_{cs_{AF}} = 2$$

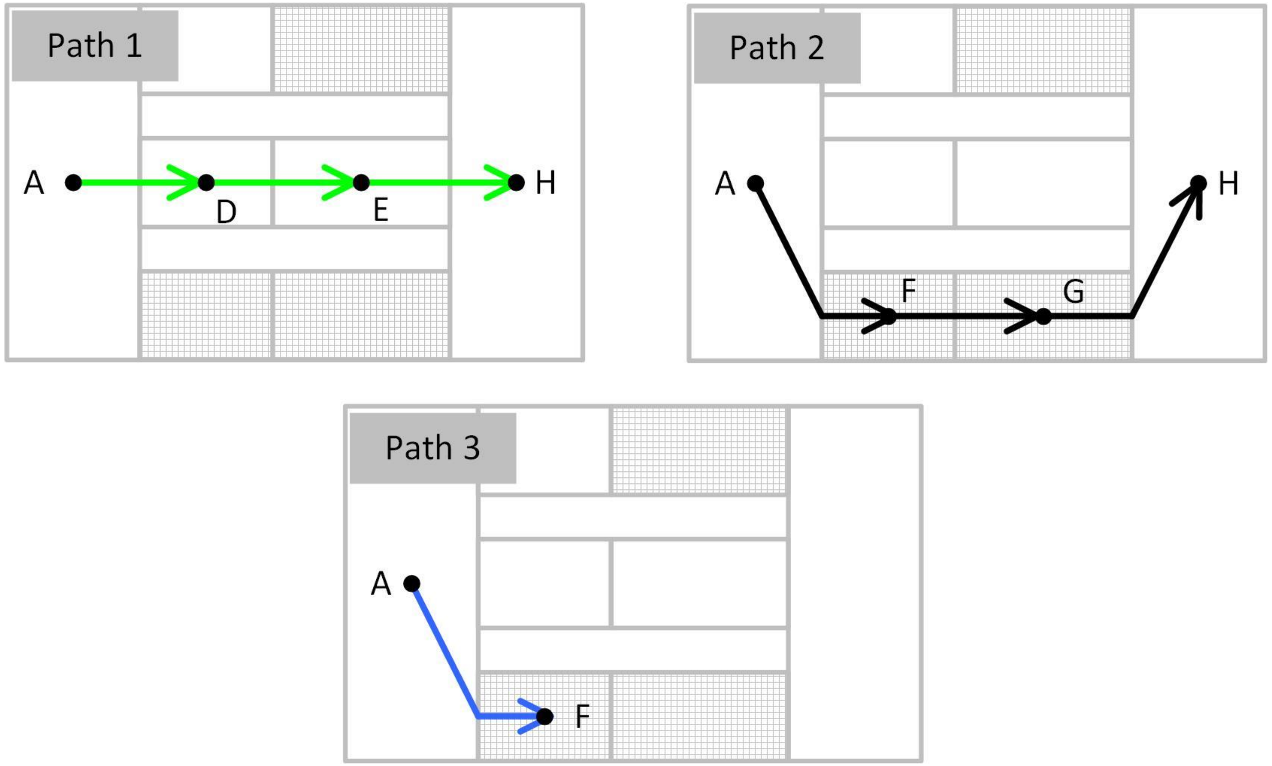
Uncovered distance

$$D_{ucs_{AF}} = 5$$

Uncovered ratio

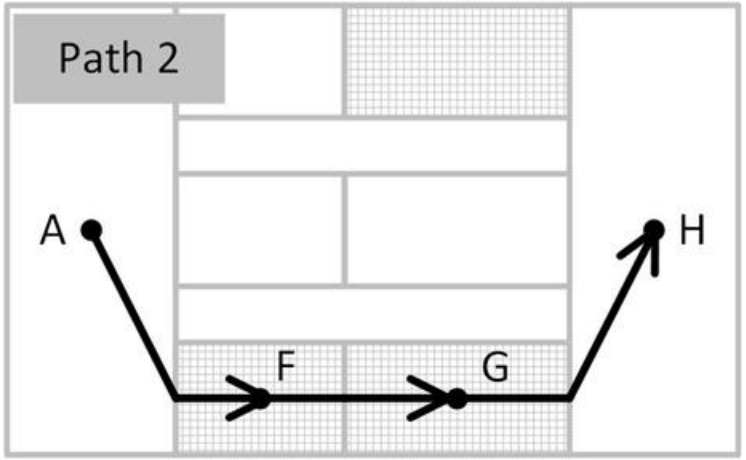
$$\lambda_{S_{AF}} = 5/7 = 0.71$$

Planned paths



The three navigation paths from S_A (departure) to S_H (destination). $S_A \rightarrow S_D \rightarrow S_E \rightarrow S_H$ is path 1 (green), $S_A \rightarrow S_F \rightarrow S_G \rightarrow S_H$ is path 2 (black), and $S_A \rightarrow S_F$ is path 3 (blue).

