

Final report 2018

Methods for identification of free navigable space

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Introduction

The research within this project is a part of four-year (2018-2022) international project named iNous focusing on seamless indoor-outdoor navigation for emergency response. The project is funded by South Korea government and led by Pusan University, South Korea.

This report covers research and developments to be completed by the end of 2018.

Administrative information

In the specified period the following researchers were involved: Mitko Aleksandrov, Abdoulaye Diakit , Sisi Zlatanova and Abdullah Alattah (visiting researcher from Delft University of Technology, The Netherlands). A series of meetings were organized between the teams involved in the project:

- Sisi Zlatanova had a meeting with the Korea team during the 2018 Seoul Metropolitan Forum 5-7 July 2018) to brainstorm on indoor-outdoor spaces and link with CityGML with Jiyeong Lee and Thomas Kolbe.
- Mitko Aleksandrov and Abdoulaye Diakite visited the Korea development team in the period (26th August – 1st September) to discuss technical details on the project and the development integration with the team of prof. Chulmin Jin.

Scientific project information

The main objective of this research is development of a framework and algorithms to support free space identification from BIM and point clouds. A framework, named Flexible Space Subdivision (FSS), introduced by the UNSW researchers is the basis for the developments. The overall scope of the research is specified as follows:

- Develop strategies to progressively evaluate the level of semantic information of spatial data (mesh, BIM) required to obtain a suitable input for the indoor disaster systems.
- Structure the indoor information. Following a space approach, approaches will be investigated to organize different spaces and their attributes. The modelling will be done in UML using Enterprise Architect.
- Realize space subdivision according to FSS framework. Investigations will focus on the type of objects and their functional spaces on one hand and the types of users and their characteristics.

Several groups of users will be identified, who typically can be distinguished during the emergency response such as firemen, injured people, etc.

- Define rules for navigation for different users such as:
 - Firemen: identifying entering spots and routes utilizing ‘functional spaces’ such as windows, under such circumstances when doors are no longer available due to fire or walls, based on the imbedded attributes, that can be broken by the firemen, as ‘functional spaces’ and as entering spots.
 - Blind or disturbed vision (smoke areas, physical disability)

The tasks of this project period (until 2018) focus on investigating to which extent the FSS can be obtained from low level input 3D mesh or point clouds.

- Use a 3D indoor mesh with a low level of semantics (e.g. cleaned and processed mesh with indoor objects) as input data.
- Development of an algorithm to subtract the R-Spaces (free)
- Investigation of necessary semantic enrichment to properly generate the F-Spaces (functional).
- Testing navigation scenarios on the resulting FSS.

Summary of results

3D indoor mesh with a low level of semantics (e.g. cleaned and processed mesh with indoor objects) as input data.

To investigate what kind of semantic can be obtained at different stages of data collection we have completed the following activities:

- Scanning the indoor of the F+R NSW building in Orchard Hill, Sydney with three different laser scanners Leica C5 (Figure 1), BLK 360 (Figure 2) and Zeb Revo (Figure 3).
- Scanning the outdoor environment of F&R NSW photogrammetrically, using a drone.
- Processing the data and obtaining one complete point cloud
- Investigating approaches for data structuring
- Investigating approaches and software for point cloud data management

