Exploring a pure landmark-based approach for indoor localisation

O.T. Willems

5rd of November 2017 – P5 presentation

Supervisors: S. Zlatanova, E. Verbree

Co-reader: P. Nourian

TU Delft

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vision and conceptual framework

Exploring

There is a need to move beyond sensor-based indoor localisation and navigation. (Winter, 2017)

- Context driven location based services (LBS)
- Seamless connection between outdoor and indoor environment
- LBS centred around the user

How can a pure landmark-based approach achieve adequate indoor localisation? To lay a foundation for landmark-based LBS

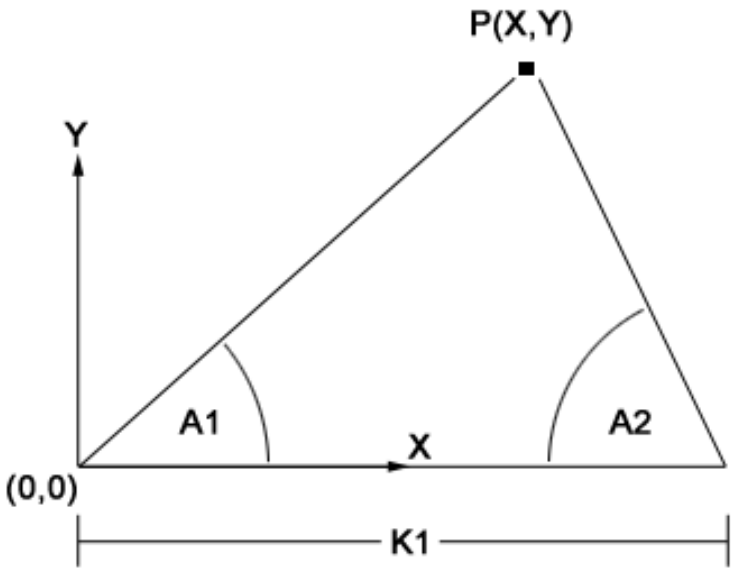
Landmark

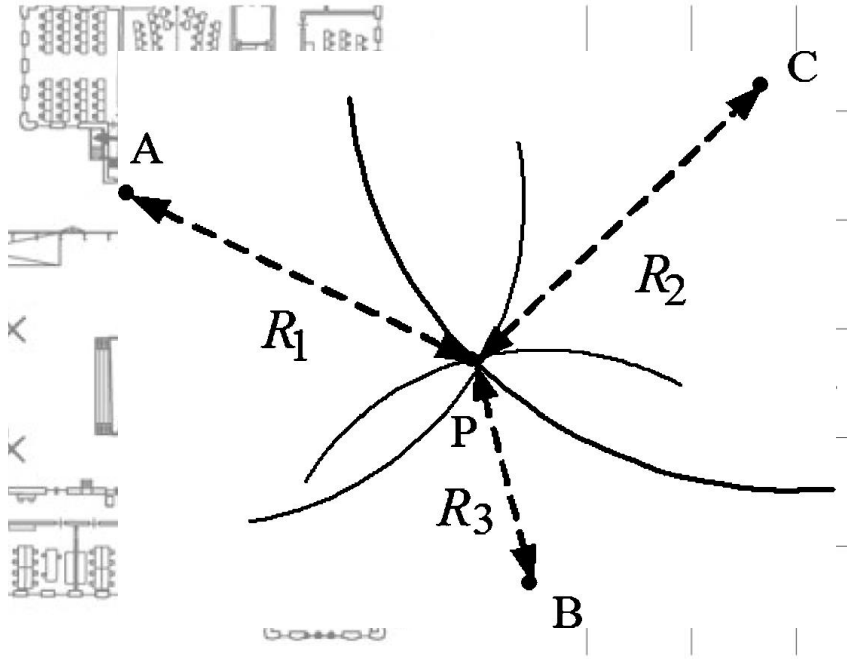
- Traditionally (unique) salient objects in the urban landscape
- 5 parameters of salience: 1) visual salience, 2) cognitive salience, 3) structural salience, 4) visibility in advance, and 5) prototypicality.

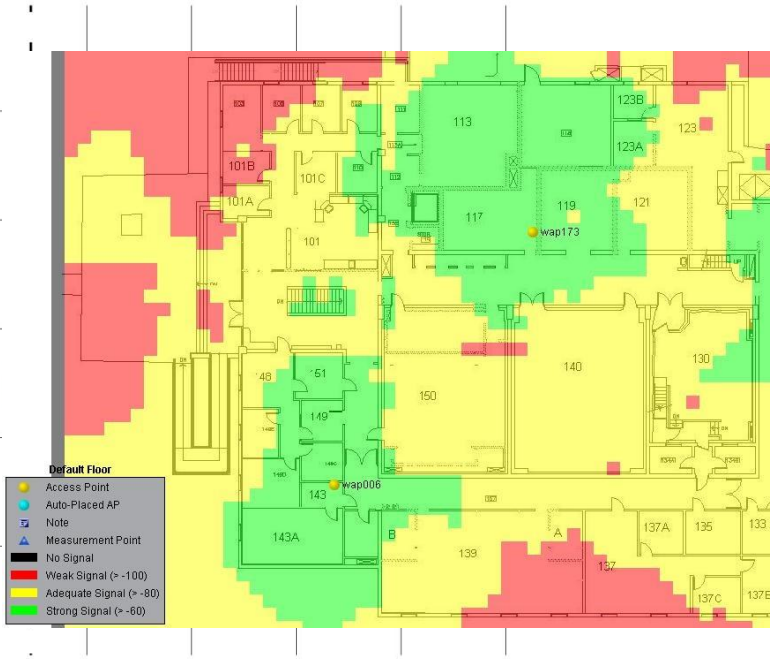
- Inc bjects eness

Any hat is met listing surroundings.

Indoor localisation (and positioning)







Location: East.bg.xxx

Position: (x,y)

Method	Landmarks	Measurements
Angulation	2+	yes (angle)
Lateration	3+	yes (distance)
Fingerprinting	1+ *	no