$\xi = 0.6$



Path length $P_l = S_{AF} + S_{FG} + S_{GH}$

$= 7 + 5 + 8$

$= 20$

Uncovered length of a path $P_{l_{uc}} = 10$

Covered length of a path $P_{l_c} = 10$

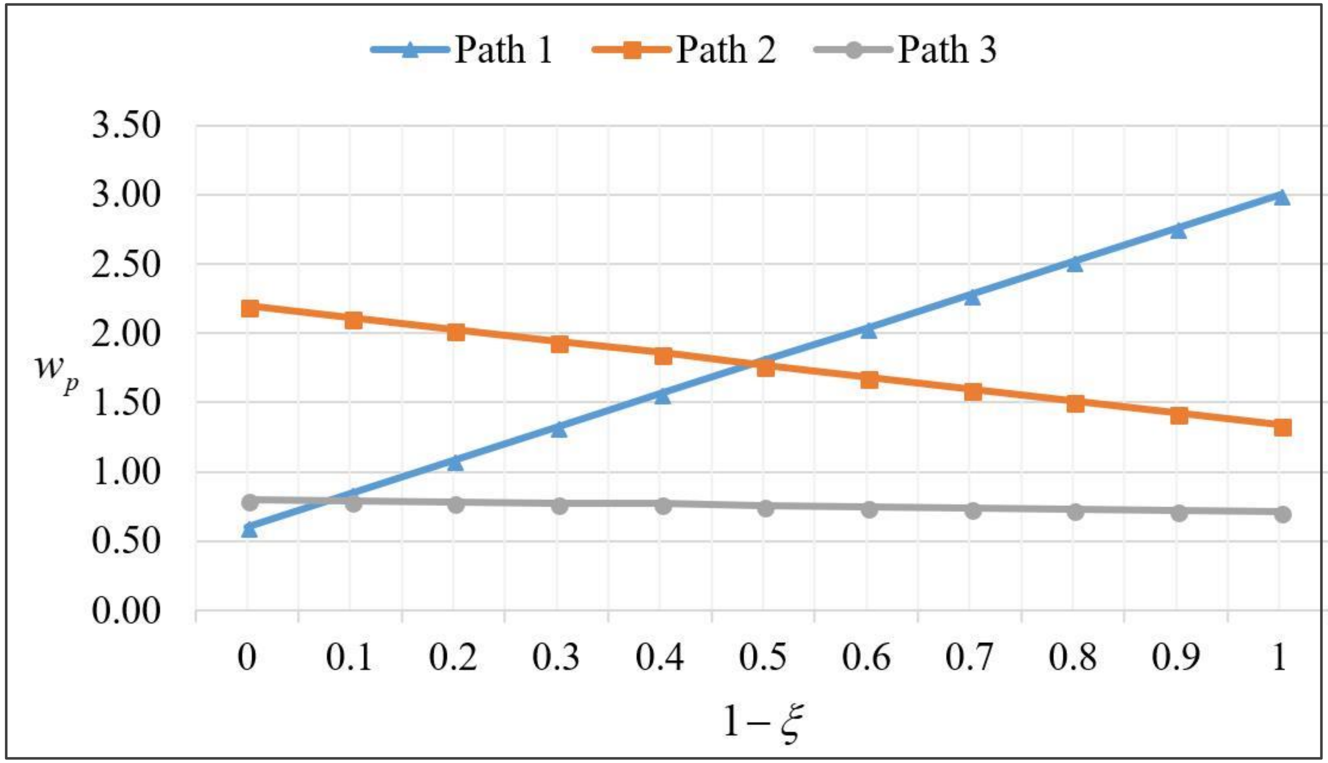
Top-coverage-ratio of a path $P_{c_r} = P_{l_c}/P_l = 10/20 = 0.5$