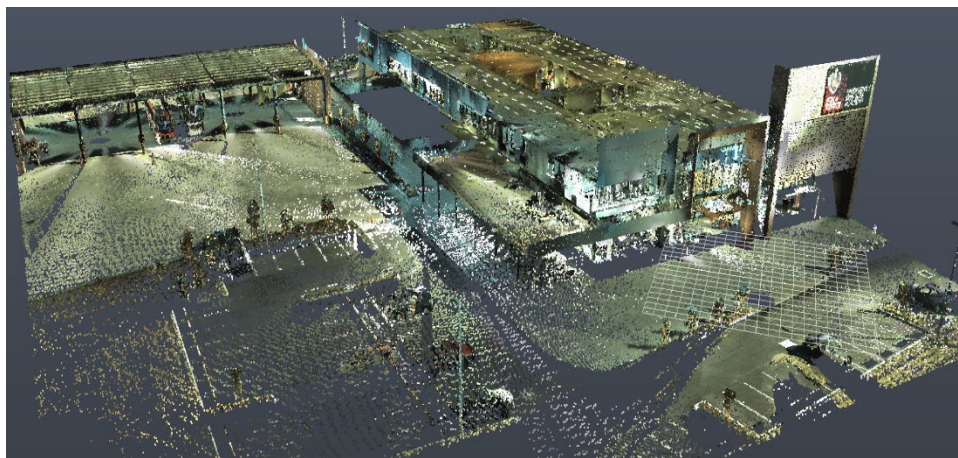


Figure 1: Indoor/outdoor scanning using Leica C5

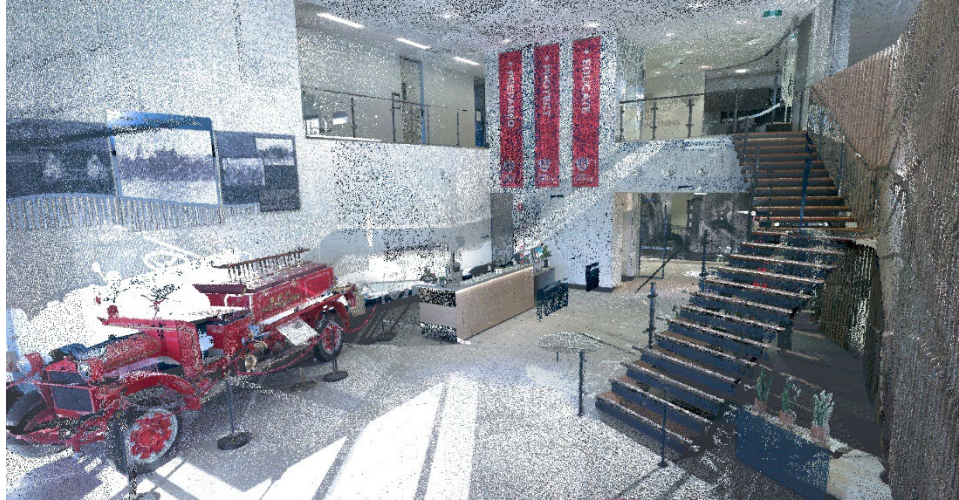


Figure 2: Indoor scanning using Leica BLK360

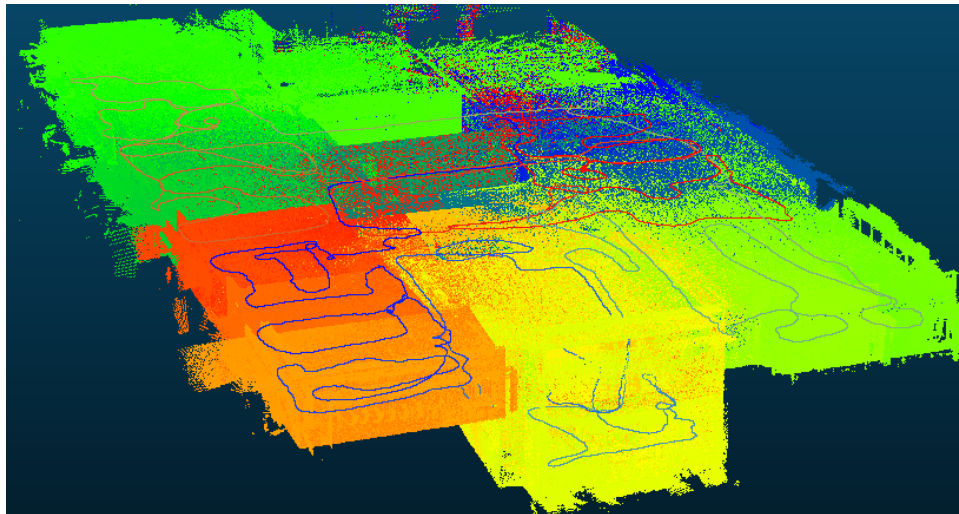


Figure 3: Indoor scanning aligned with agent's scanning trajectory using Zeb Revo

Additional scanning has been conducted of an indoor space for which BIM model is already available in order to obtain and compare IndoorGML models from two different sources. The next step would be classification of point clouds of outdoor space (Figure 4), which were also collected, in order to obtain outdoor spaces, and make a seamless navigation between indoor and outdoor environments.