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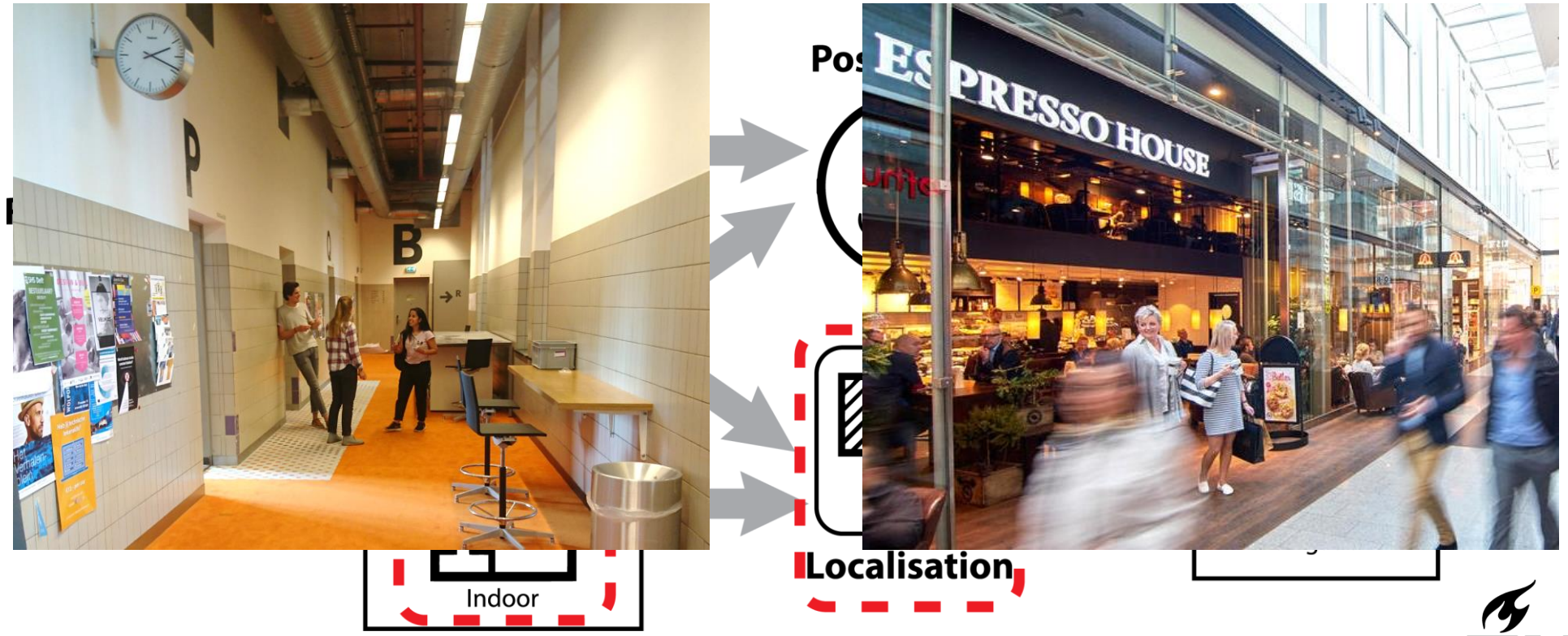
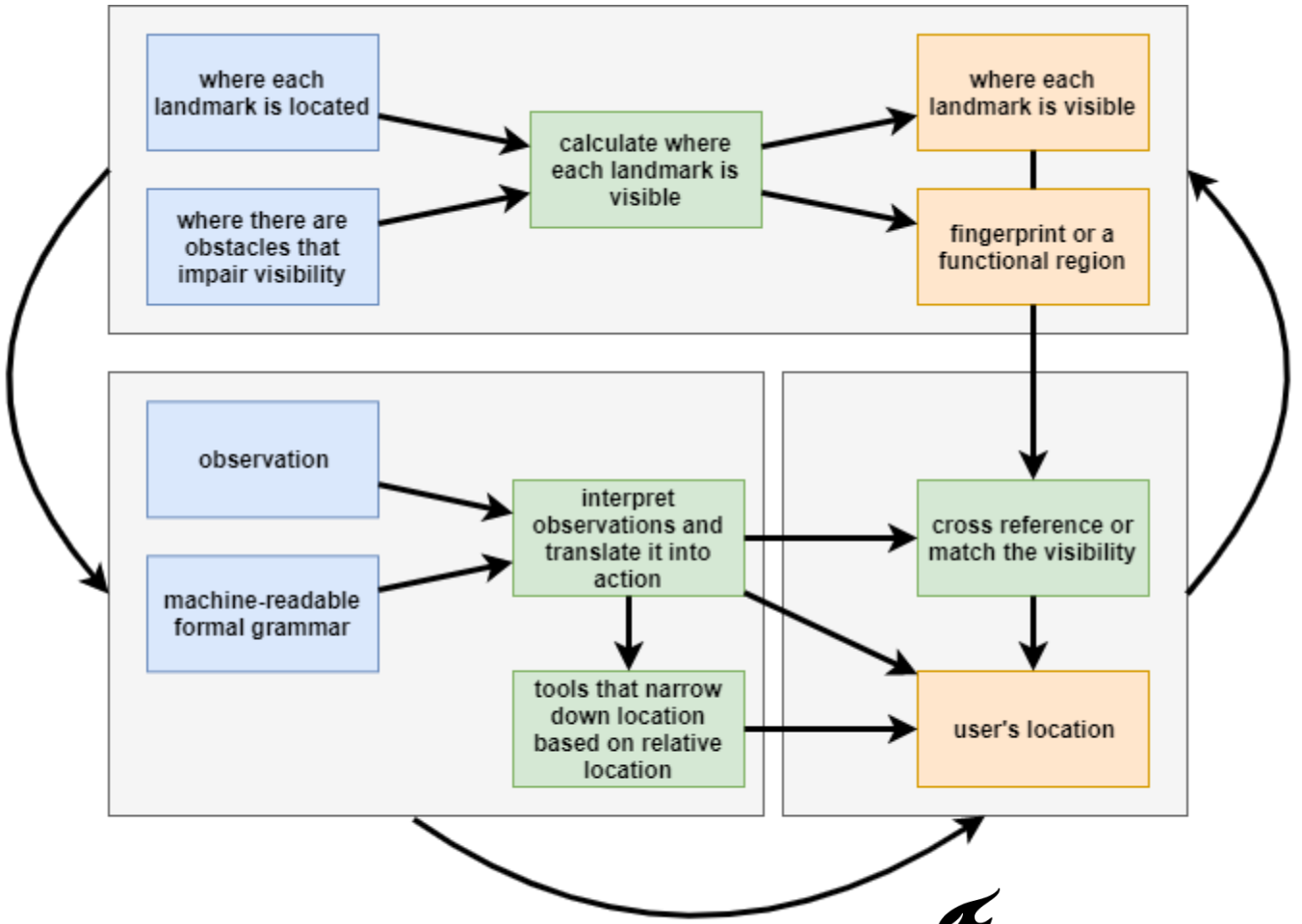
Vision

- Describe the environment (i.e. what is visible and how visible objects relate to each other) and get a location from the system.



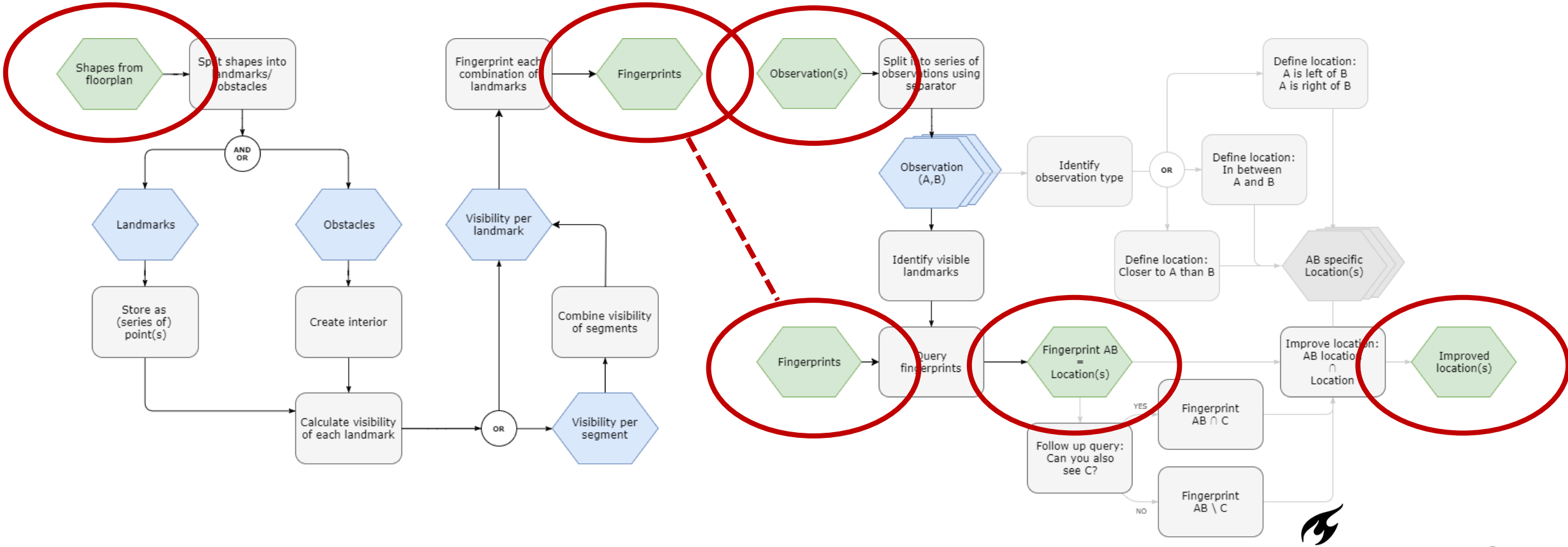
Conceptual framework

The system must be able to **interpret observations and translate it into action**, in this case, observations which landmarks are visible, and the relative locations of landmarks. For a system to understand observations, the observations require being according to a **machine-readable formal grammar**. The system must know **where each landmark is located** and **where each landmark is visible**. To **calculate where each landmark is visible** the systems must also know or be able to **where there are obstacles that impair visibility**. After interpreting the observations, the system should also be able to **cross reference or match the visibility** of various landmarks that are observed by the user. Given there might be **observations that talk about the relative location of one landmark to another landmark**, the system should provide **tools that narrow down location based on relative location**. With as a result a **user's location**. The visibility of landmarks could be considered as a **fingerprint or a functional region**.



