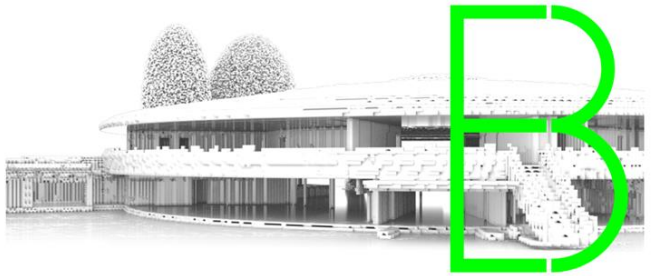

Modélisation 3D unifiée de l'espace pour une navigation intérieure/extérieure fluide

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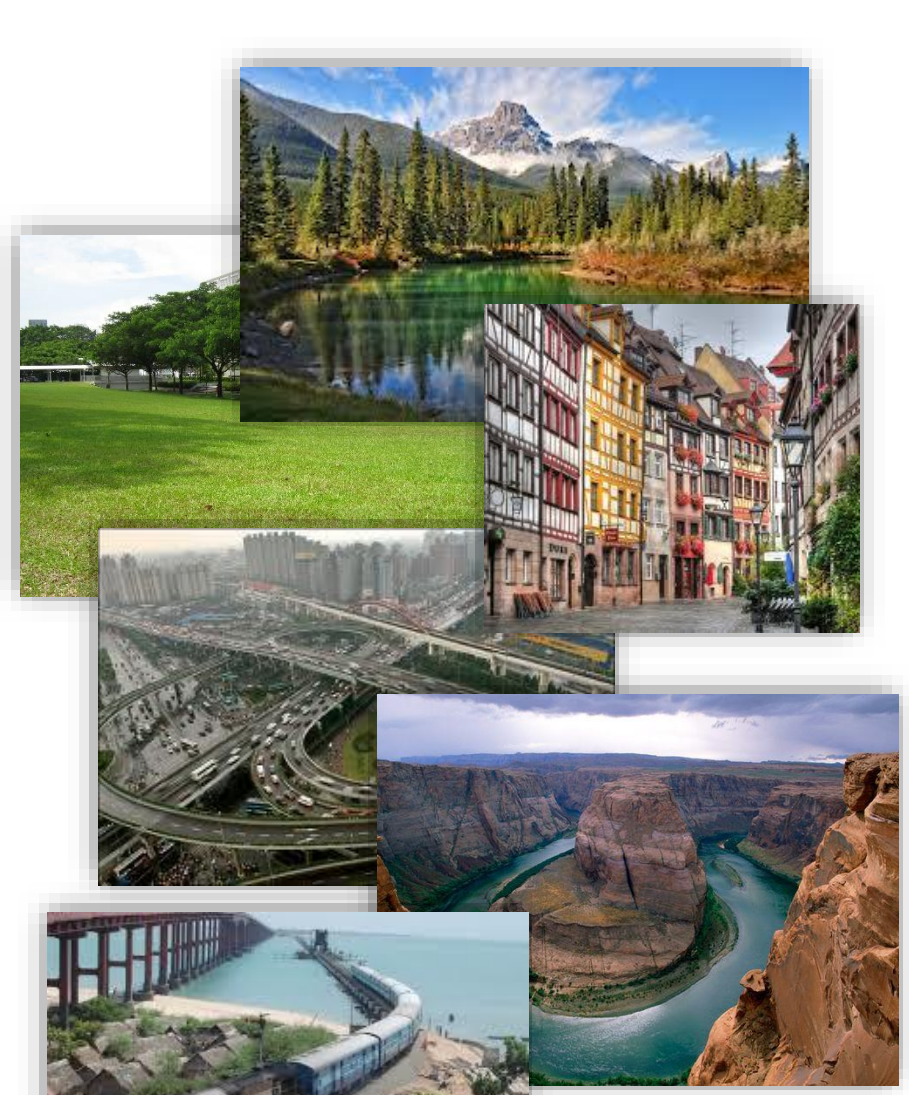
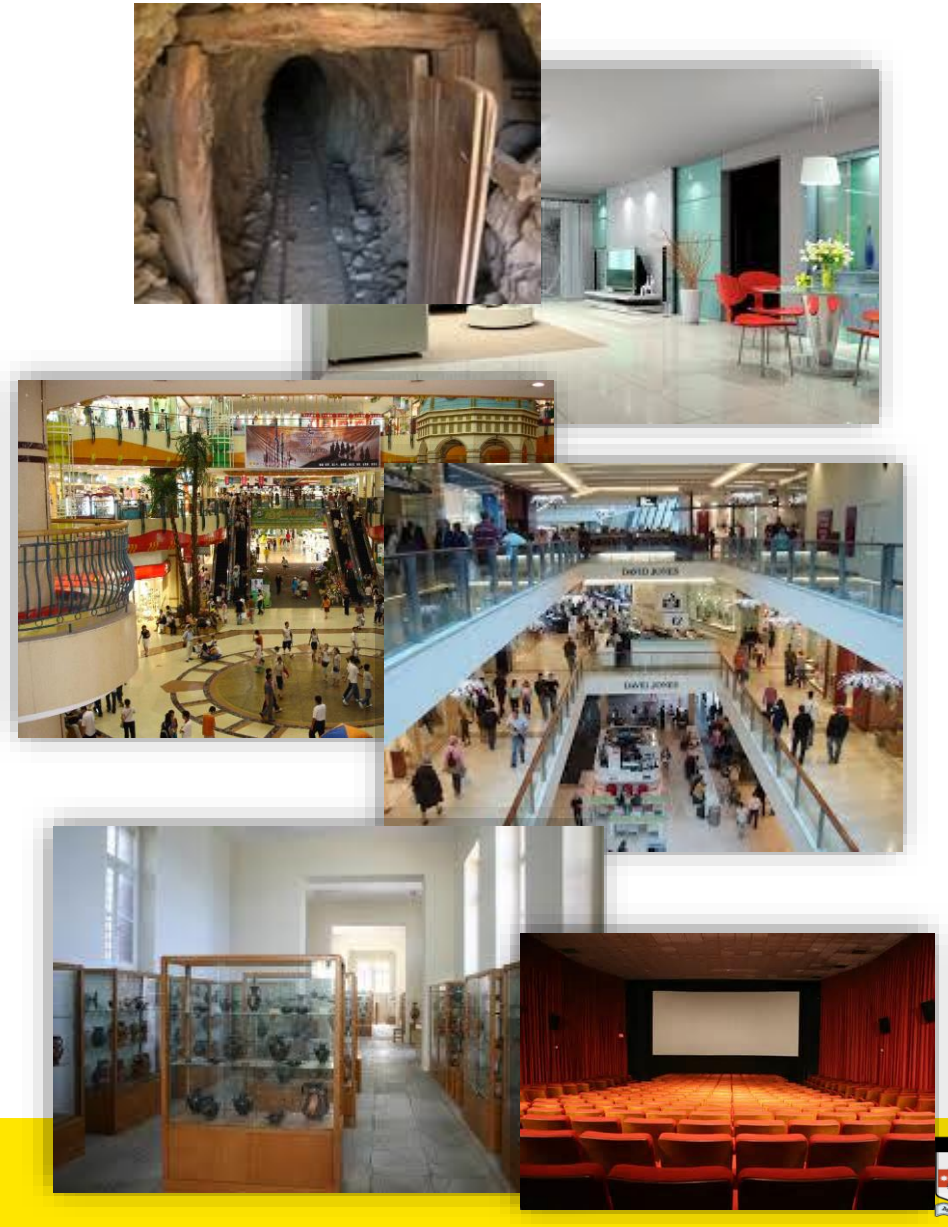
Content

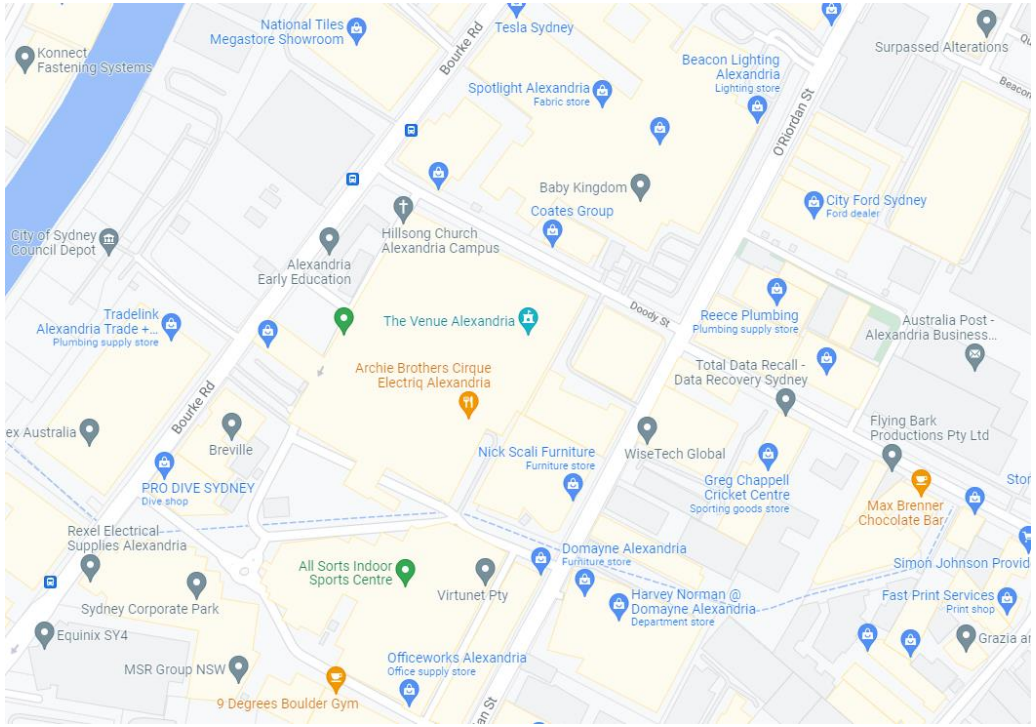
- Context
- 3D indoor navigation
- 3D outdoor navigation
- Unified model and use case example
- Discussion