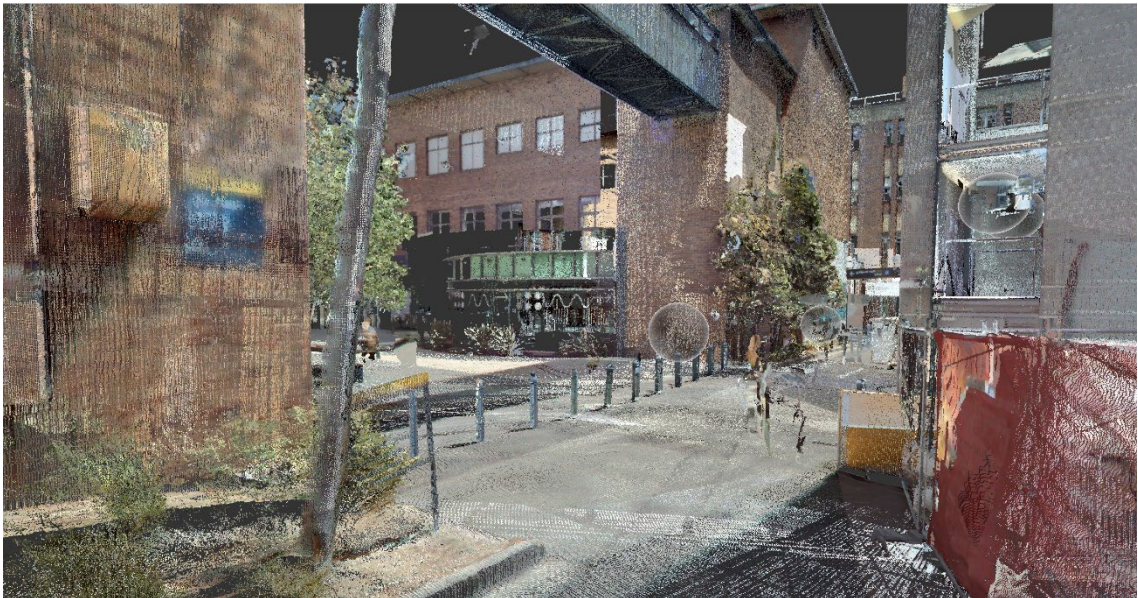


Figure 4: Indoor-Outdoor scanning of UNSW campus

Classification of point clouds using voxels

Using voxels for classification of point clouds has become a common method due to their structuring format. The main idea behind this is to identify IndoorGML for large indoor point cloud models automatically. As a starting point, classification of horizontal and vertical planes has been conducted (Figure 5, 6 and 7). The next step would be identification of walls and doors to build an IndoorGML model.