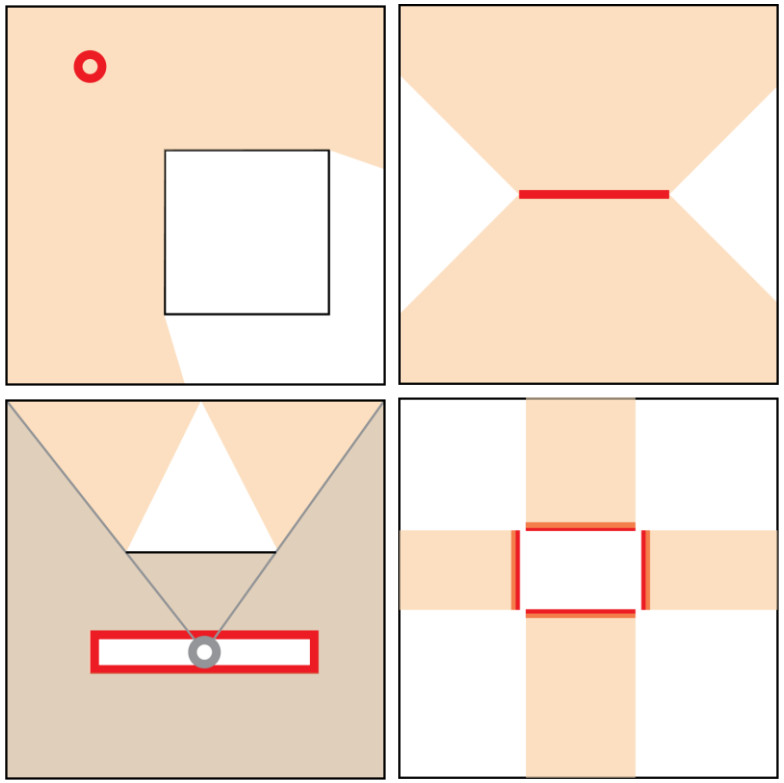
Conceptual framework: Workflow

- Pre-processing: fingerprinting
- Processing: localisation

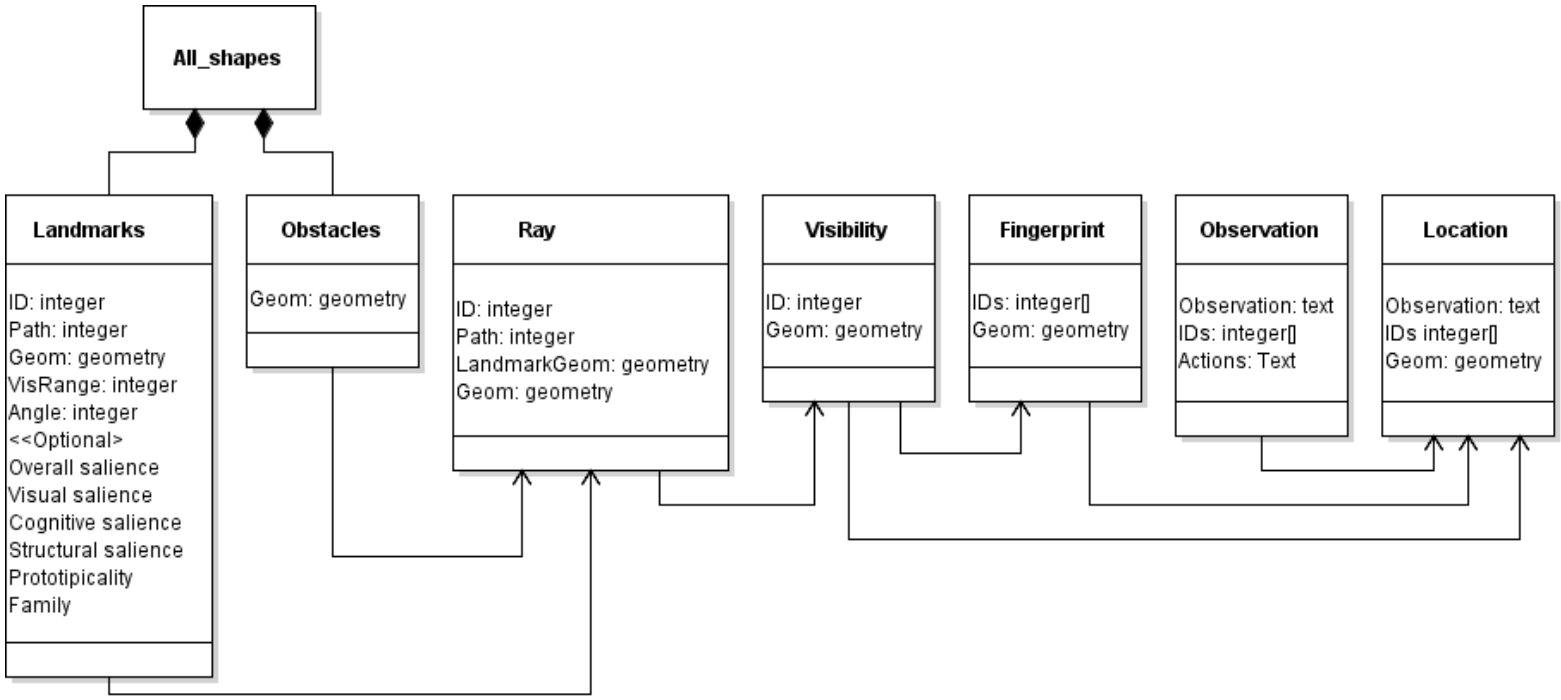


Conceptual framework: data specifications

- Geometric representation
  - Based on size and visibility

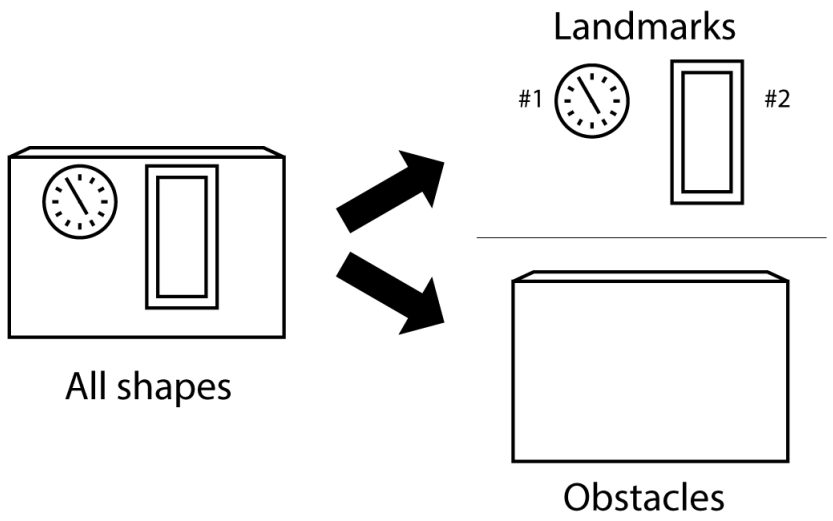


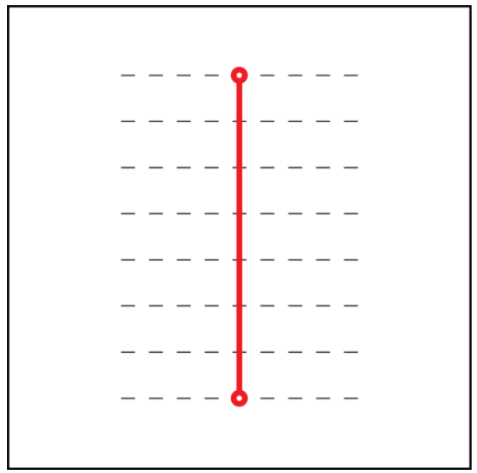
- Data model
  - Uniqueness
  - Visibility modifiers



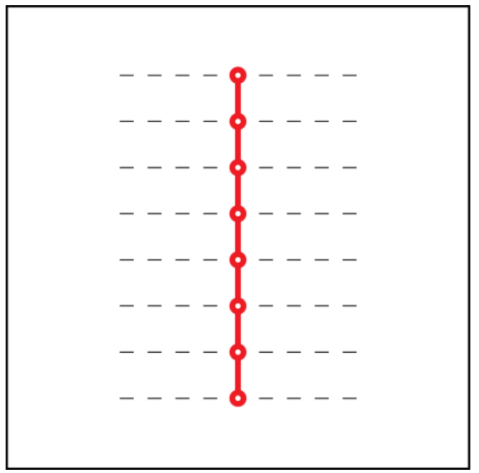
Workflow: data preparation

- Split objects into landmarks and obstacles
- Homogenise shapes
  - Subdivide linear landmarks
  - Create interior for obstacles