Outdoor vs. Indoor navigation



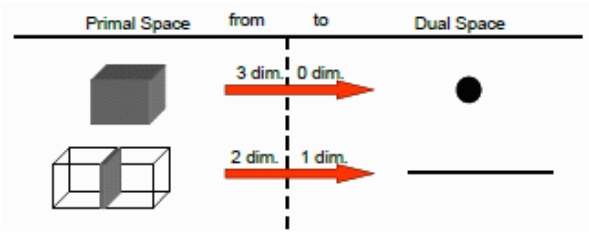


Outdoor vs. Indoor navigation

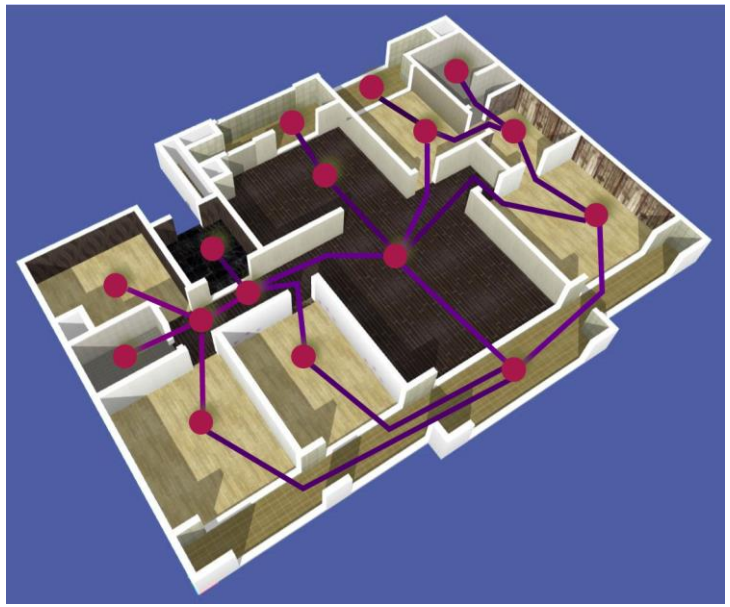


Basic navigation principle

- How to provide guidance?
  - Model → Geometry + Semantic
  - Network → Connectivity information
  - Positioning → (localization technologies)

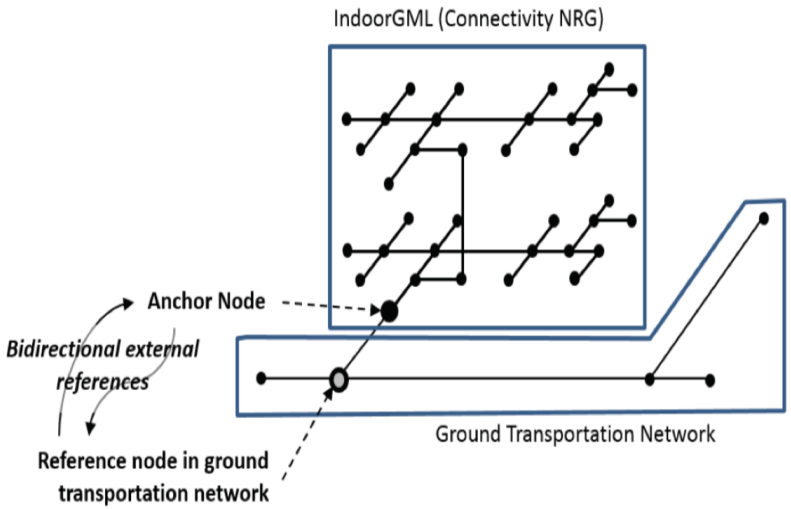


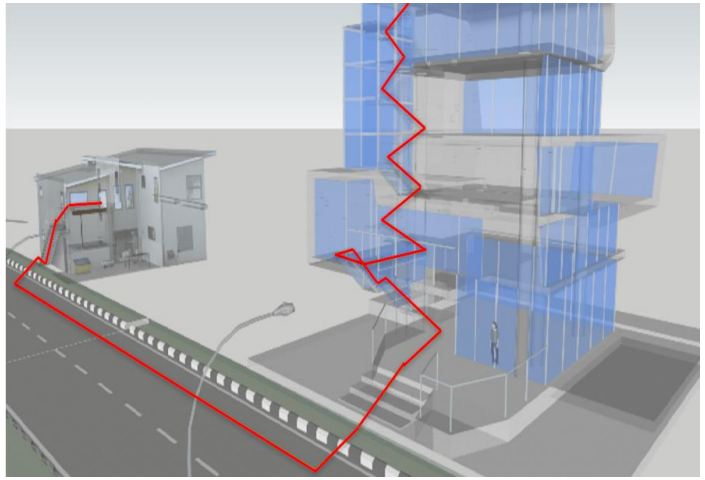
Poincaré Duality



Basic navigation principle

- Simply “gluing” indoor and outdoor network is not enough!
- Networks are of different kind depending on the environment.

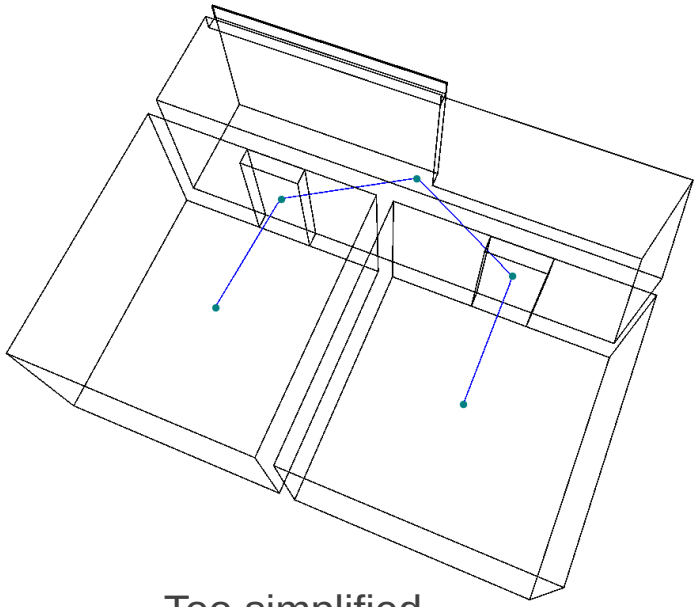




Space-based indoor navigation

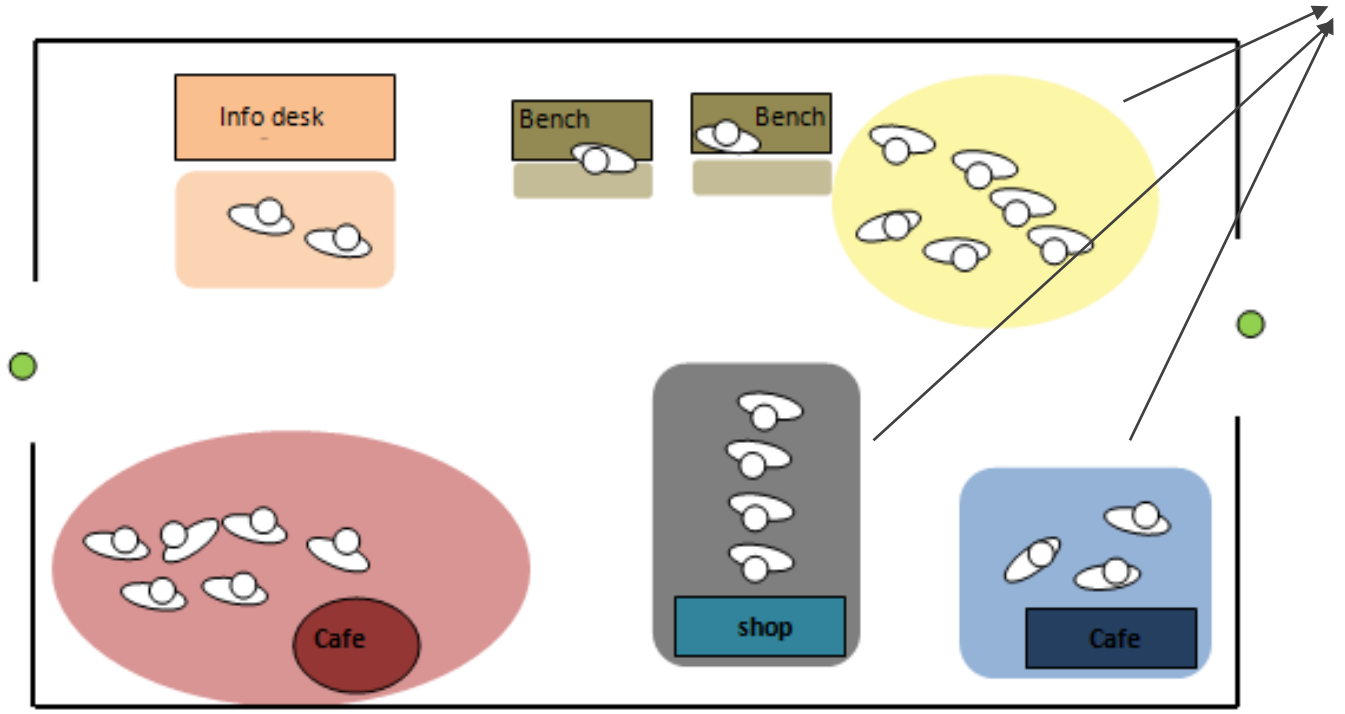
Complex environment:

- Large spaces in public buildings
- People: presence and their behaviour
- Objects in indoor environment