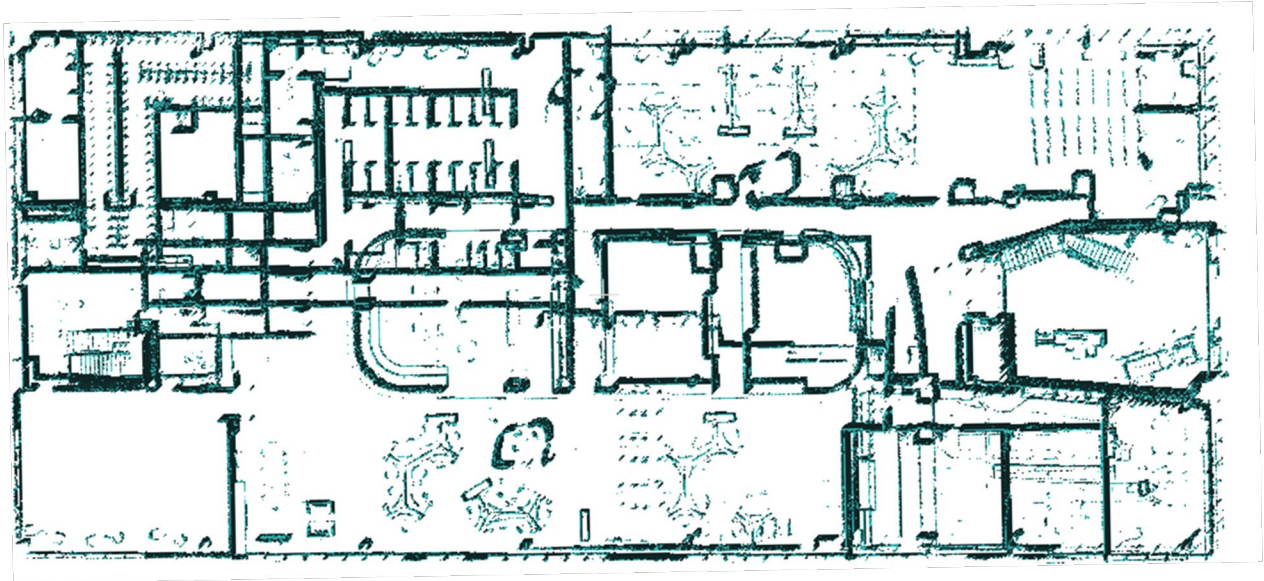


Figure 5: Vertical planes of F+R NSW building

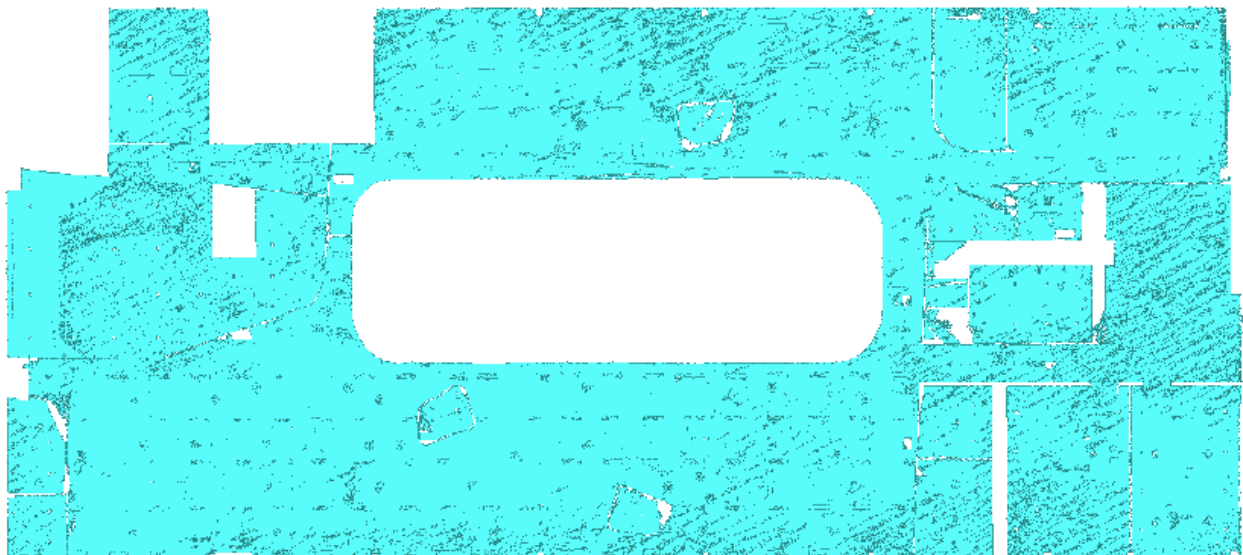


Figure 6: Ceiling identification



Figure 7: Identification of floors, ceilings and stairs

Indoor navigation using point clouds and voxels

Indoor navigation has been done combining point clouds and voxels considering the F+R NSW building data set (Figure 8). Based on the point cloud, several voxel models were identified separating horizontal, vertical and other objects. The navigation was performed on top of the voxel models, where the points cloud was presented as well to realistically represent the environment (Figure 9). A dynamic wayfinding as well as the point cloud and voxel model presentation were done using Unity3D game engine.

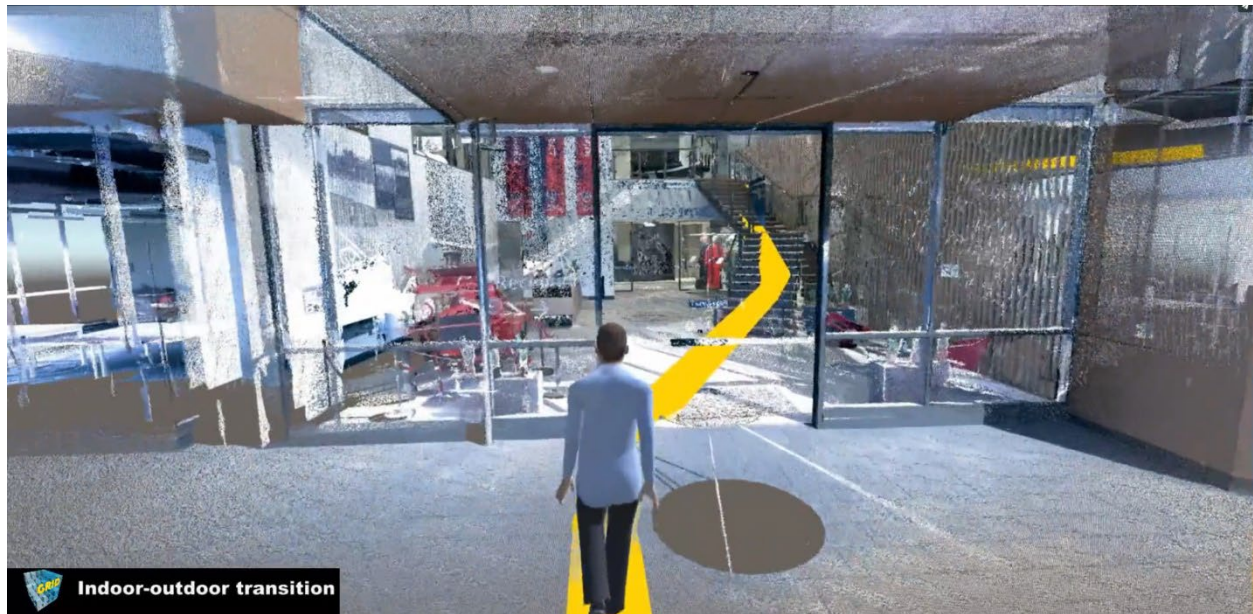


Figure 8: Indoor-outdoor navigation through points clouds



Figure 9: Using voxel-based model for indoor navigation

Development of an algorithm to subtract the R-Spaces (free)

Assuming that we are provided with a 3D mesh representing a building's geometry and its contained objects (furnishing elements), we developed an algorithm that allows to subtract the space occupied by those objects. The algorithm follows the FSS framework:

- it starts by determining the O-Spaces that represent the physically occupied areas;
- If some O-Spaces are intersecting, their aggregation into bigger O-Space is considered;
- finally, the R-Spaces (the remaining free spaces) are obtained by applying boolean operations to subtract the O-Spaces from original spaces.

This process results in another mesh representing the space that is considered as free and navigable in the 3D space. Figure 10 illustrates the details of the process, while Figure 5 shows the final result on the first floor of a furnished house building model.