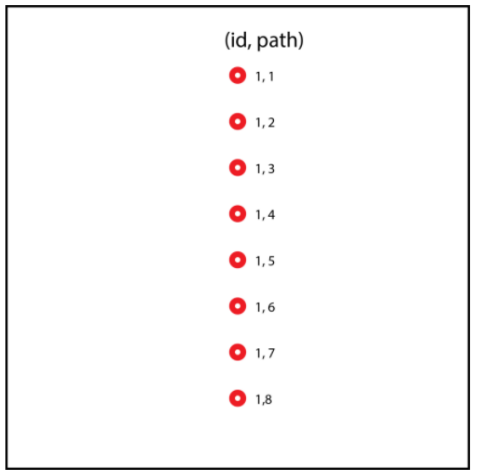




Line is split into segments



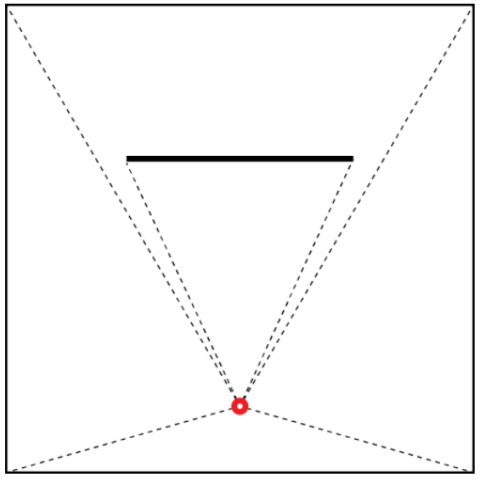
Take endpoints of each segment



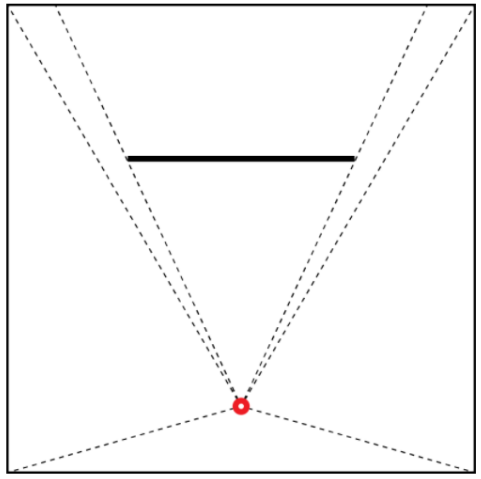
Represent landmark as points

Workflow: calculate visibility

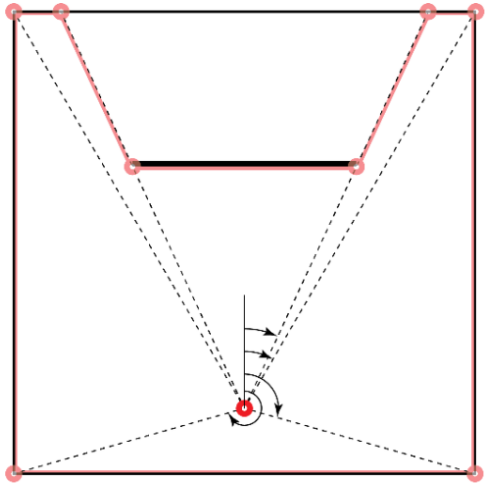
- Viewshed / isovist field analysis
- Ray-trace landmarks
- Stitch polygon together



Ray-trace to every corner



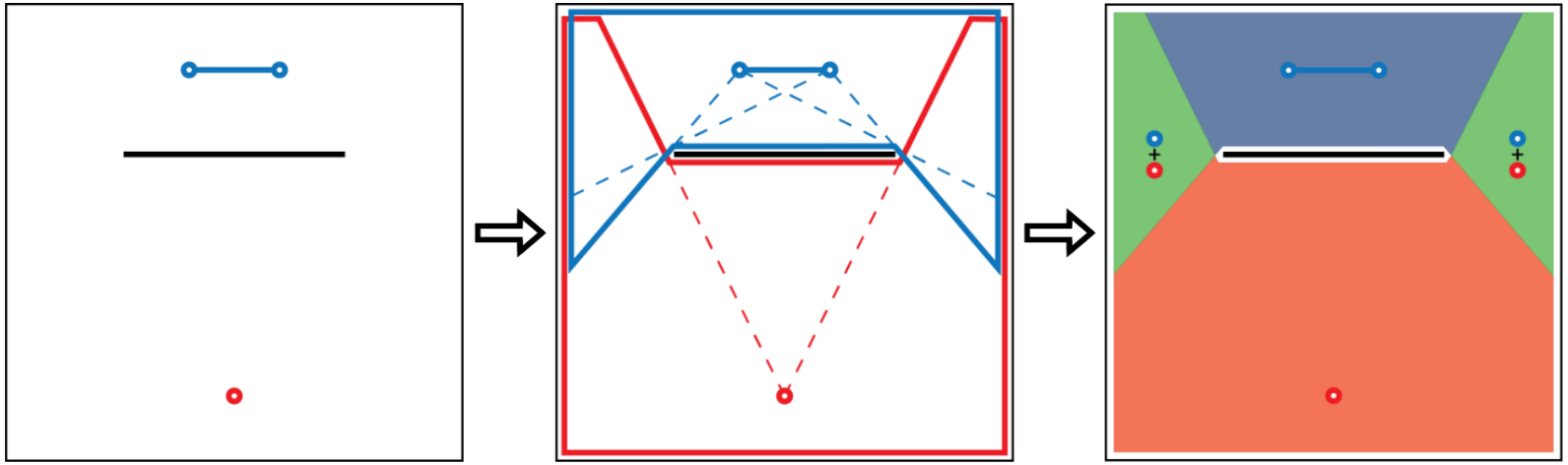
Extend rays to 'look' past corners



Stitch polygon together by azimuth angle

Workflow: fingerprint

- Single landmark visibility
- Combinations of landmarks
- Cross reference visibility



Split into obstacles and landmarks

Calculate visibility for each landmark

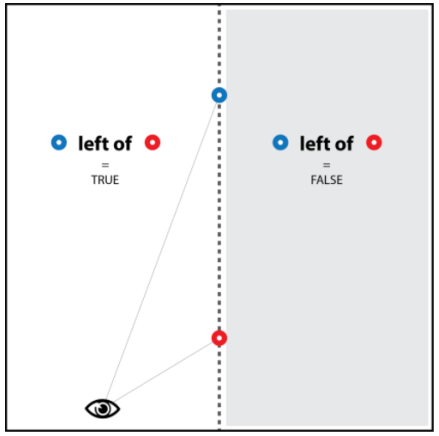
Cross-reference the visibility of landmarks

All combinations of A, B, and C		
A	AB	ABC
B	AC	
C	BC	

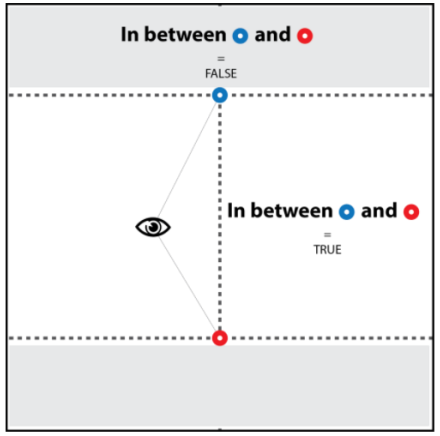
Workflow: machine-readable observations

- Interpret observations
- Calculate A-B specific location
  - Angle-based (unambiguous)
  - Distance-based (unambiguous)