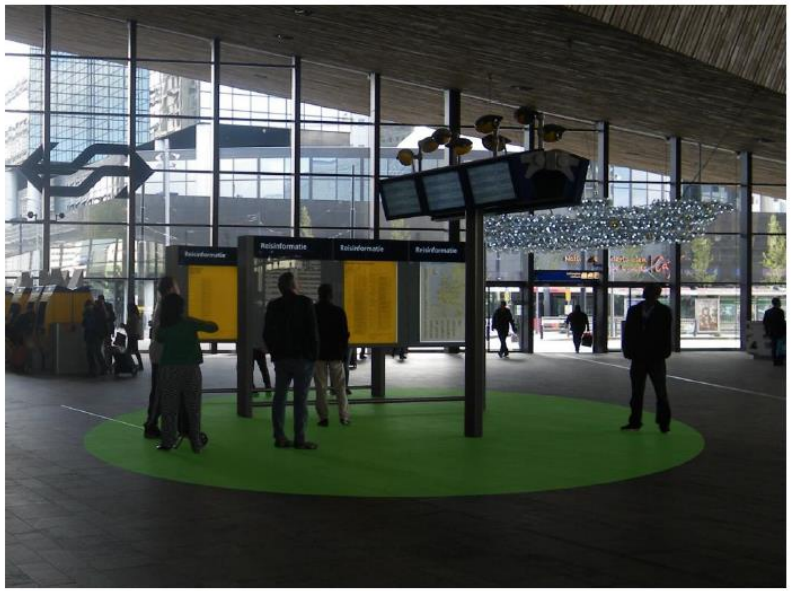


Too simplified

None-accessible areas



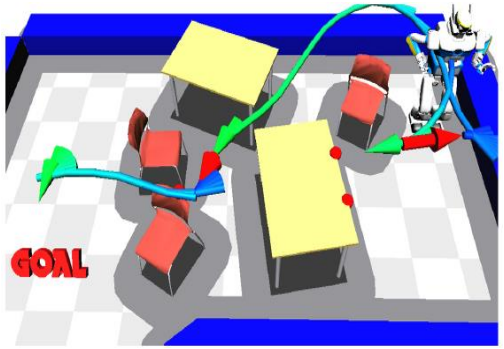
Space-based indoor navigation

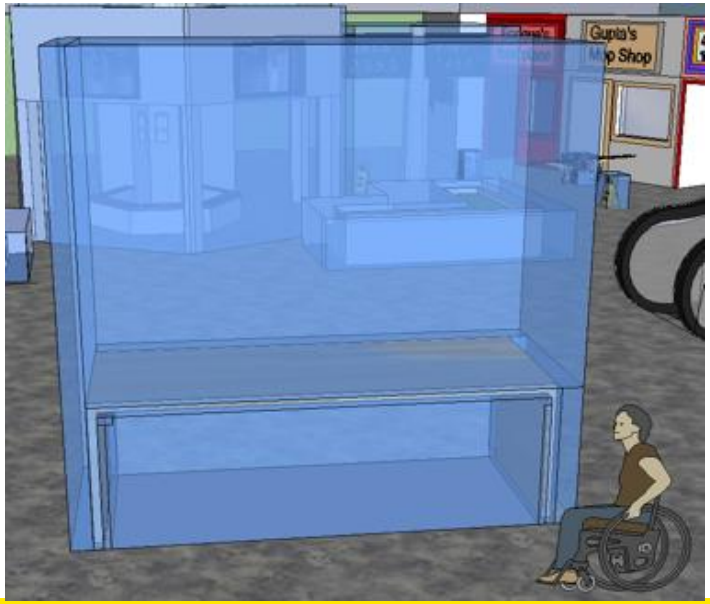


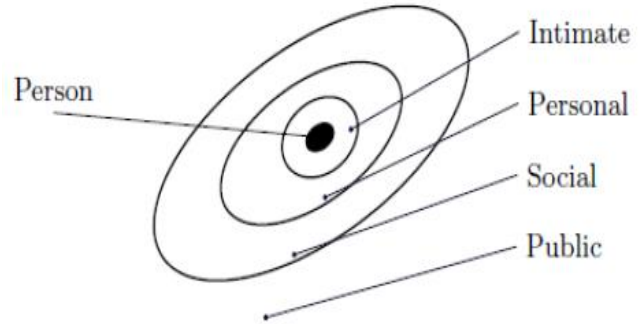
Space-based indoor navigation

Space subdivision is needed:

- To better represent: location, path or destination
- Navigable / Non-navigable spaces need to be identified.
- Spatial Properties and functions of the objects (resources) as well as the users (agents) need to be considered.



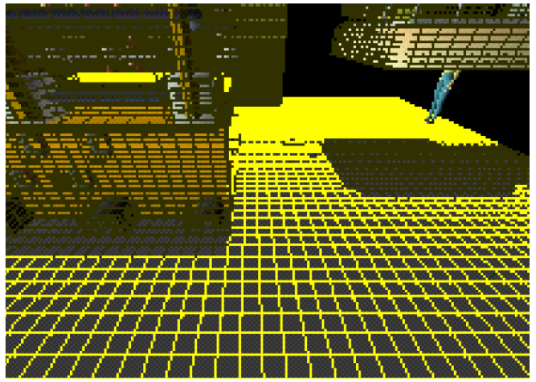




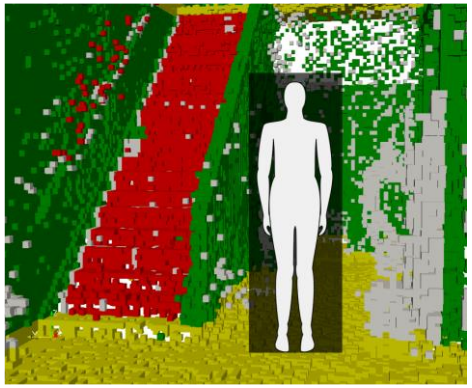
Space-based indoor navigation

Subdivision approaches:

- Grid-based (raster domain)

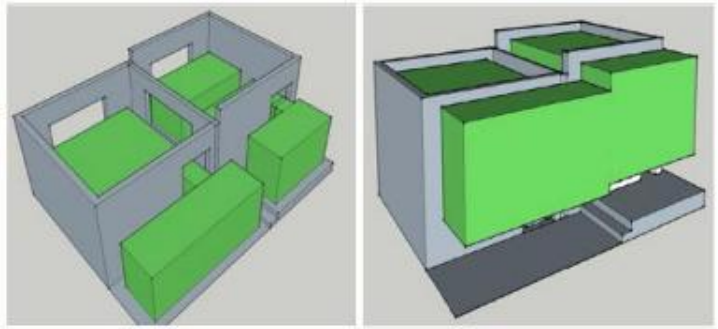


(Bandi and Thalmann, 1998)

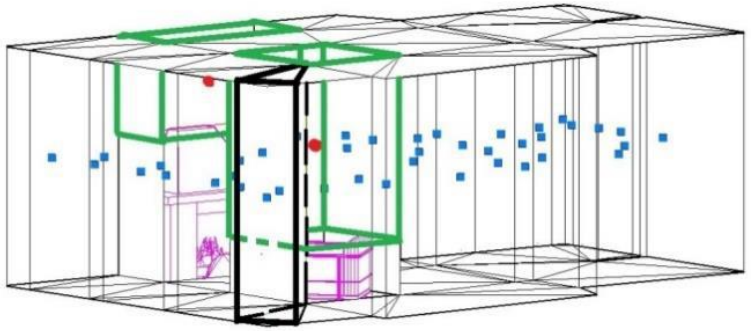


(Fichtner, Diakite and Zlatanova., 2017)

- Polyhedron-based (vector domain)



(Khan and Kolbe, 2013)



(Xu, Wei, Zlatanova and Zhang, 2017)

Space-based indoor navigation

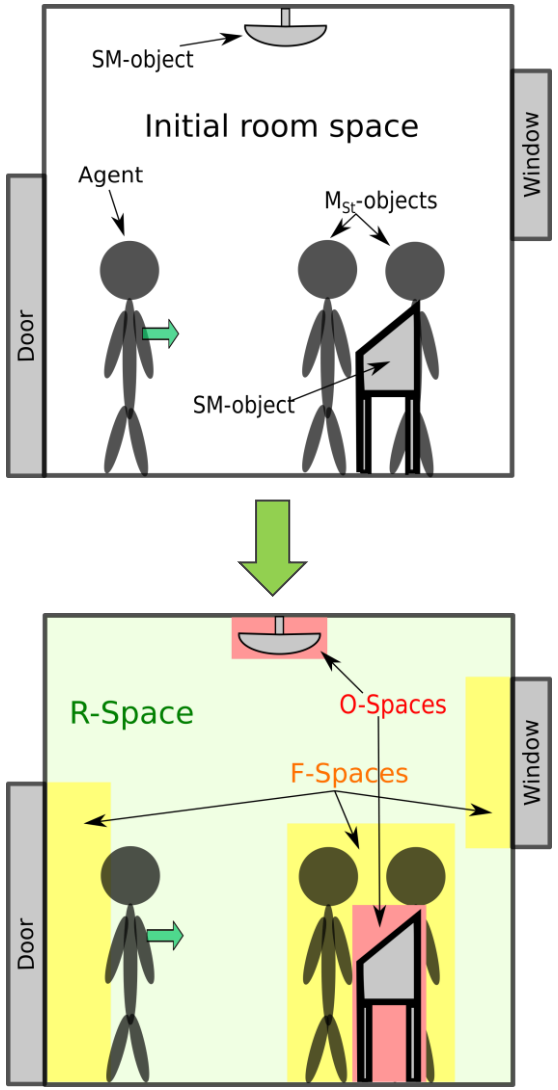
Flexible Space Subdivision (FSS) framework.

Mobility of objects:

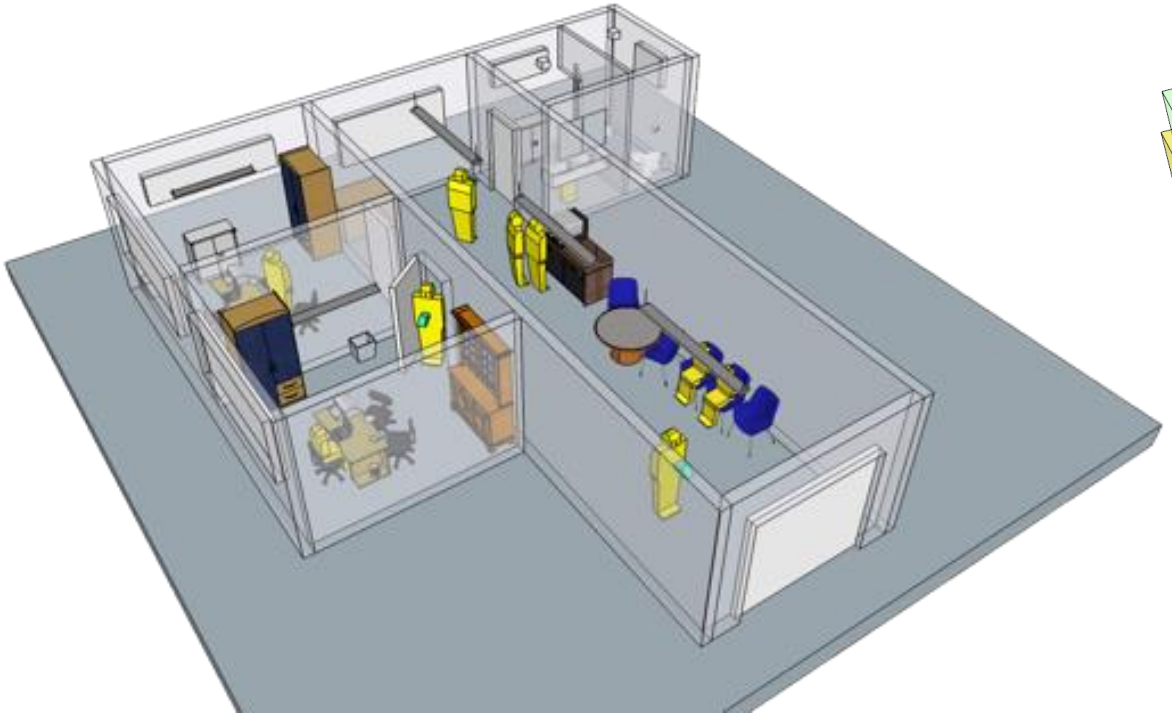
- Static (S-objects) e.g. wall
- Semi-mobile (SM-objects) e.g. furniture, crowd
- Mobile (M-object) e.g. human

Subspaces:

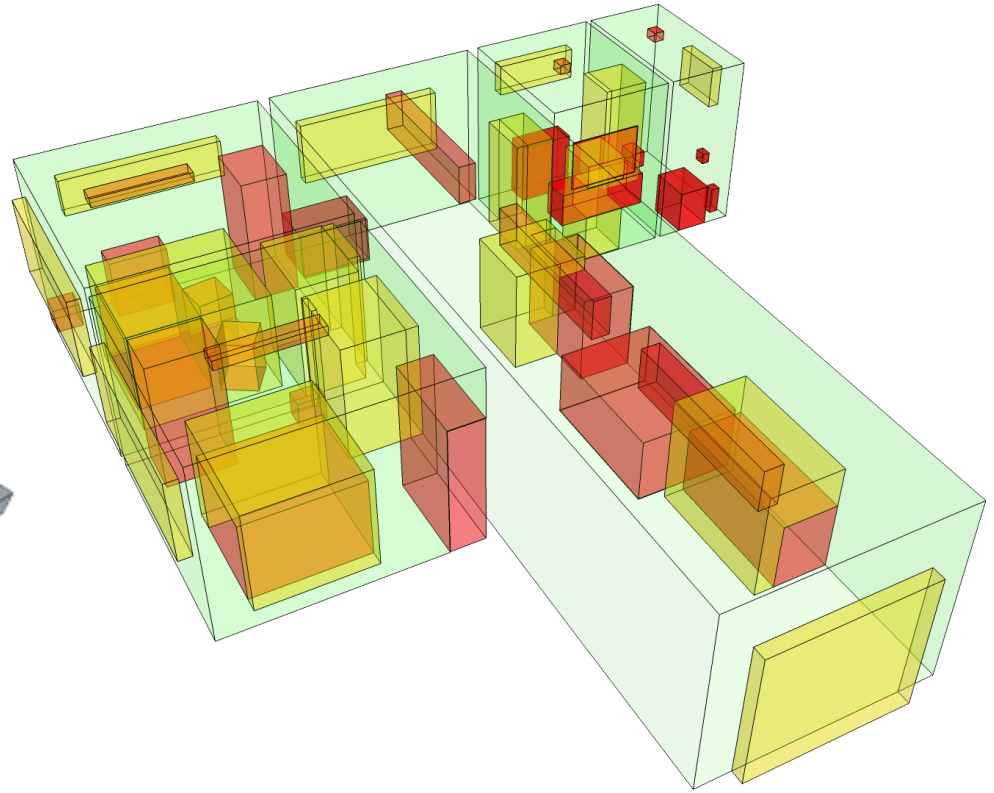
- Object spaces (O-Spaces) -> SM-objects
- Functional spaces (F-Spaces) -> SM and M-objects
- Remaining free spaces (R-Spaces) -> M-objects



Space-based indoor navigation

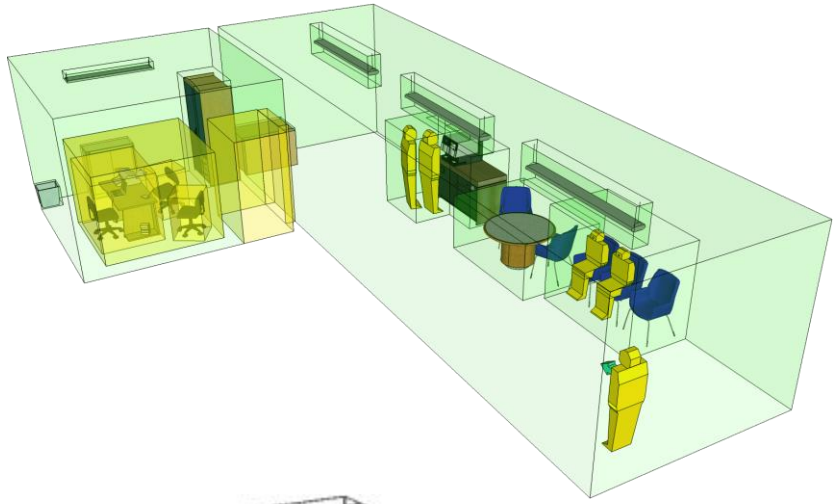


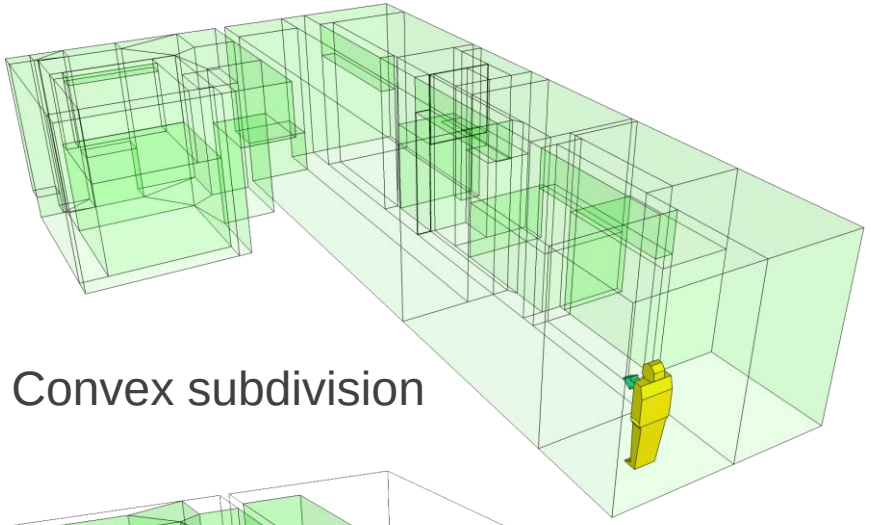
Original BIM model



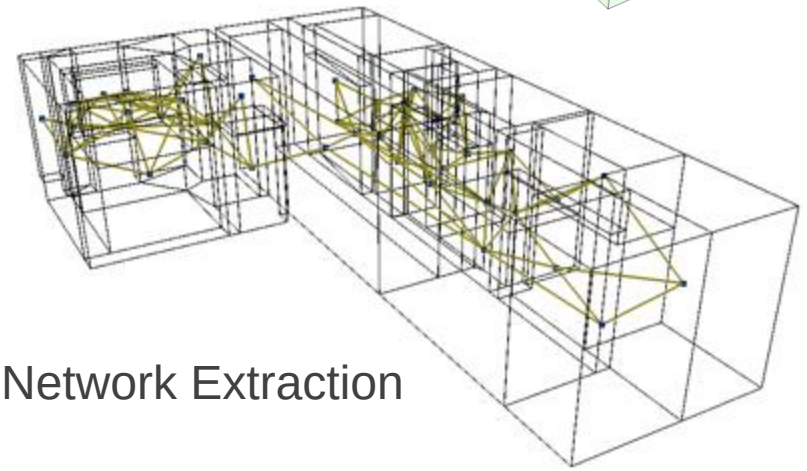
FSS subdivision

Space-based indoor navigation

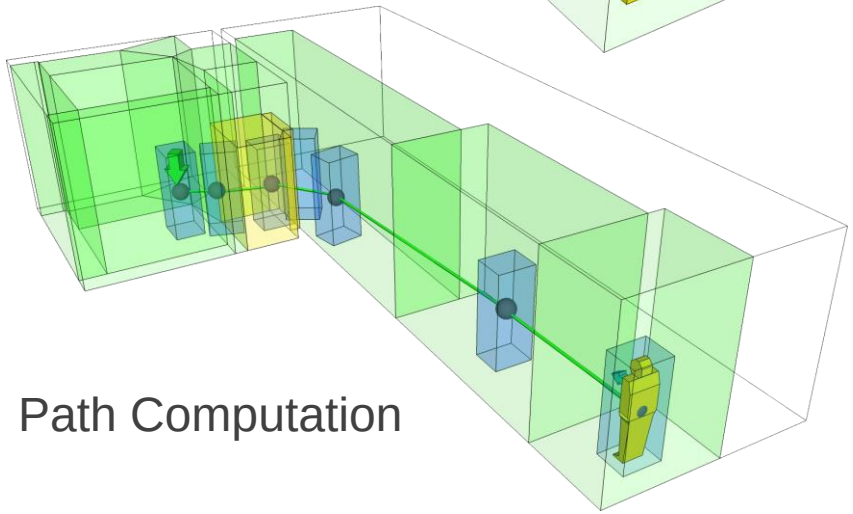




Convex subdivision



Network Extraction



Path Computation

Space-based outdoor navigation?

Can the same principle be applied to the outdoor environment?

- Different “boundaries”
- Different organisation/subdivision patterns

Indoor

Outdoor

Space-based outdoor navigation?

Spaces between indoor and outdoor?

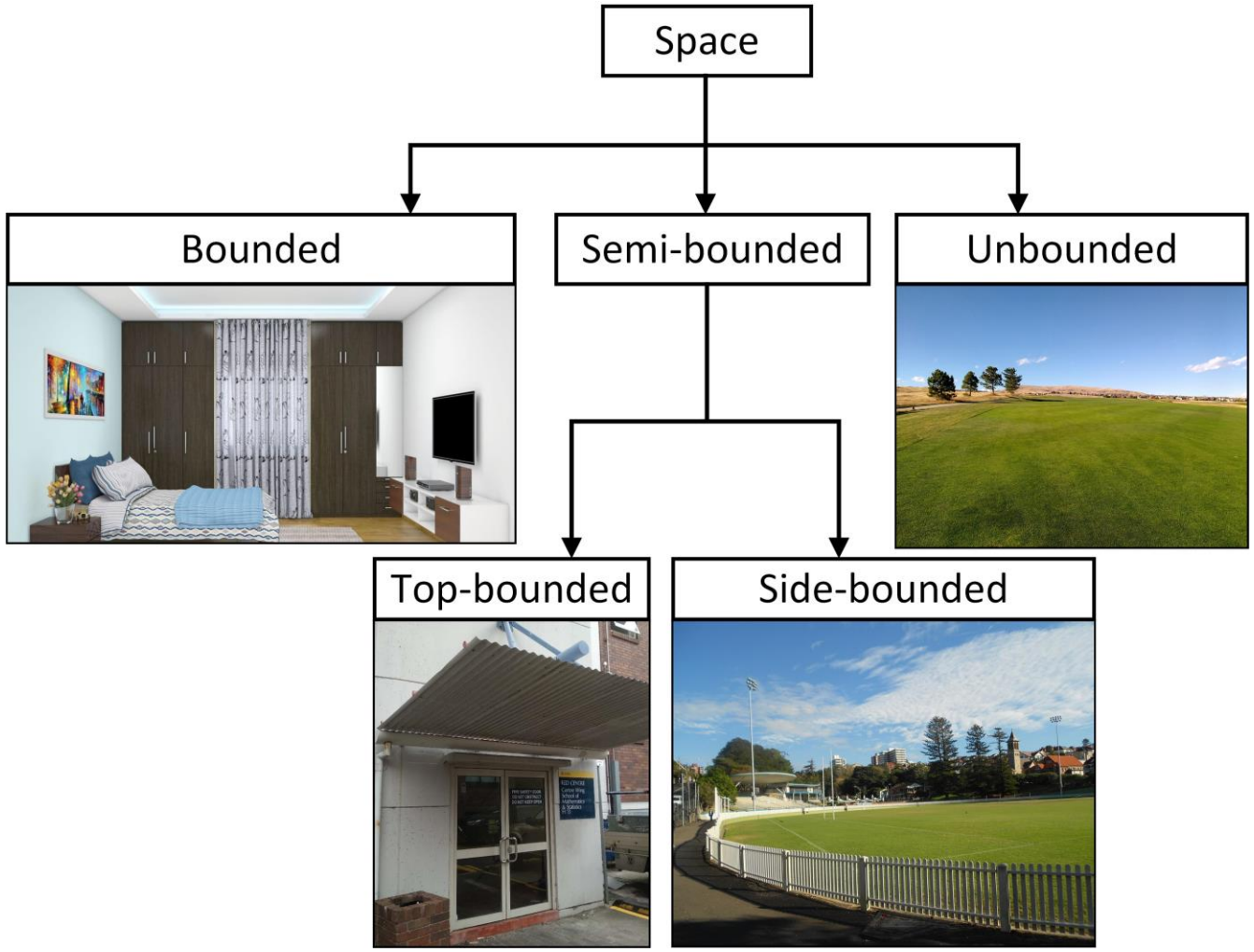
No formal definition.