Weight-based path length $W_p = W''_{S_{AF}} + W''_{S_{FG}} + W''_{S_{GH}}$

$= 0.77 + 0.24 + 0.85$

$= 1.86$

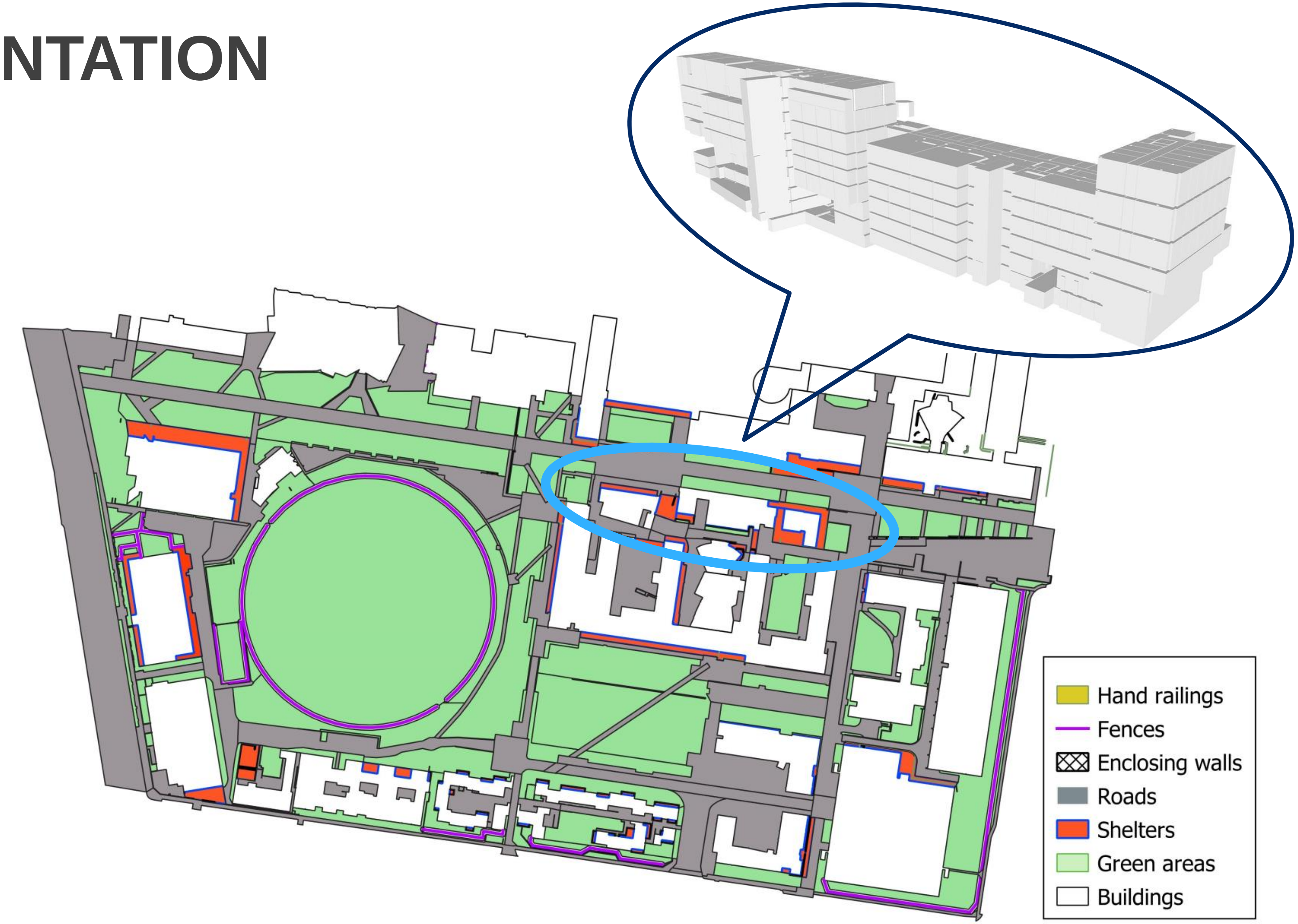
Path selection



The changes of Wp with the changing of the coefficient ξ.

It reveals that with paying more attention to the top-coverage-ratio of the path, the traditional shortest path becomes less attractive.