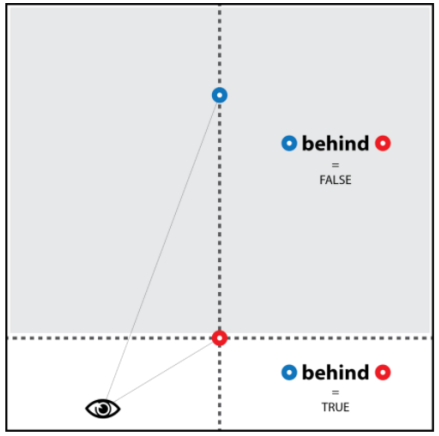
- I see landmark **A** (and **B**)
- I see **A** left/right of **B**
- I am closer to **A** compared to **B**



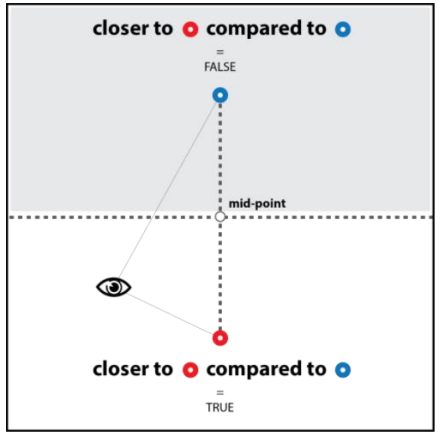
I see A is left of B



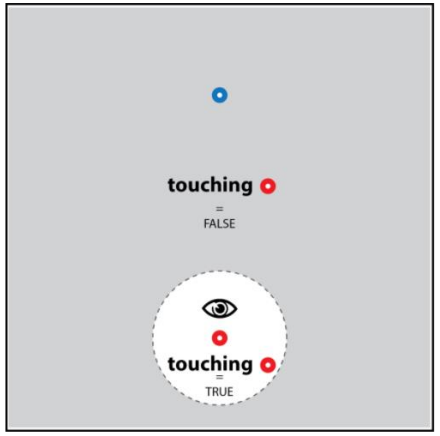
I am in between A and B



I see B behind A



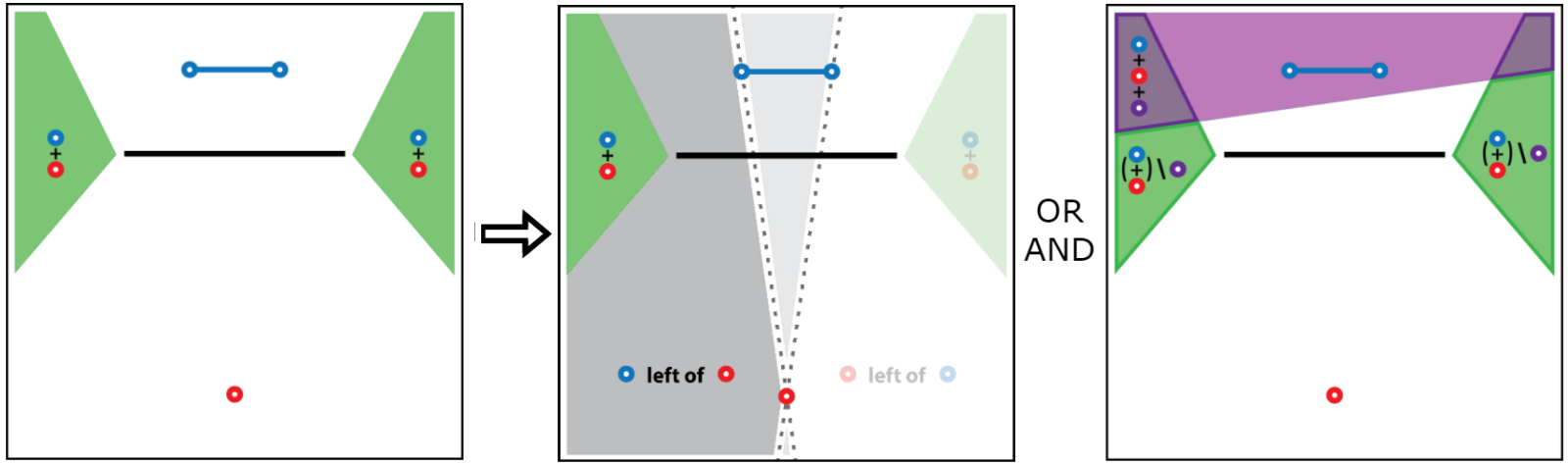
I am closer to A compared to B



I am touching A

Workflow: localisation

- Retrieve location
- Refine location
- Ask follow-up questions



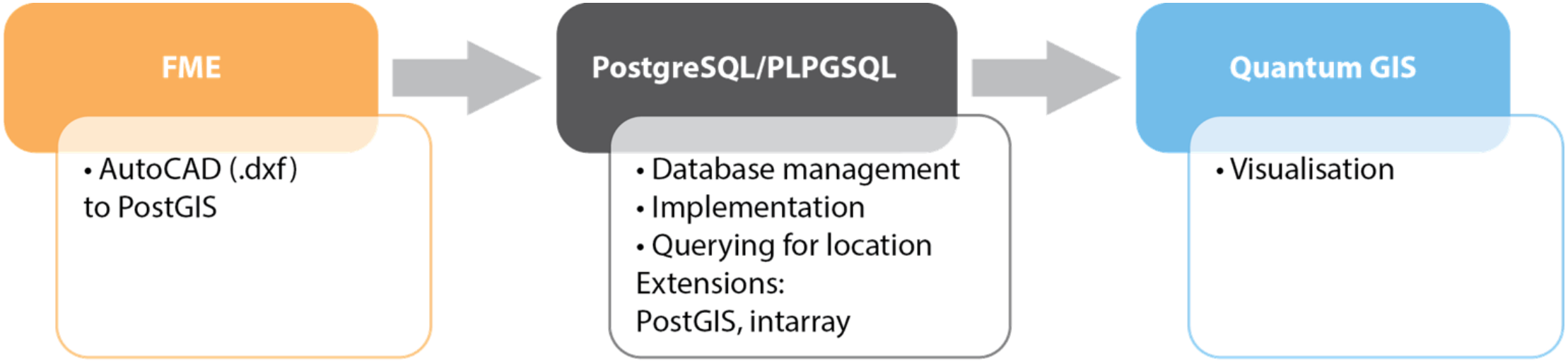
Location where A and B are visible