(a) (b) (c)

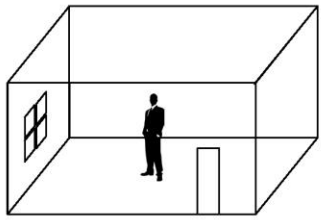
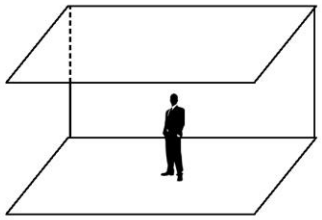
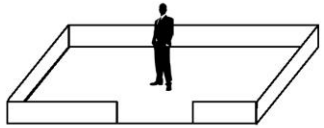
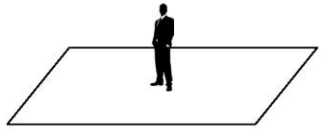
(d) (e) (f)

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.

Outdoor Space classification

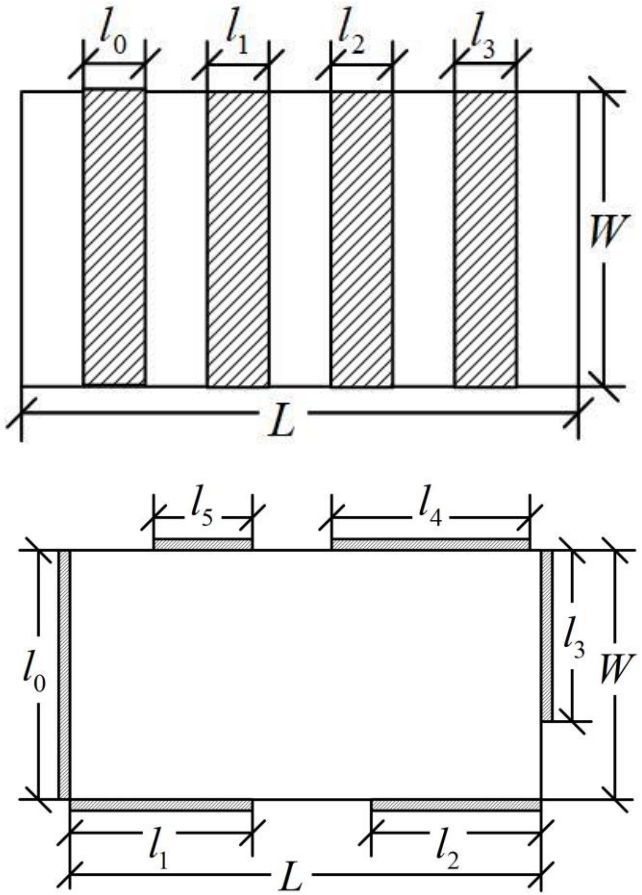


Outdoor Space classification

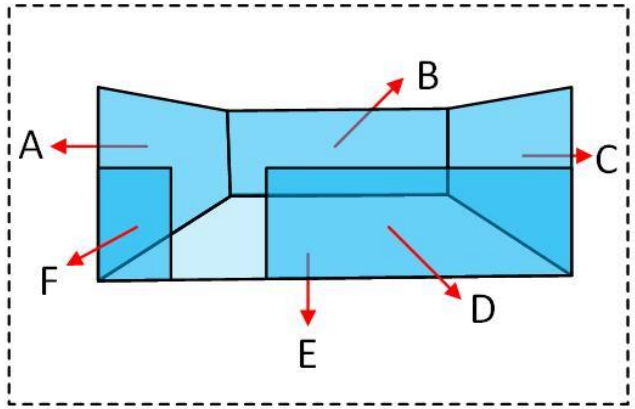
Environment	I-space	sI-space	sO-space	O-space
Definition	$C^T \geq \beta$ & $C^S \geq \delta$	$C^T \geq \eta$ & $C^S \in [0,1]$ *except* $C^T \geq \beta$ & $C^S \geq \delta$	$C^T < \eta$ & $C^S \in [0,1]$ *except* $C^T < \alpha$ & $C^S < \gamma$	$C^T < \alpha$ & $C^S < \gamma$
Example				
Scene				
Thresholds	$0 \leq \alpha \leq \eta \leq \beta \leq 1$ & $0 \leq \gamma \leq \delta \leq 1$			

Outdoor Space boundaries

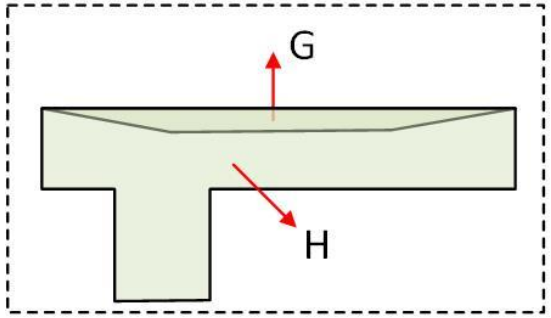
Space closure implies identification of physical and virtual boundaries.



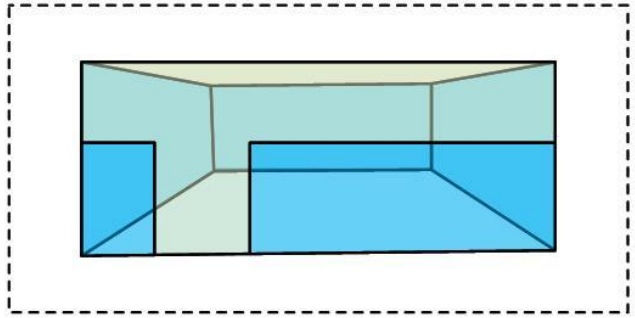
(a)



(b)

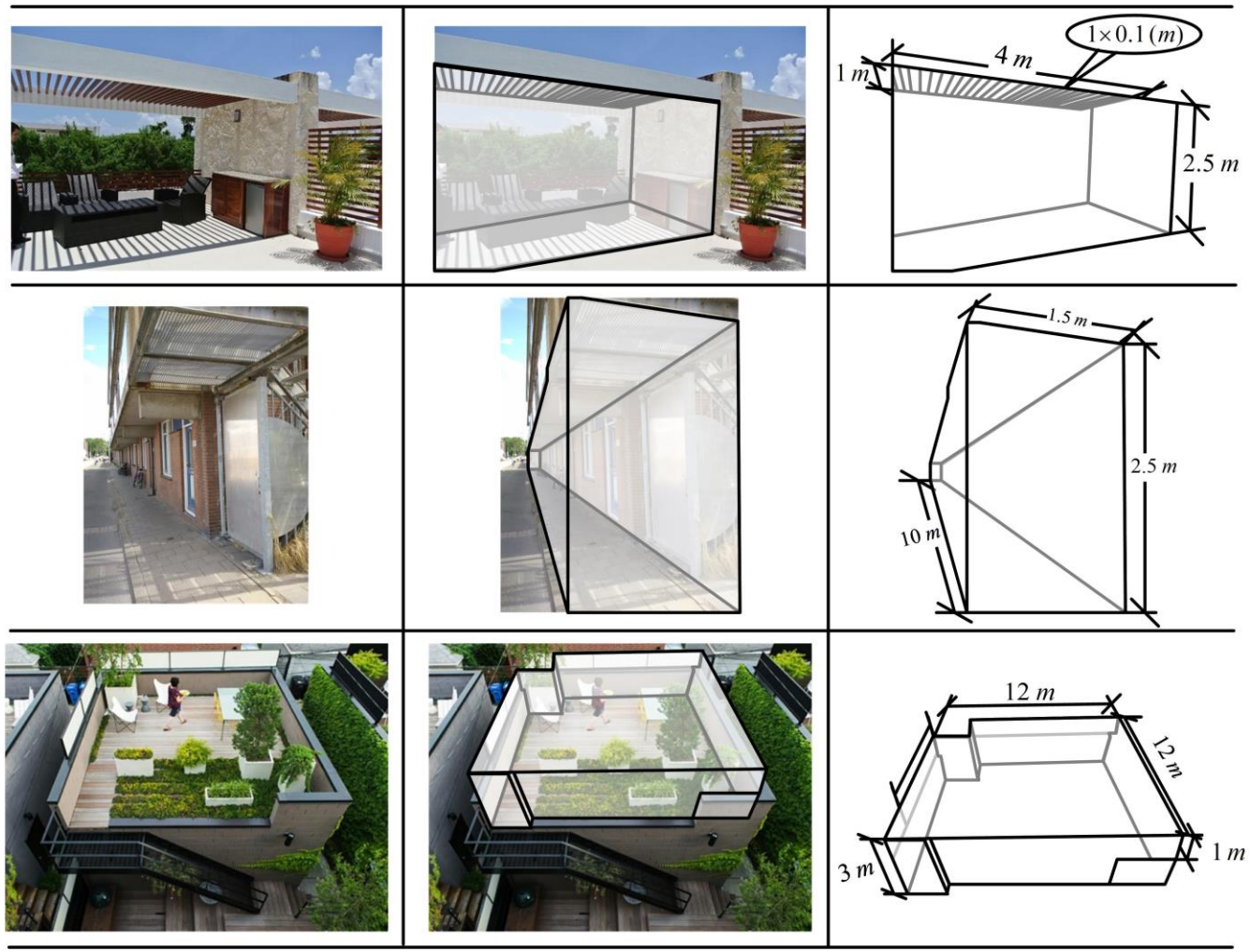


(c)



(d)