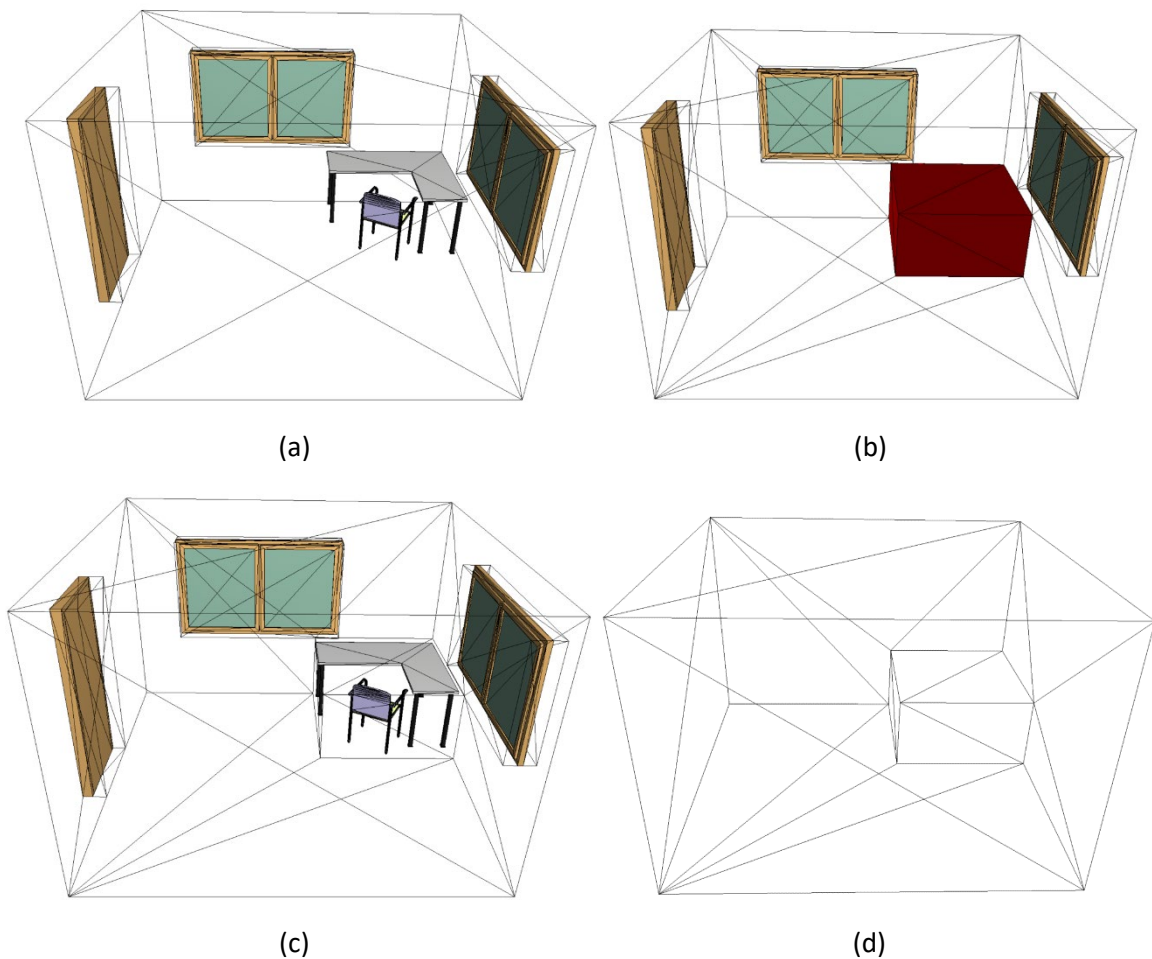
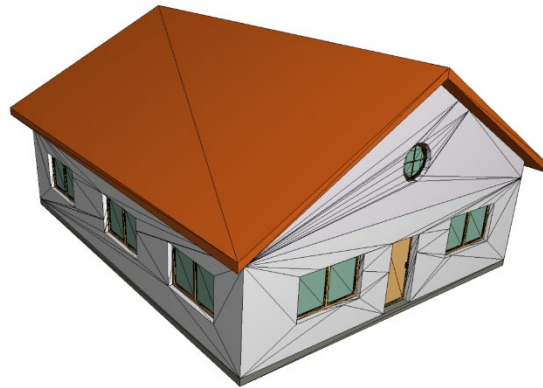


Figure 10: (a) A room volume from a mesh model (in wireframe), its contained furniture (one chair and one table) and its surrounding openings (two windows and one door). (b) Generation of the O-Space. (c) Extraction of the O-Space to obtain the R-Space. (d) Final visualization of the R-Space mesh.

The O-Spaces are obtained based on the Oriented Bounding Box (OBB) approach, which allows to reduce the amount of free space lost around the object consequently to the simplification. However, as it can be seen in Fig. 10 (d) and Fig. 11 (d) and (e), the resulting R-Spaces can be complex in shape, despite that

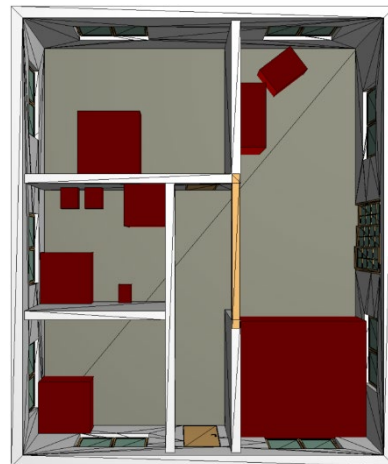
simplification. But the algorithm proves to be robust when the input mesh does not present artifacts on the volumes it describes (mainly the room volumes).