IMPLEMENTATION

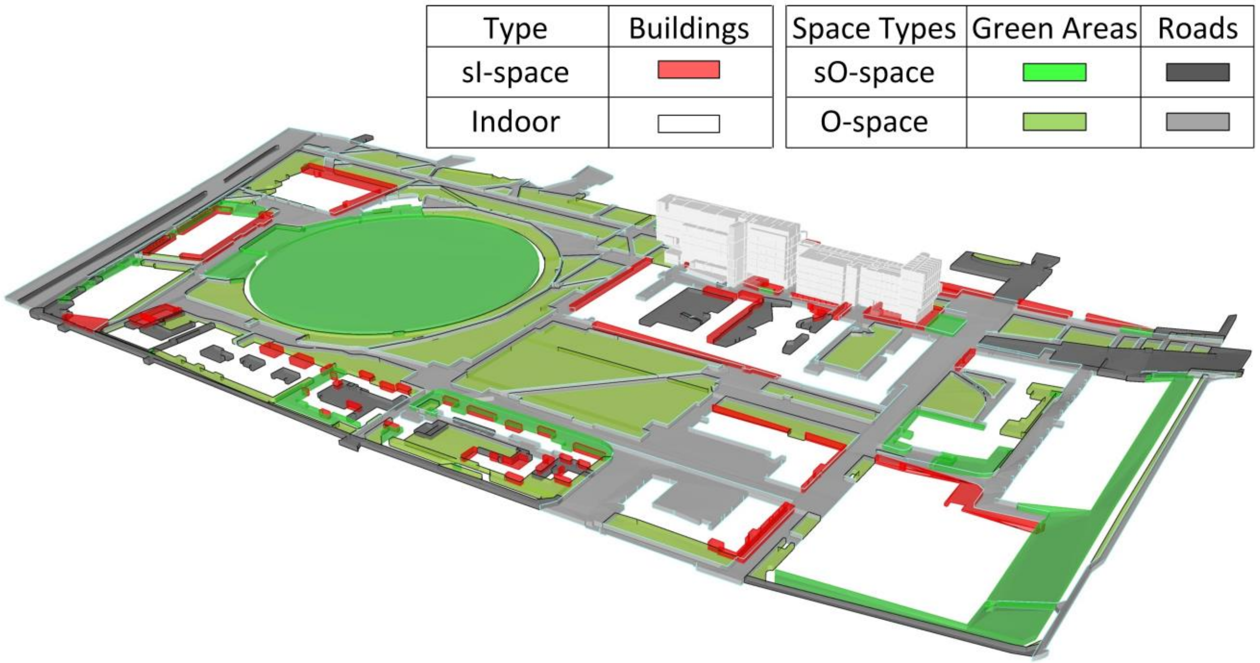


Selected area of university campus for testing.

Yan, J.*, Diakité, A.A., Zlatanova, S. Finding Boundaries of Outdoor for 3D Space-based Navigation. Transactions in GIS. 2020, 24(2): 371–389.