Use the relative position of A and B

Follow-up query into visibility of C

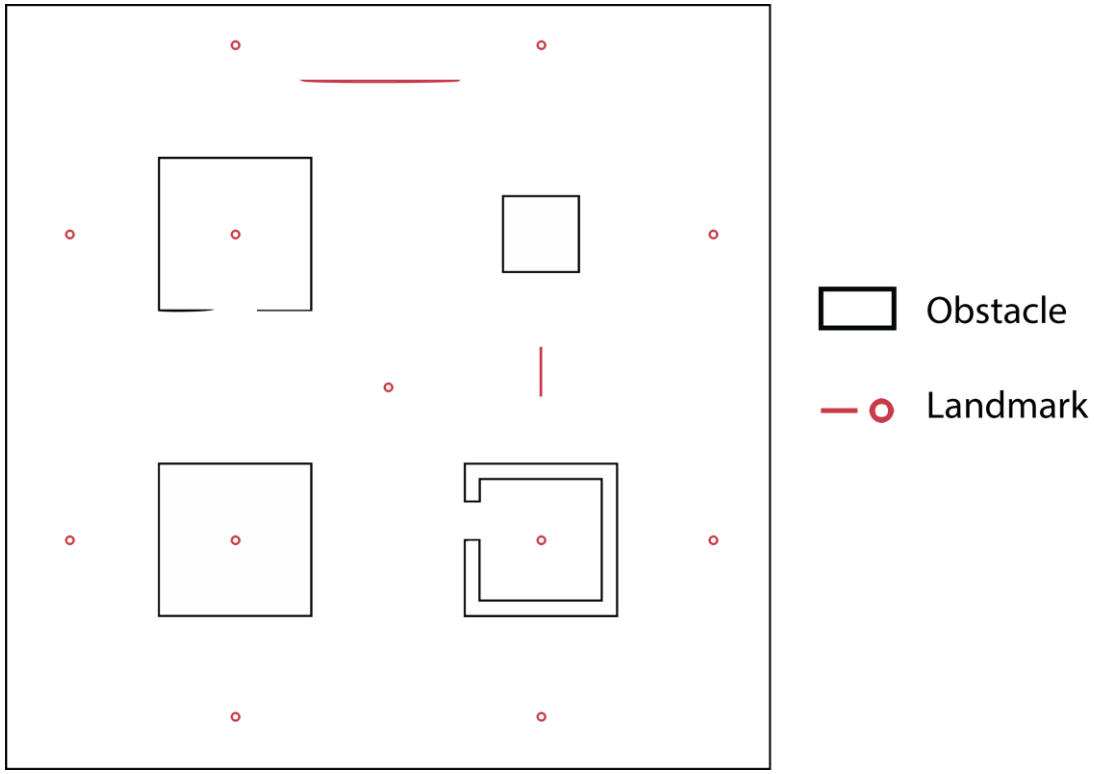
Implementation

- PostgreSQL + PLPGSQL
- PostGIS + intarray extension
- FME and QGIS



Implementation: Artificial cases

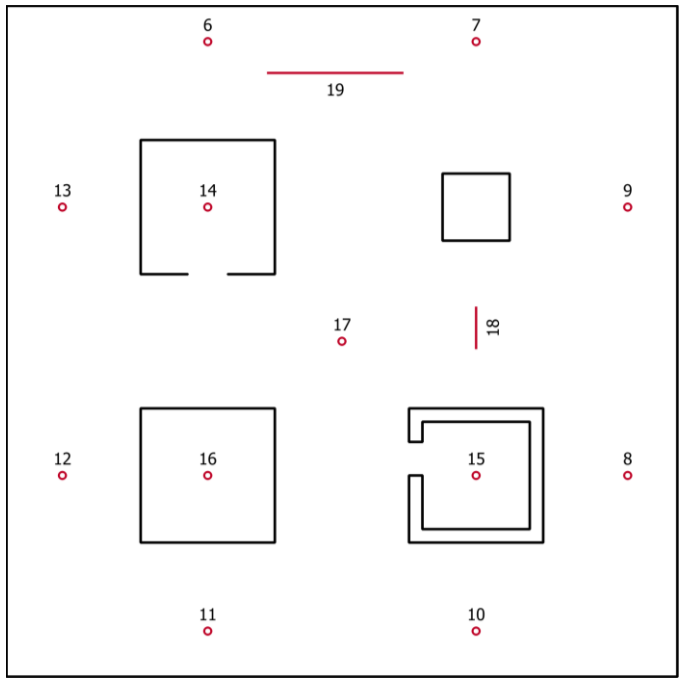
Case to create minimal viable products



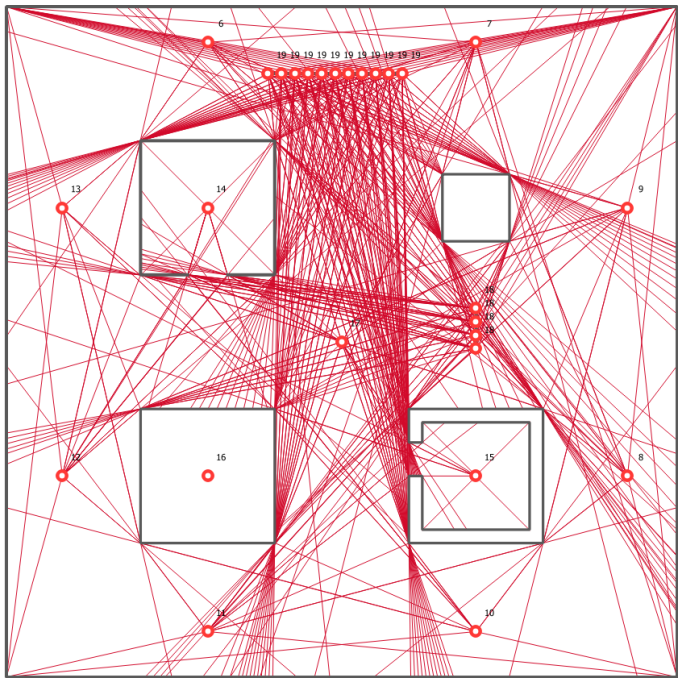
Case to test and evaluate MVPs

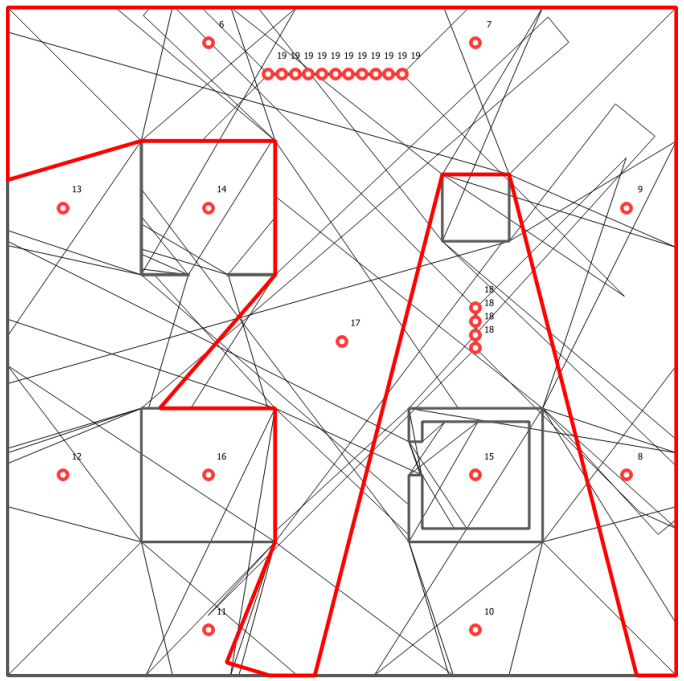
Implementation: Artificial case #1

- Initialise fingerprint (54 seconds)
- Localise (12 milliseconds)



- Initialise (2.5 seconds)
- Localise (25 milliseconds)