Outdoor Space boundaries



$C^T = 0.625$

$C^S = 0.2$

→ **sI-space**

$C^T = 1$

$C^S = 0.43$

→ **sI-space**

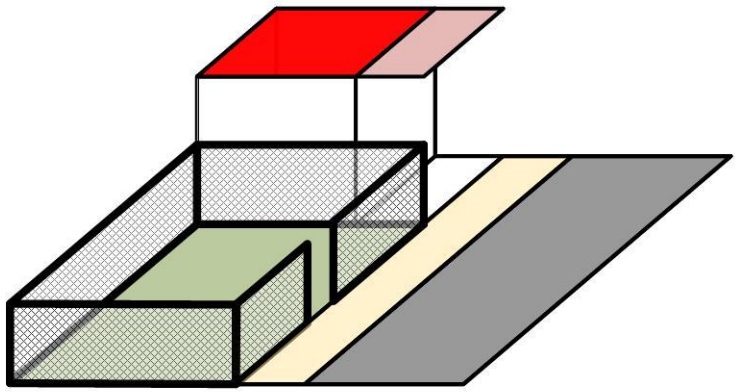
$C^T = 0$

$C^S = 0.67$

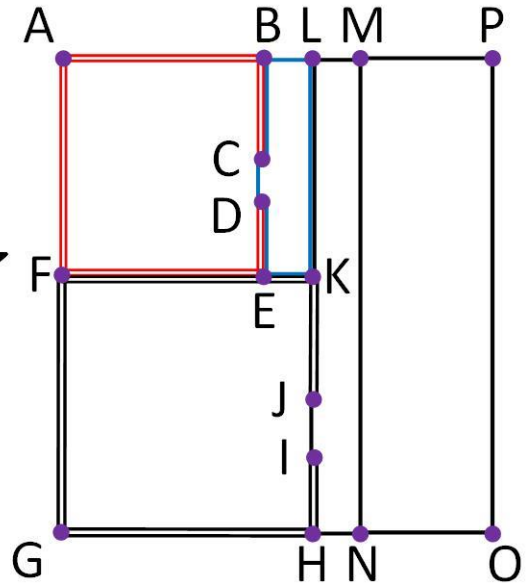
→ **sO-space**

Outdoor Space classification

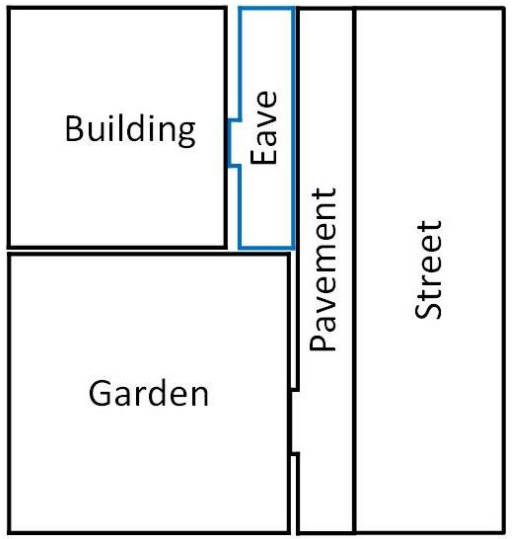
Classic **outdoor classification** can be used to enhance the creation of “bounded” outdoor spaces.



Built objects



corresponding footprints

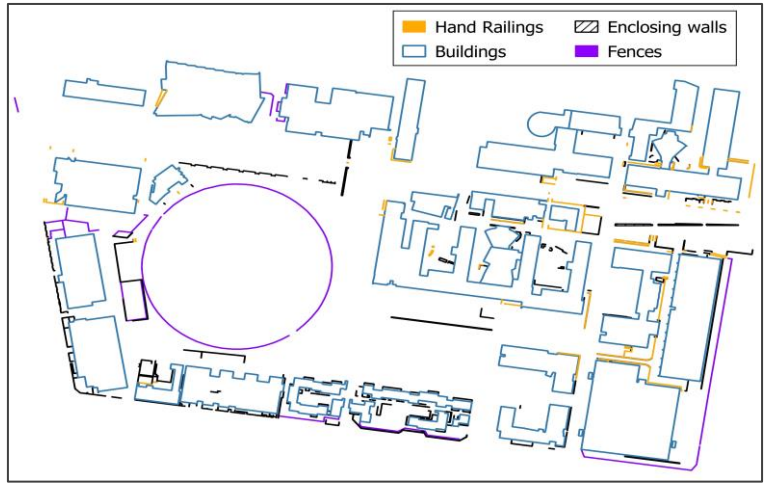


classification

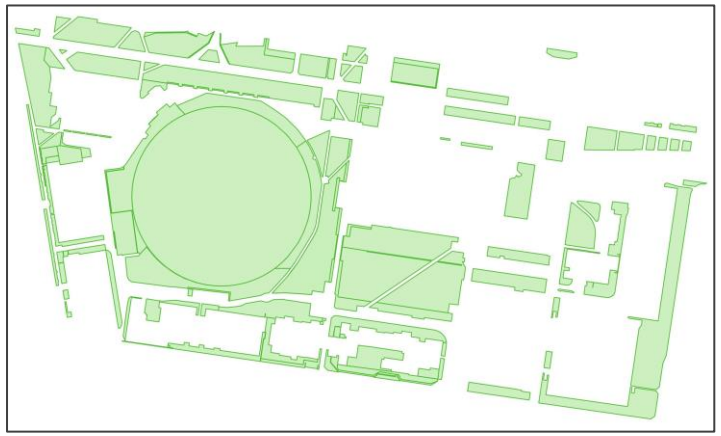
Building a unified model for navigation

Footprints classification

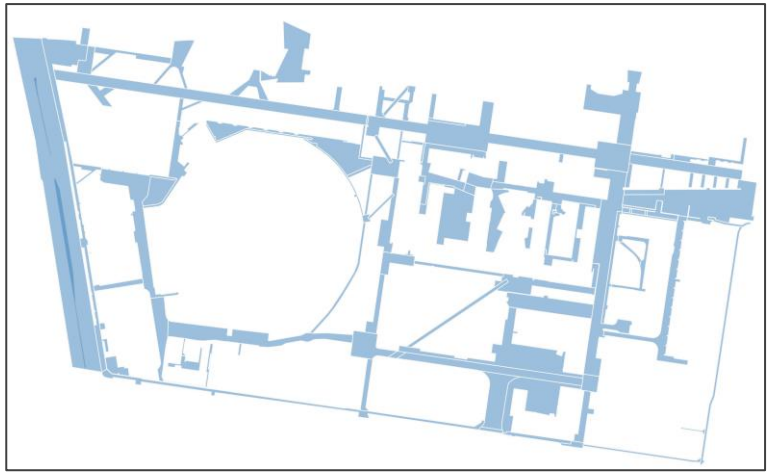
Road and green area footprints determination based on physical boundaries (fences, enclosing walls, hand railings, and buildings). The threshold is 0.75.