(a)



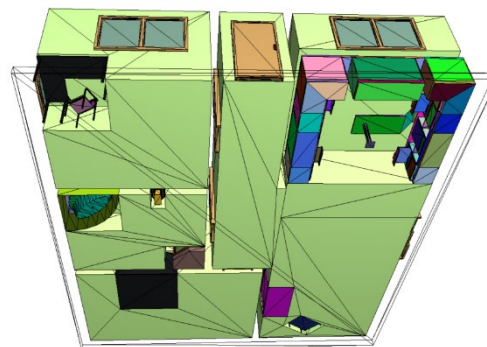
(b)



(c)



(d)



(e)

Figure 11: (a) Sample house model. (b) Top view of the first-floor's indoor equipment and (c) their computed O-Spaces. (d) Top-Perspective view of the resulting R-Spaces (wireframed). (e) Bottom-perspective view of the generated R-Spaces (light green volumes).

More experiences will be conducted in order to test the algorithm on building models with more complex features.

Investigation of necessary semantic enrichment to properly generate the F-Spaces (functional).

We have investigated how the R-spaces obtained from the developed algorithms can be enriched with semantics in two steps considering:

- empty rooms and
- rooms with furniture, which act as obstacles.

In this project period we have concentrated on providing semantics to rooms without considering the interior furniture. The semantics considered was related to function of spaces, which is further used to estimate the accessibility of each user to each space. Generally, users of a building have different rights to enter sections and rooms of a building. Some of the spaces are accessible to all users and some only to a specific group of people. In a related research we have distinguished between four groups of users in educational environment: visitors, students, staff and maintenance teams. The users of a building can then be assigned rights, restrictions and responsibilities as specified in the international ISO standard LADM. These properties are then used to define which spaces are accessible to whom. The spaces were also linked to the semantics of the OGC international standard IndoorGML

The information about spaces, enriched with functionality, the different groups of users and their rights responsibilities and restrictions organized in a DBMS (PostGIS) and a number of tests were executed. The figure 12 below shows

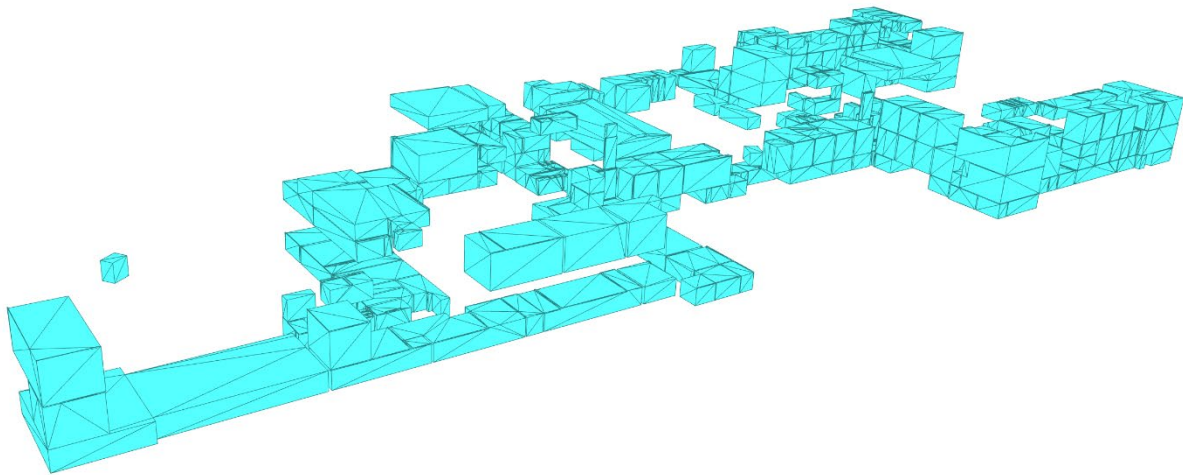


Figure 12: The spaces accessible for staff, obtained from the SQL query: `select * from generalspace where usage='staff'` (presented in a conference paper)

To be able experiment with different UNSW environment we have created a 3D BIM model of Red Center building from floor plans obtained from Estate Management. The above-mentioned approach for assigning functional information about rights, restrictions and responsibilities to rooms will be applied for the Red Centre building in the coming weeks and the models

Testing navigation scenarios on the resulting FSS.

In order to be able to test navigation scenarios, the extraction of navigation network needs to be considered first. Therefore, our first step to address this part was to investigate the possible networks that can result from the FSS outputs obtained throughout our tests. At this stage, it leaves us with two possible networks:

- A simple network simply relying on the (empty) rooms and their functions
- A more advanced network that avoid the obstacles by using refined R-Spaces