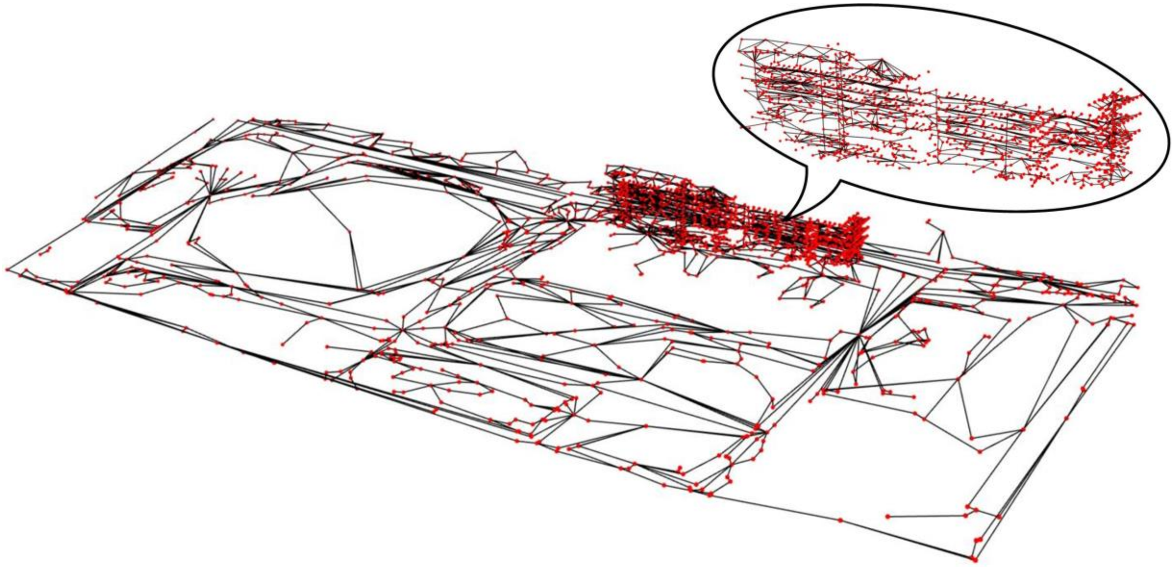
Space & Navigation Network

Space reconstruction



BIM spaces and 3D spaces in the test area.

Navigation network derivation based on duality

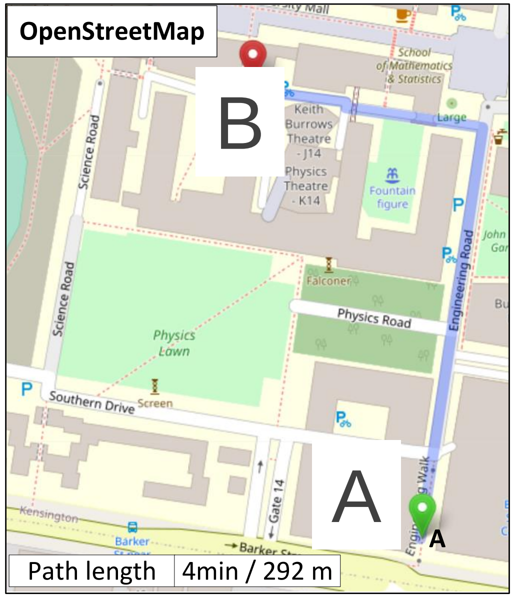


The navigation network automatically derived from 3D spaces based on duality.

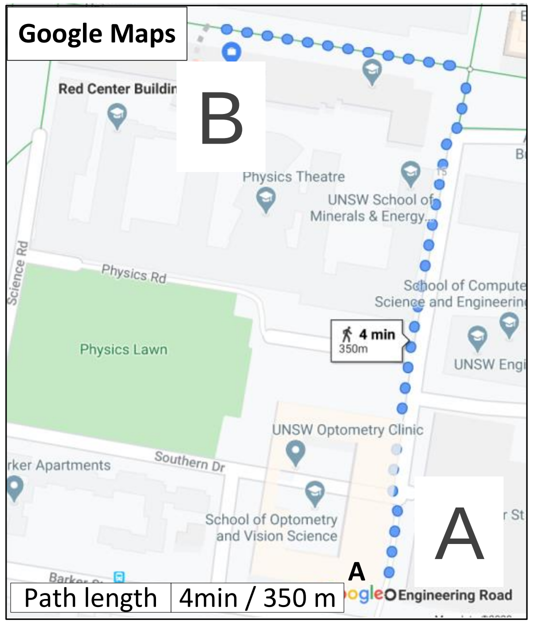
Yan, J.*, Diakité, A.A., Zlatanova, S. Finding Boundaries of Outdoor for 3D Space-based Navigation. Transactions in GIS. 2020, 24(2): 371–389.