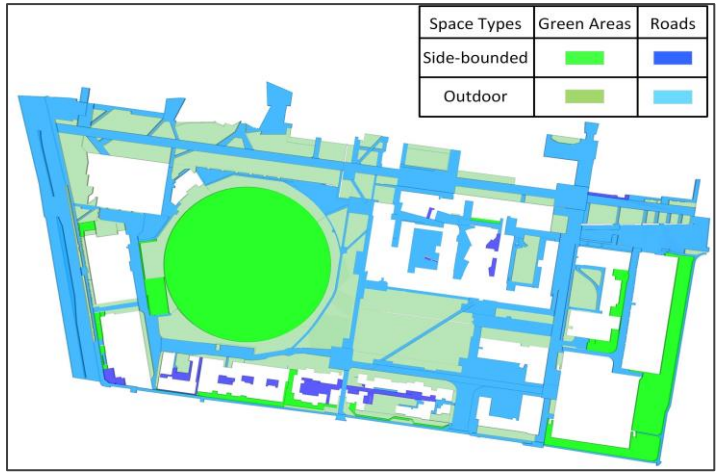
(a) Physical boundaries



(b) Road footprints



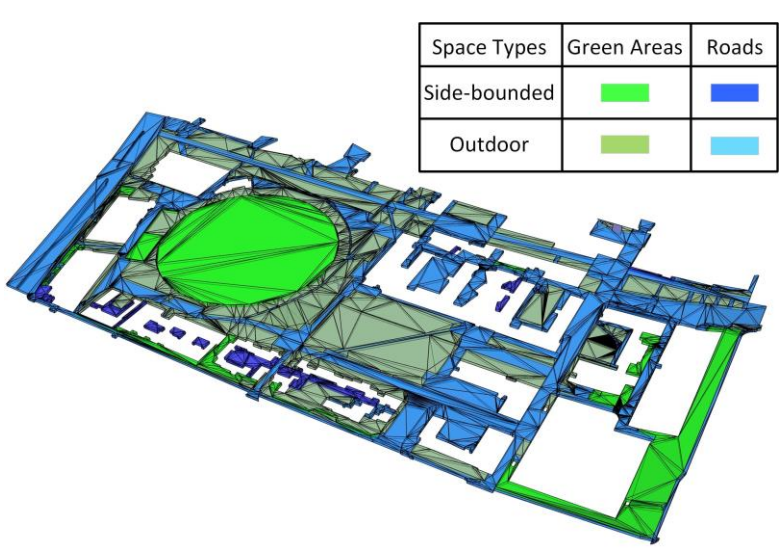
(c) Green areas footprint



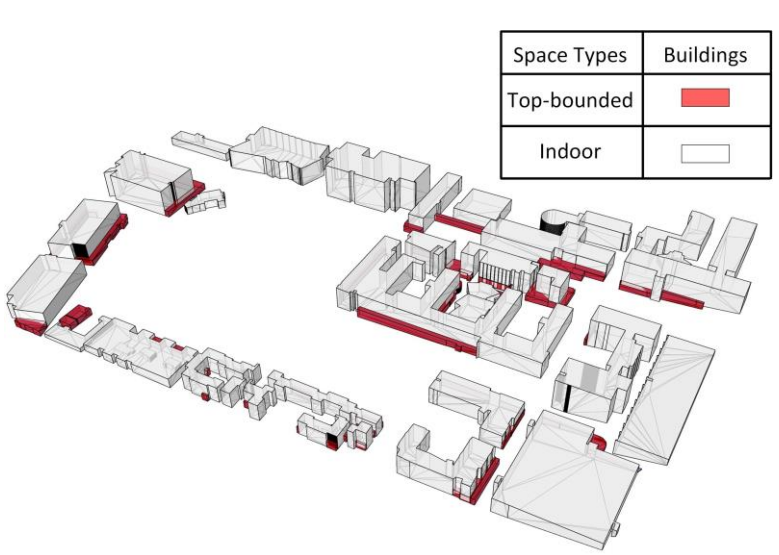
(d) Classified footprints

Building a unified model for navigation

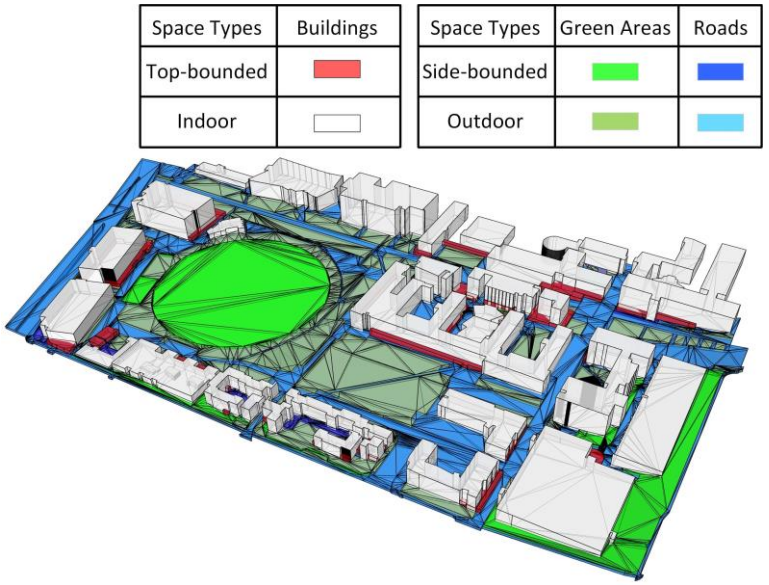
Space creation



(a) Side-bounded and outdoor spaces



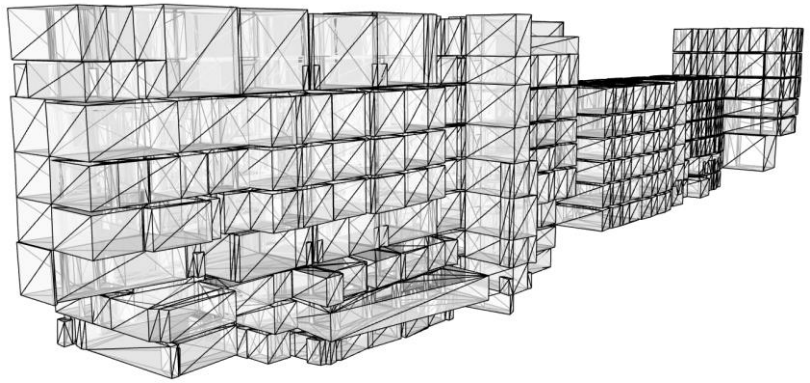
(b) Top-bounded and indoor spaces



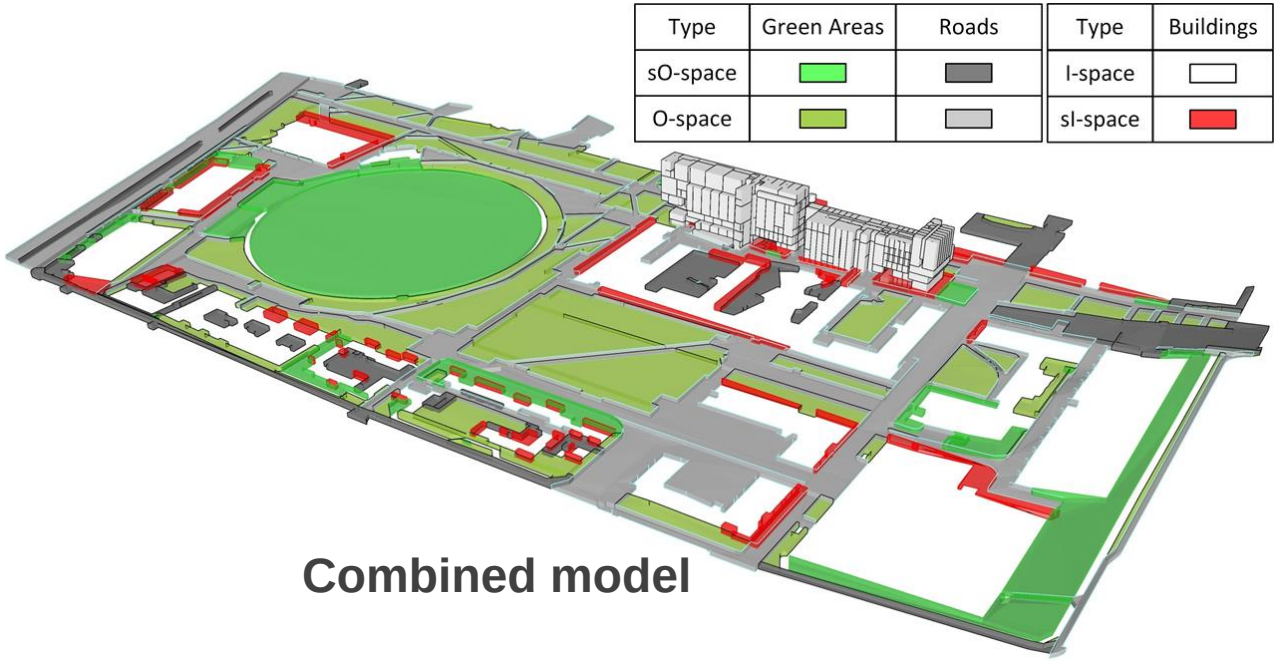
(c) All the four types of spaces together