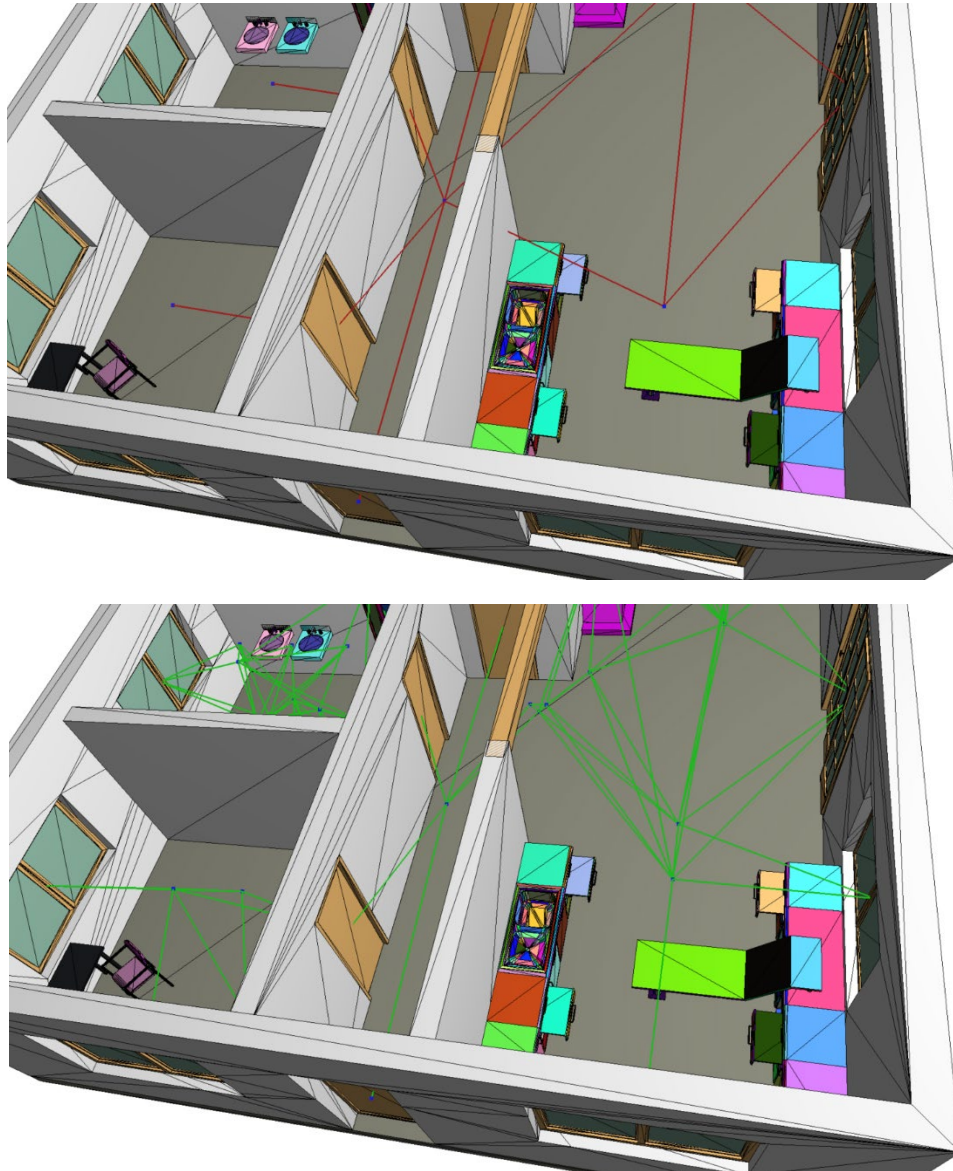


Figure 13: Navigation network from the regular room spaces (top) and the R-Spaces (bottom).

Figure 13 illustrate the resulting networks from the two listed cases. The first network is currently the mostly used one in the literature. It is straightforward to obtain but it does not reflect the complexity of the space properly. For this reason, some path may include intersection with walls (see Fig. 7 - top). On the opposite, it appears that when it comes to a path that avoids the obstacles, the R-Space are more

reliable as shown in Fig. 13-bottom. For this purpose, a refinement of the R-Space into several simpler shapes is needed. For this experience, we tested a simple convex subdivision approach which lead to reliable nodes for the graph. Unfortunately, the mesh models on hand do not contain enough information to explore a scenario that considers the different room functions. Thus, more complex and complete models will be sought for the future tests.

However, since finding good 3D building models is not a trivial task, we are also working on producing our own models. Figure 14 is the recently produced BIM model of the Red Centre Building of the faculty of Built Environment of UNSW, which will be used extensively for future experiments.