Navigation Path A to B

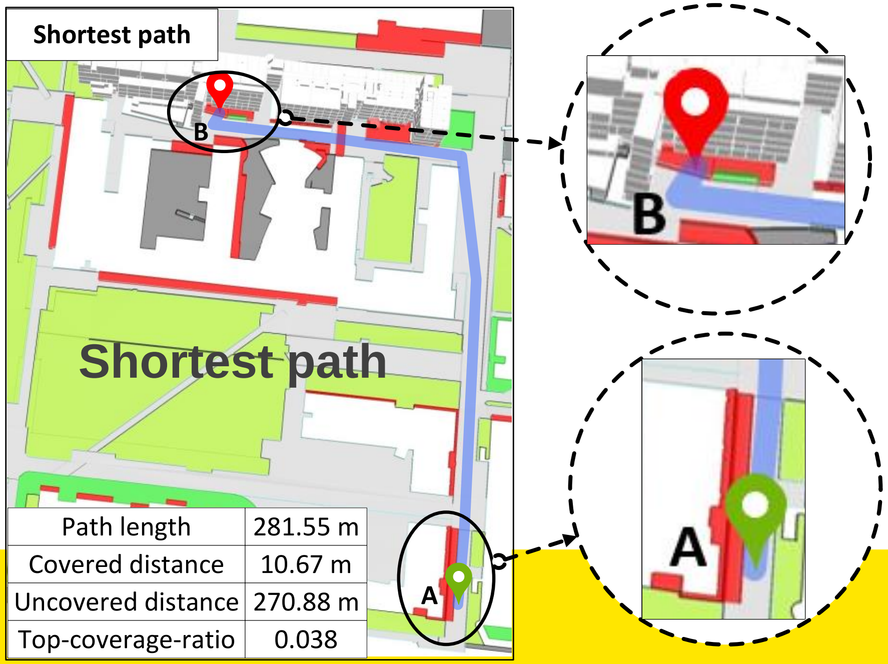
OpenStreetMap



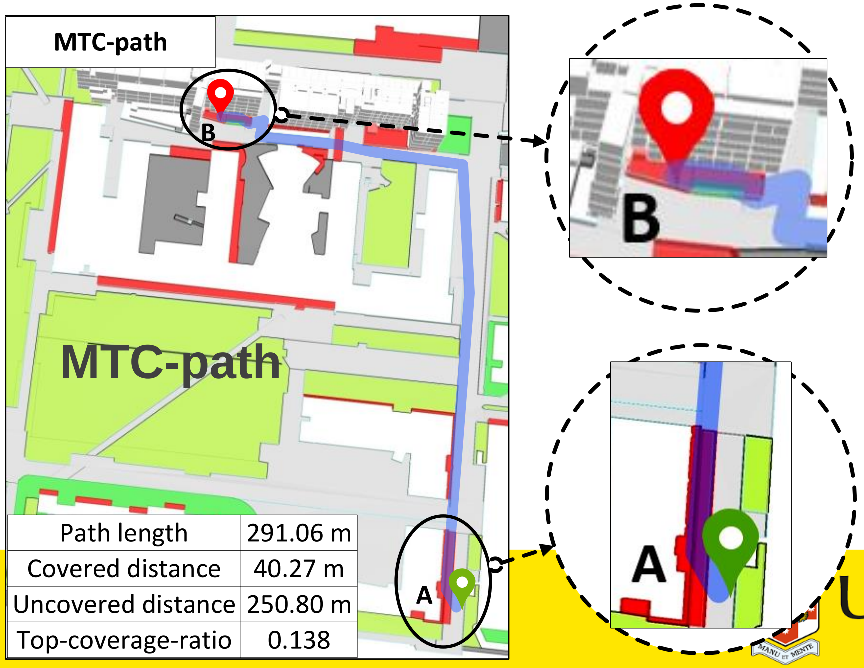
Google Maps



Our approach



Path length	281.55 m
Covered distance	10.67 m
Uncovered distance	270.88 m
Top-coverage-ratio	0.038



Path length	291.06 m
Covered distance	40.27 m
Uncovered distance	250.80 m
Top-coverage-ratio	0.138