Artificial case #1

---/ Observation #1

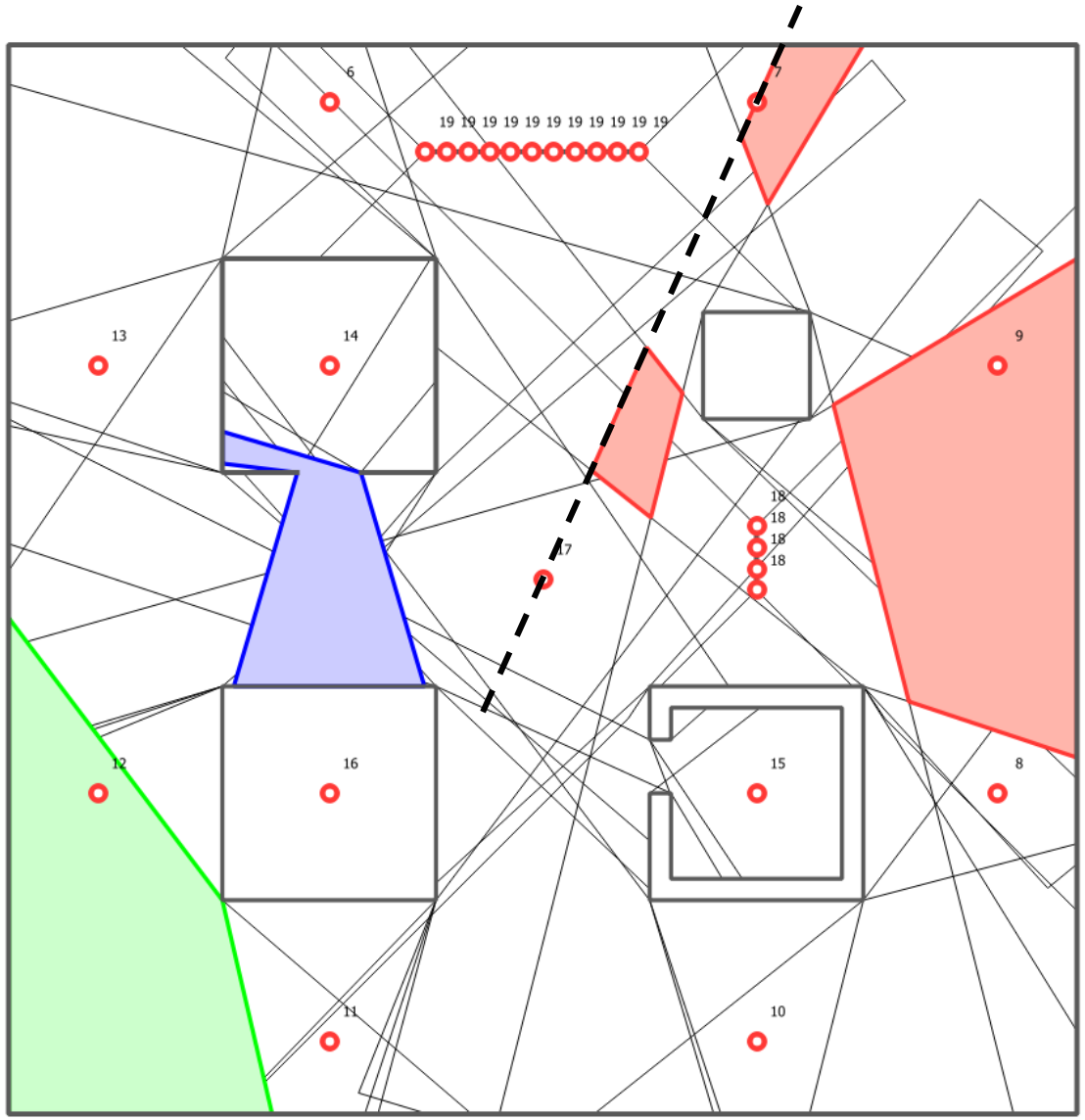
I see 7, I see 8, I see 7 right of 17

---/ Observation #2

I see 11, I see 12, I see 13

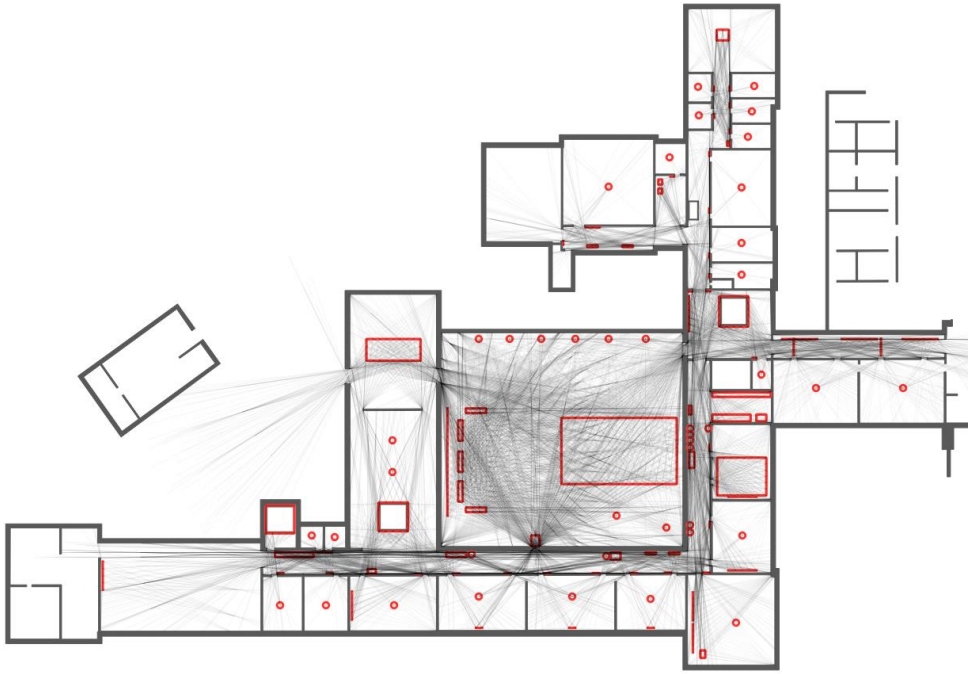
---/ Observation #3

I see 14, I see 18

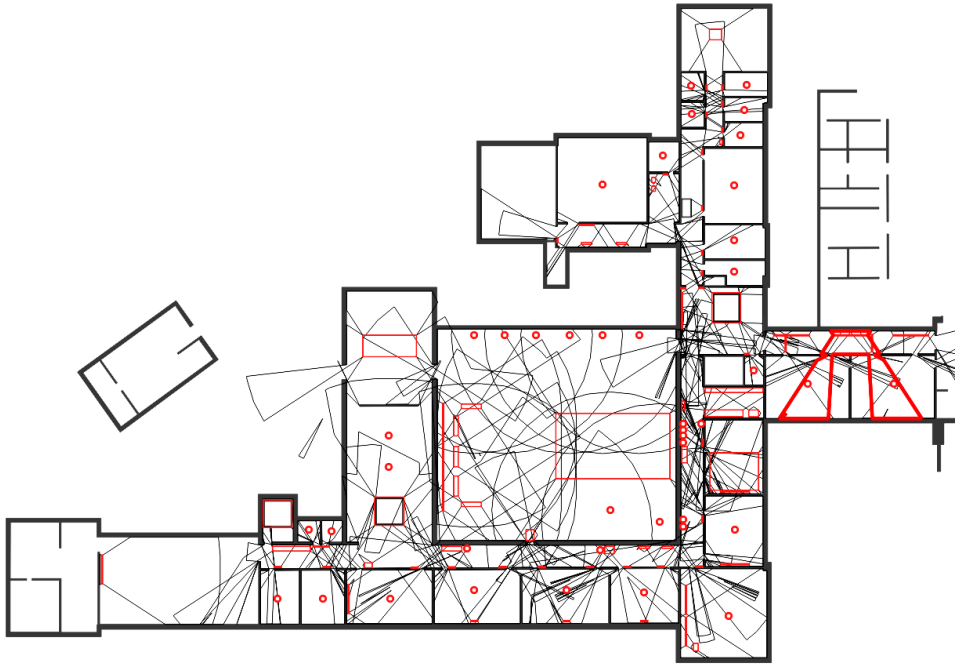


Implementation: Artificial case #2: BK-City

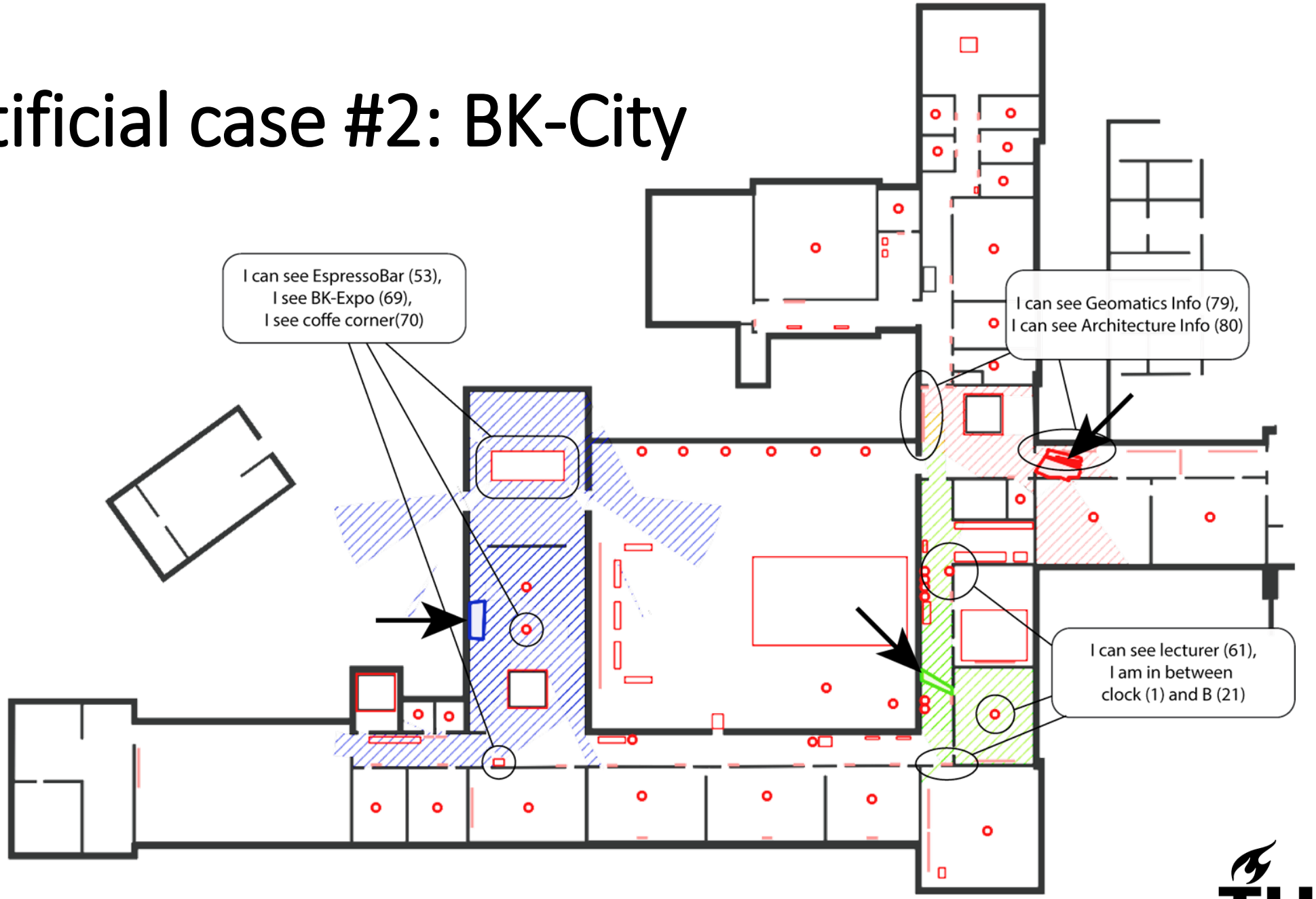
- Initialise 1.0m (9:30 minutes)
- Localise (25-30 milliseconds)