Building a unified model for navigation

Outdoor inputs

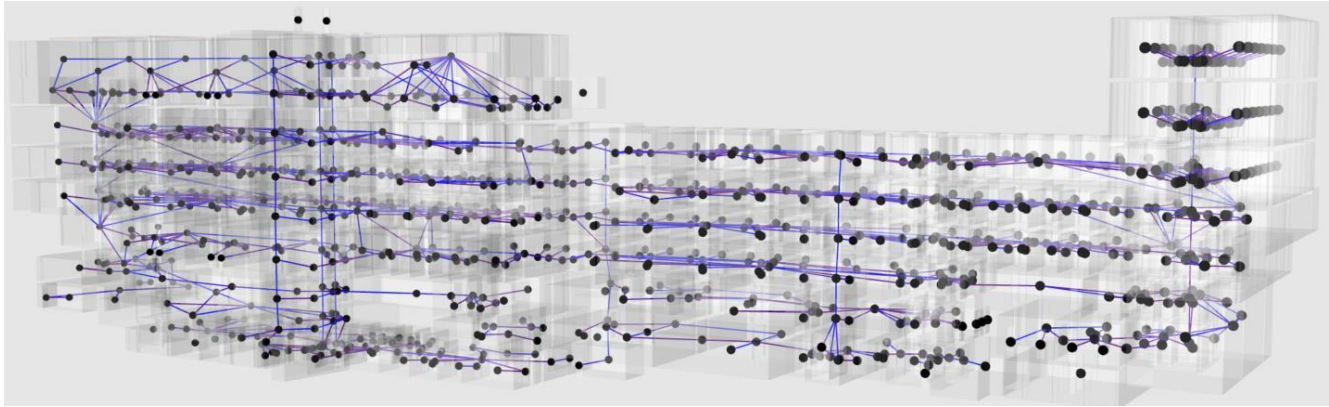


Indoor inputs

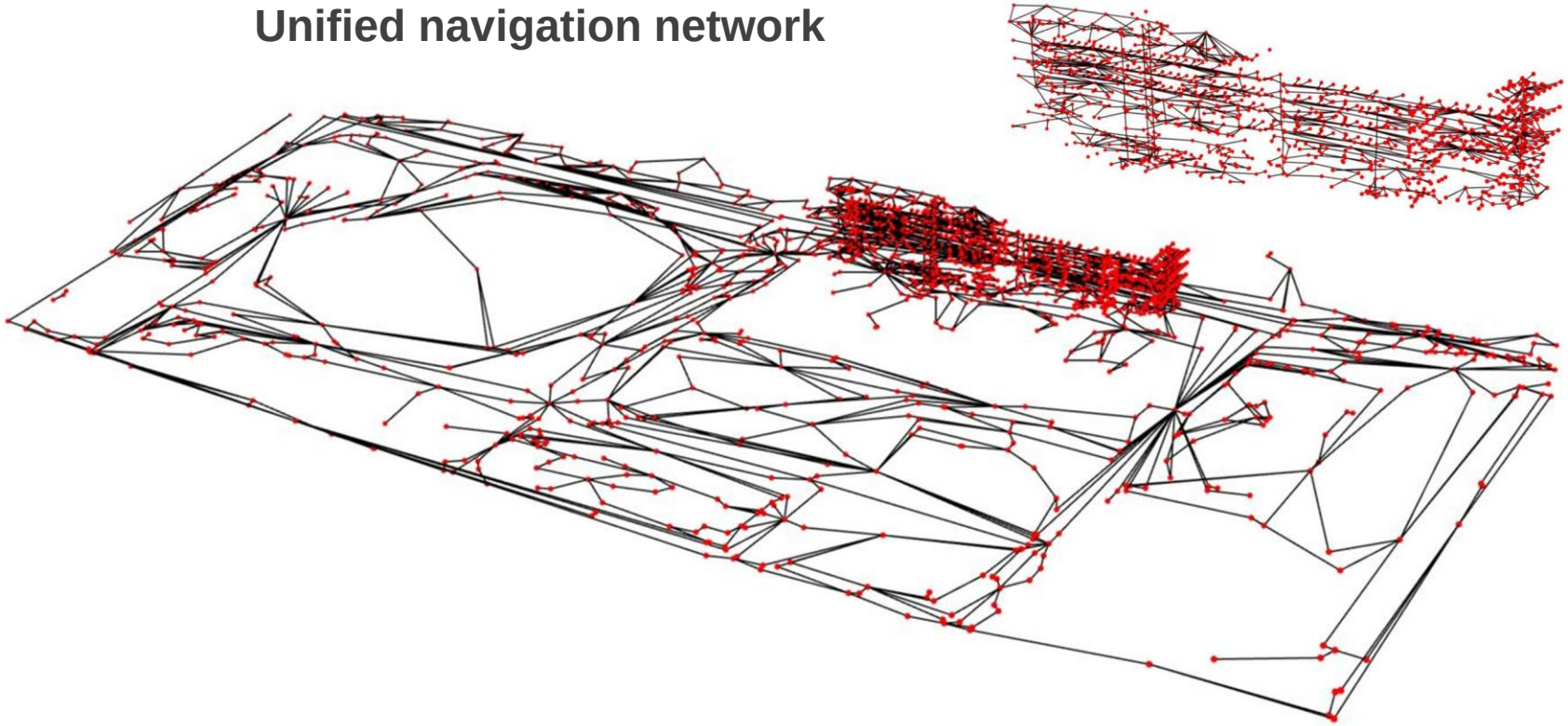


Combined model

Building a unified model for navigation



Unified navigation network



Unified navigation model use cases

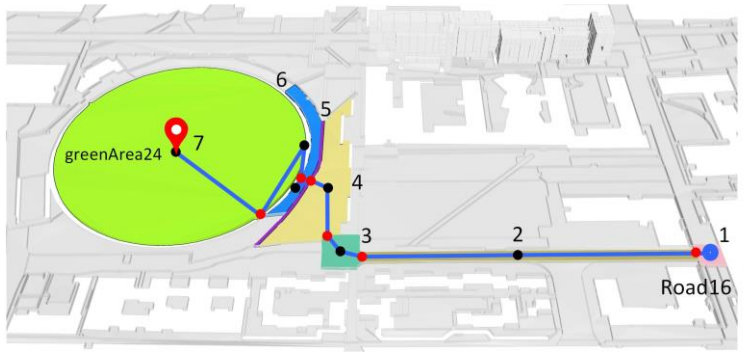
Rai
n

Strong
wind

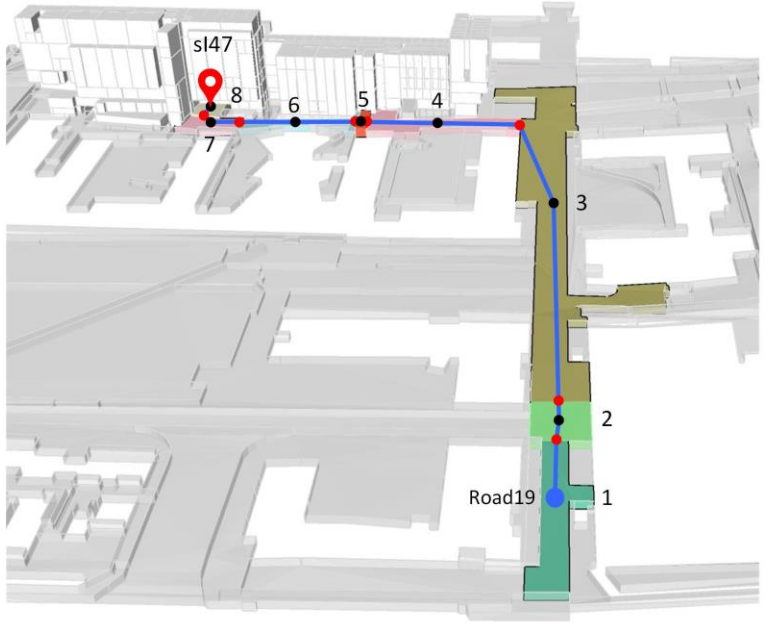
Hot
sun

Tired for walking

Unified navigation model use cases

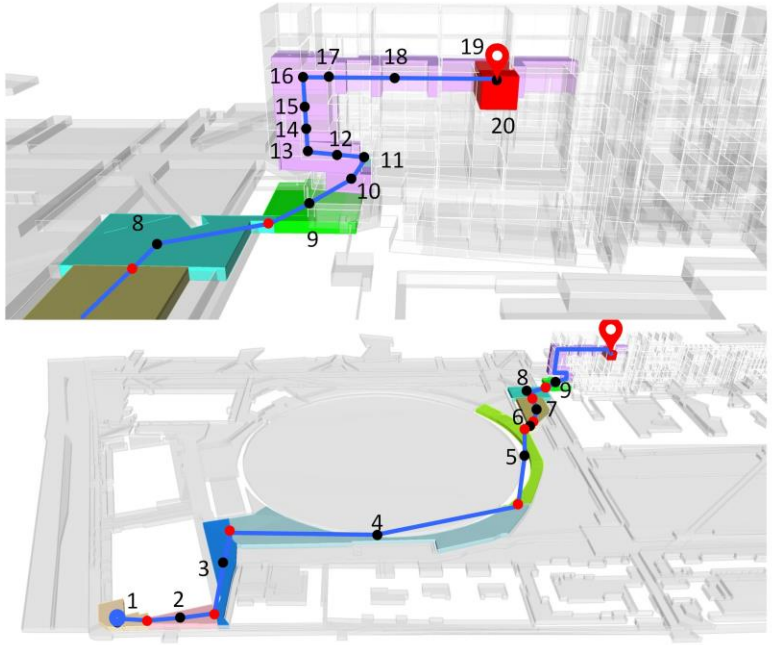


No.	Name	closure			SpaceType
		C^T	C^S	C^B	
1	road16	0	0.30	1	O-space
2	road17	0	0.37	1	O-space
3	road37	0	0	1	O-space
4	greenArea25	0	0.27	1	O-space
5	road34	0	0.26	1	O-space
6	greenArea29	0	0.49	1	O-space
7	greenArea24	0	0.99	1	sO-space



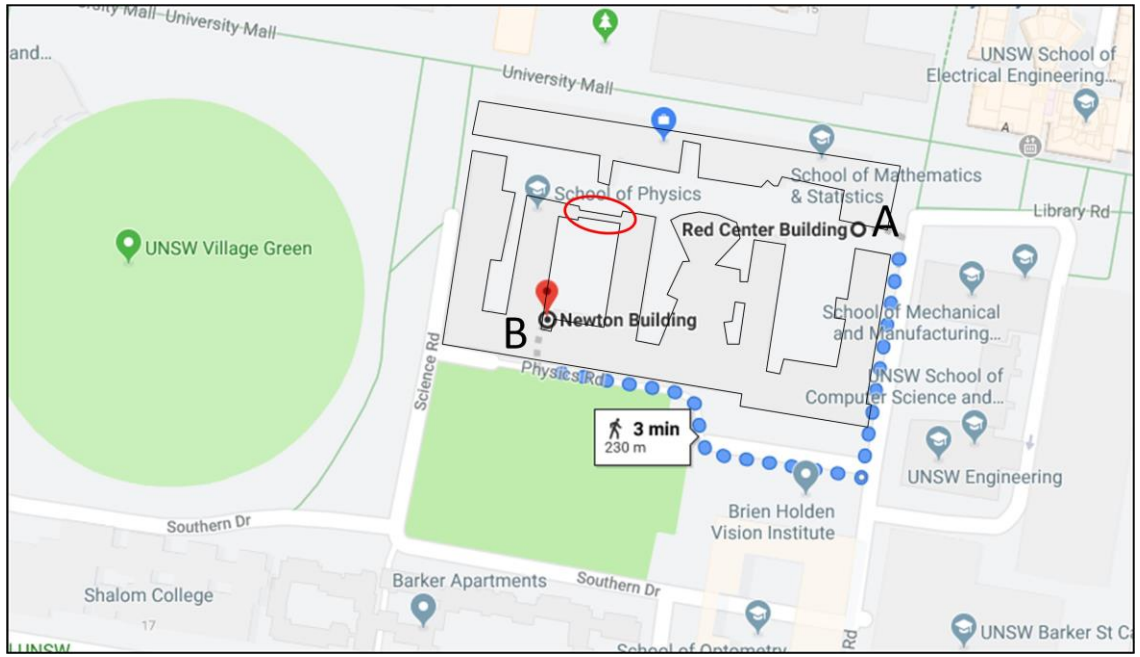
No.	Name	closure			SpaceType
		C^T	C^S	C^B	
1	road19	0	0.42	1	O-space
2	road16	0	0.30	1	O-space
3	road62	0	0.50	1	O-space
4	road128	0	0.70	1	O-space
5	sl60	1	0.27	1	sl-space
6	road127	0	0.73	1	O-space
7	road106	0	0.70	1	O-space
8	sl47	1	0.48	1	sl-space

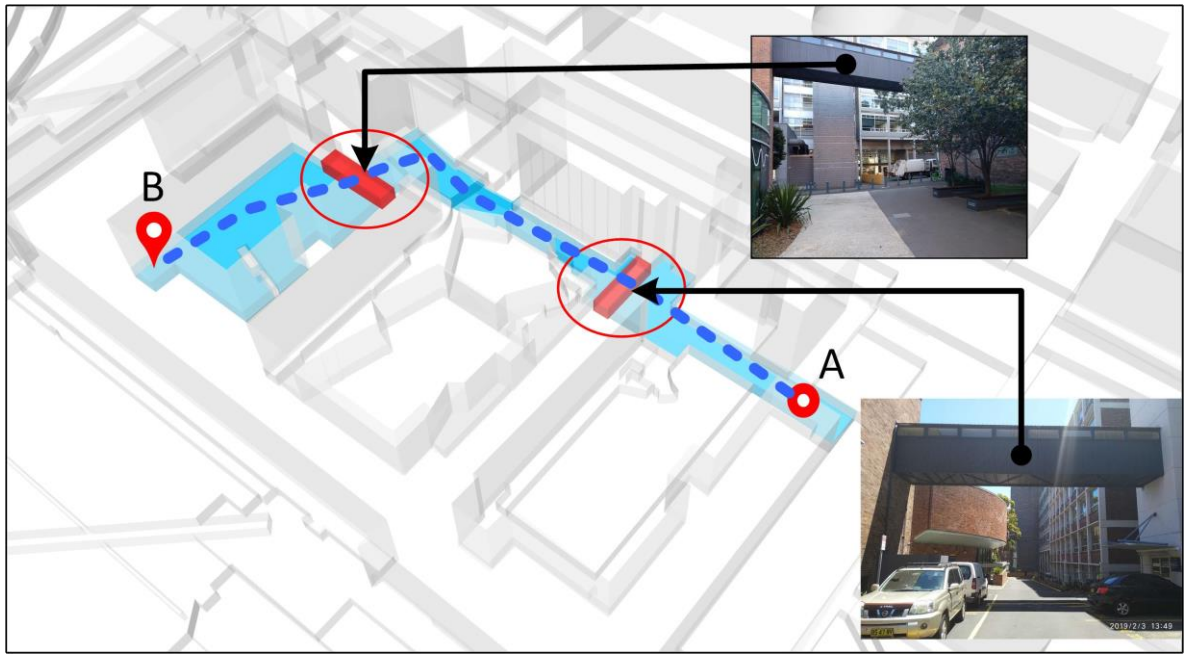
Navigation cases



No.	Name	closure			SpaceType
		C^T	C^S	C^B	
1	road80	0	0.99	1	sO-space
2	sl19	1	0.71	1	sl-space
3	road71	0	0.08	1	O-space
4	greenArea36	0	0.49	1	O-space
5	greenArea29	0	0.49	1	O-space
6	road33	0	0	1	O-space
7	greenArea44	0	0	1	O-space
8	road25	0	0.19	1	O-space
9	greenArea49	0	0.20	1	O-space
10	G032	1	1	1	I-space
11	MQ01	1	1	1	I-space
12	MQ02	1	1	1	I-space
13	1Q01	1	1	1	I-space
14	2Q01	1	1	1	I-space
15	3Q01	1	1	1	I-space
16	4Q01	1	1	1	I-space
17	Door	1	1	1	I-space
18	4Q04	1	1	1	I-space
19	Door	1	1	1	I-space
20	4036	1	1	1	I-space

Unified navigation model use cases





Discussion

Contributions

- Extension of 3D space-based indoor navigation concepts to outdoor
- Adapted definition for indoor, outdoor and spaces in-between
- Unified 3D space model for generating navigation network
- Enabling interesting use cases

Limitations

- 3D city models with enough details to make such unified models
- Consistent threshold definition for top and side boundaries
- Indoor localization is still a big issue

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Thank you!

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