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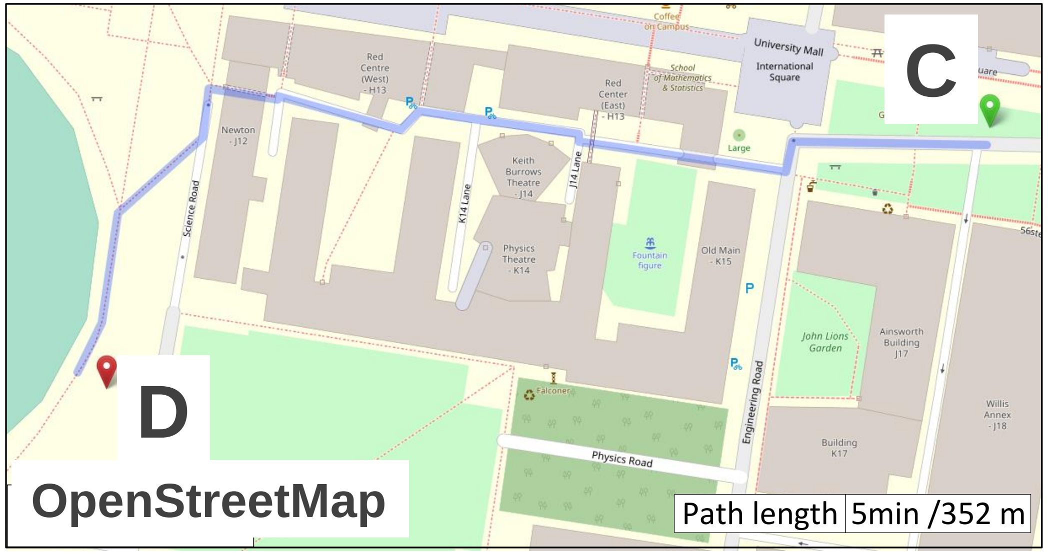
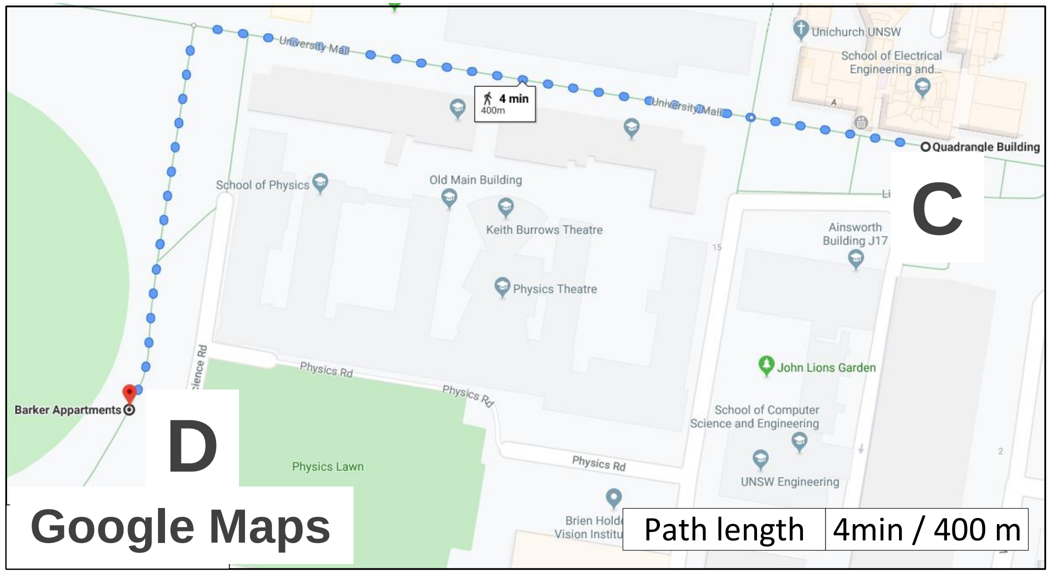
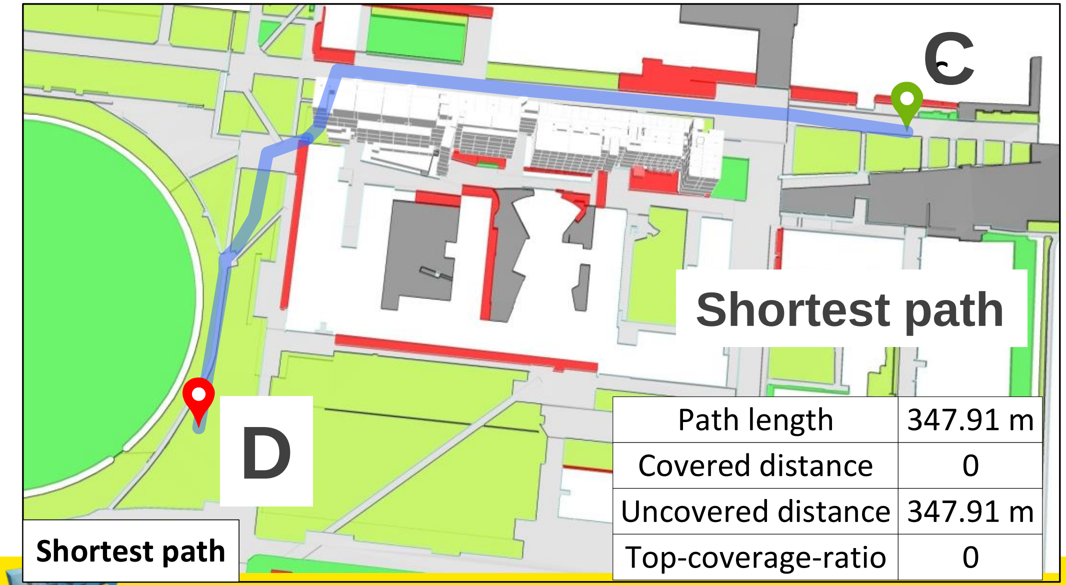
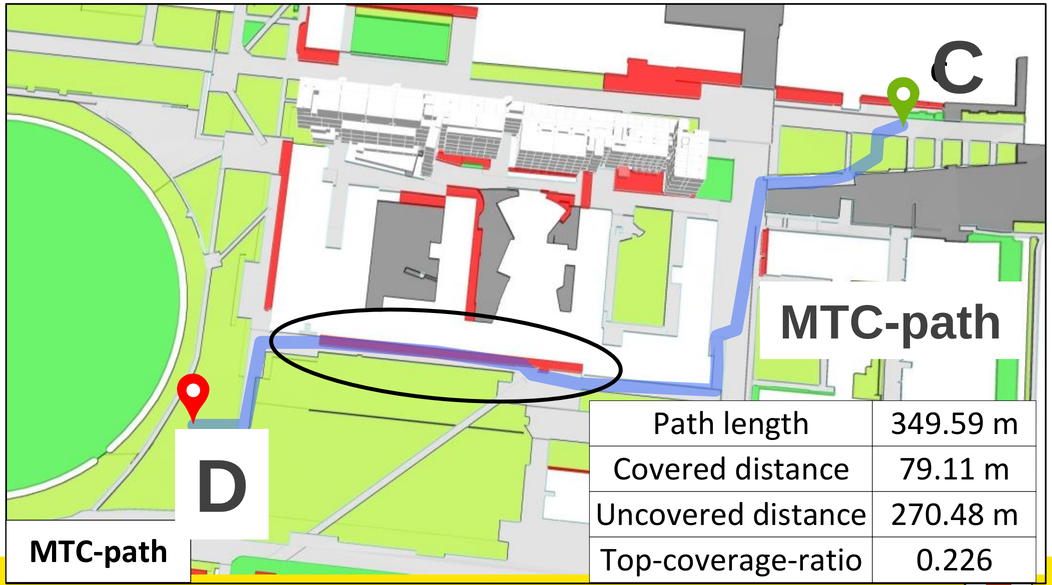
Navigation Path C to D