- Initialise 0.5m (14:38 minutes)
- Localise (25-30 milliseconds)

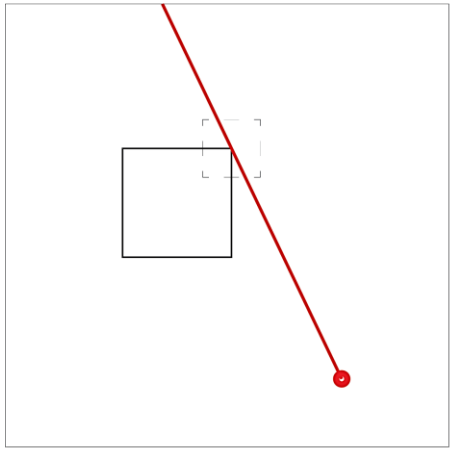


Artificial case #2: BK-City

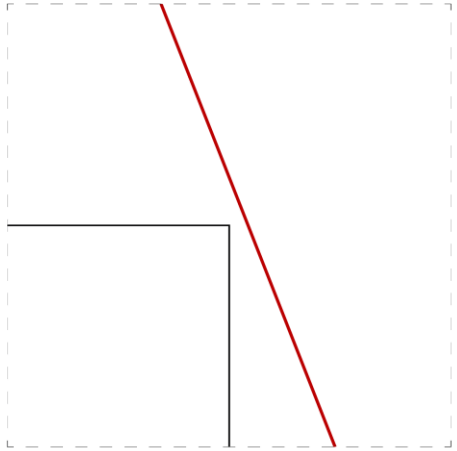


Challenges

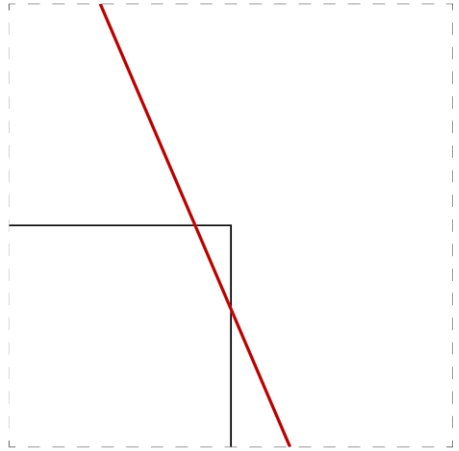
- Precision



Extended line 'through' corner

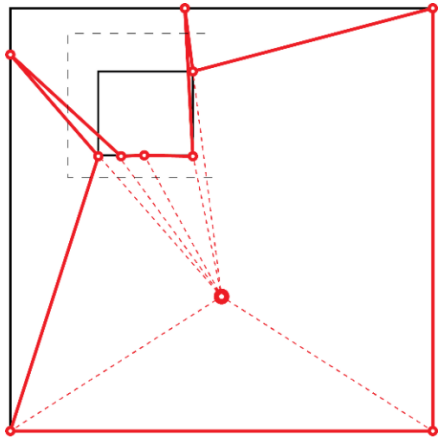


Extended line misses corner

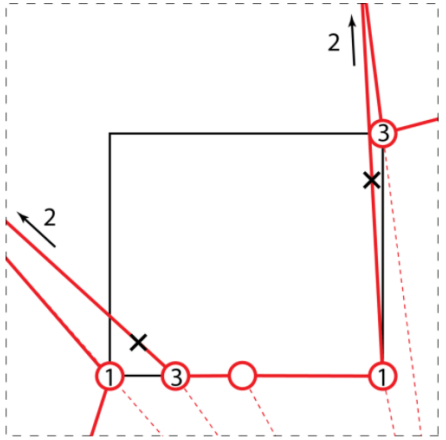


Extended line intersects with interior

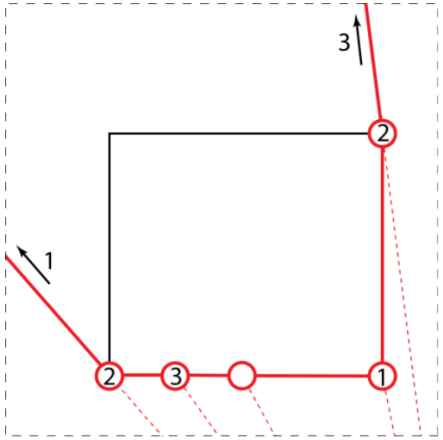
- Visibility polygon
  - Valid geometry
  - No self-intersection
  - No context intersection



Problem with same angle



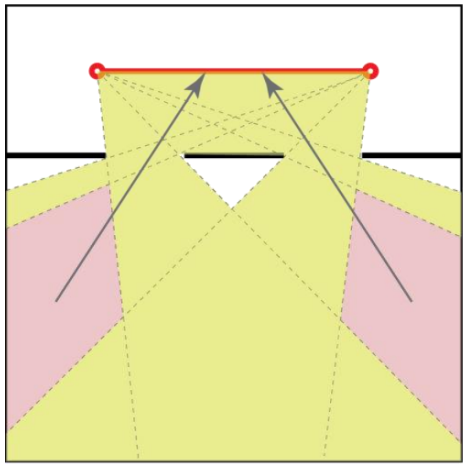
Zoom in: problem with same angle



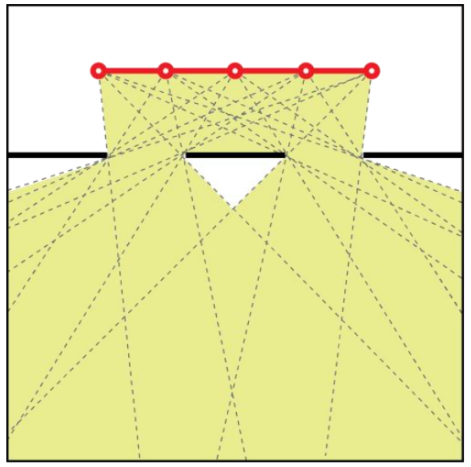
Fix problem by flipping 1-2 / 2-3

Challenges

- Visibility
  - Estimate correctly
  - Boolean vs Fuzzy
  - Key-hole visibility



Using just the ends of
a linear landmark



Subdividing linear landmark
to provide more accurate visibility

- 2D representation of 3D objects

Conclusion

How can a pure landmark-based approach achieve adequate indoor localisation? To lay a foundation for landmark-based LBS

- A landmark-based approach is achievable: a location can be obtained by using a visual fingerprinting adaptation and can be improved using lateration and angulation principles.
- Any object that distinguishes itself from surroundings is a landmark
  - Uniqueness is most important
  - Attributes that impact the visibility are optional
  - Hierarchy to improve user-interaction

Recommendations

- Extend the use of salience (i.e. for user interaction)
- Use a spatial standard as input for obstacles/landmarks (CityGML, …)
- Account for fuzzy visibility and ‘key-hole’ visibility

Future work

- Seamlessly connect with automatic data acquisition and navigation
- Provide the implementation in 3D
- Use landmarks in context-aware applications

Exploring a pure landmark-based approach for indoor localisation

Thank you for your attention!

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