Path length	347.91 m
Covered distance	0
Uncovered distance	347.91 m
Top-coverage-ratio	0



Path length	349.59 m
Covered distance	79.11 m
Uncovered distance	270.48 m
Top-coverage-ratio	0.226

Our Approach

Our Approach

Results

	Shortest path			MTC-path		Recommended path
A → B	Path length	281.55 m		Path length	291.06 m	MTC-path
	Covered distance	10.67 m		Covered distance	40.27 m	
	Uncovered distance	270.88 m	>	Uncovered distance	250.80 m	
	Top-coverage-ratio	0.038	<	Top-coverage-ratio	0.138	
C → D	Path length	347.91 m		Path length	349.59 m	MTC-path
	Covered distance	0		Covered distance	79.11 m	
	Uncovered distance	347.91 m	>	Uncovered distance	270.48 m	
	Top-coverage-ratio	0	<	Top-coverage-ratio	0.226	

Table 4. Comparisons of three navigation systems.

Approach	sI-space	2D/3D	Shortest path	MTC-path	NSI-path
OSM	×	2D	✓	×	×
Google Maps	×	2D	✓	×	×
Our approach	✓	3D	✓	✓	✓

CONCLUSION

This research has two contributions to navigation path planning:

- sI-spaces are included in navigation paths as destination or departure;
- MTC-path and NSI-path are computed for users who need the shortest path with as many covers from the top as possible;

FUTURE WORK

- Extend this research to new path options with sI-spaces to I-spaces, even sO-spaces or O-spaces;
- Investigate more aspects that are related to sI-spaces;
- Investigate the preferences of users.

THANKS

Two New Pedestrian Navigation Path Options based on Semi-indoor Space

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