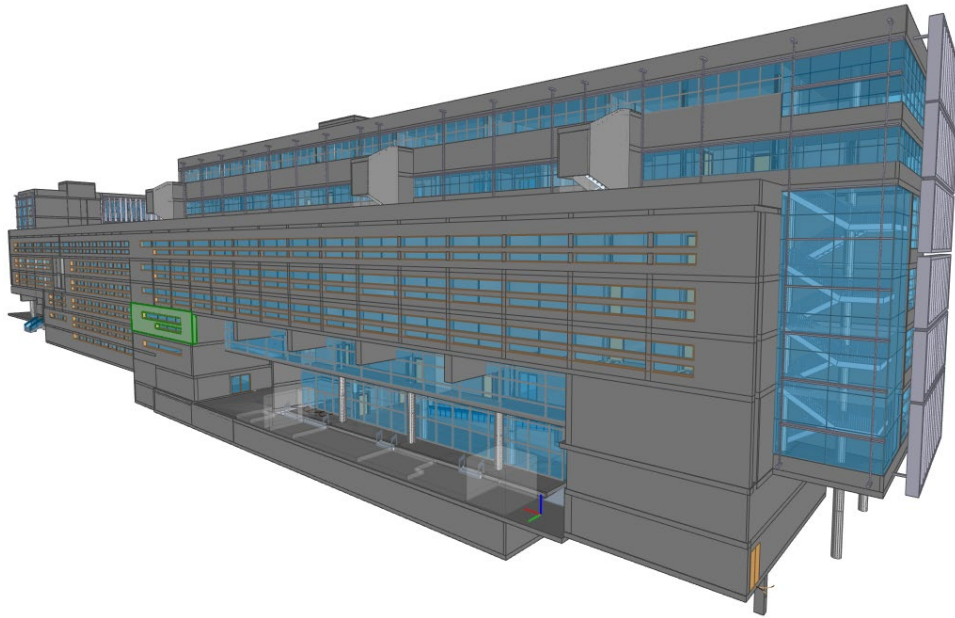


Figure 14: BIM model of the Faculty of Built Environment (UNSW).

IndoorGML 2.0

The version 2 of IndoorGML was presented at the OGC meeting introducing new classes and updating other classes within the UML model to represent different spaces and their features in an optimal way (Figure 15).

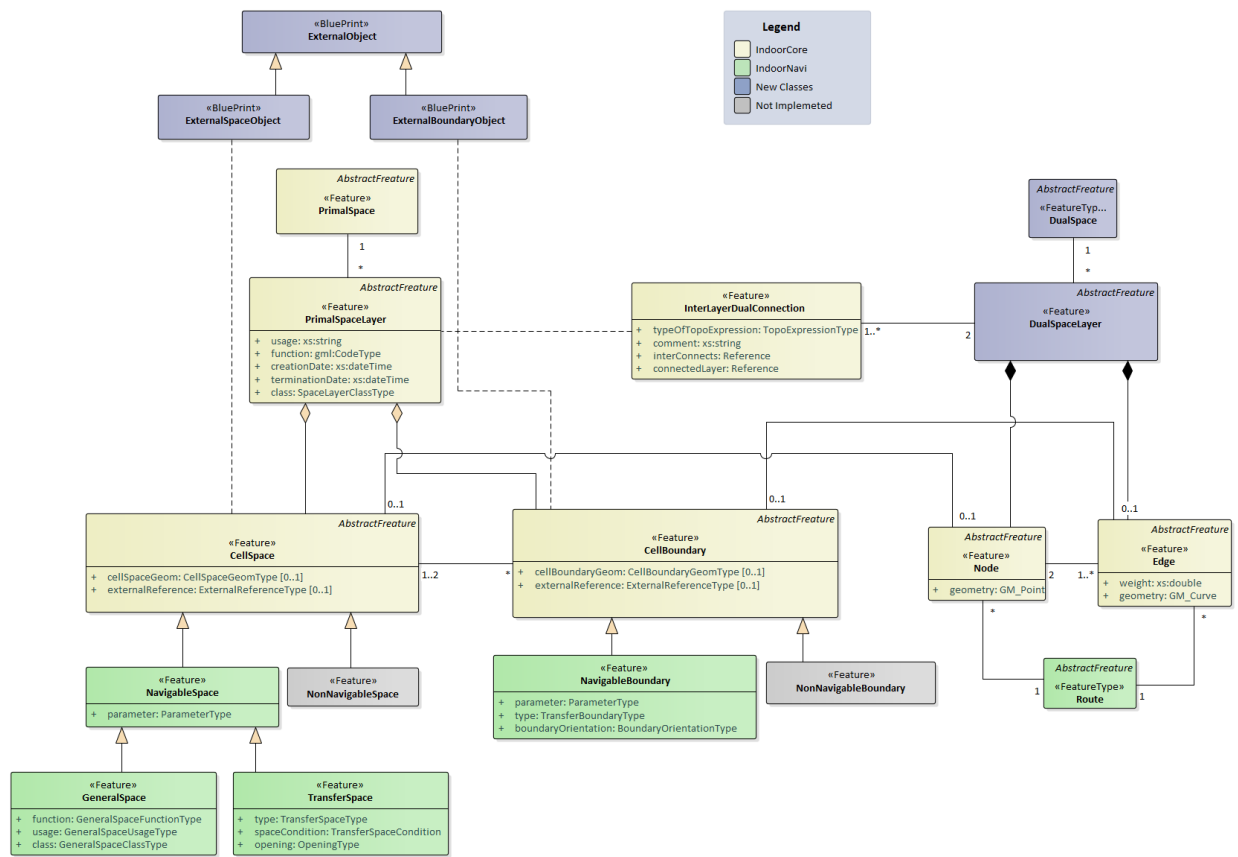


Figure 15: UML model of IndoorGML 2.0

Newly emerged topic: Outdoor space subdivision

Considering the importance of space subdivision concept, we have spent substantial effort on extending the indoor space subdivision for outdoor. We are working on a generic framework for space subdivision considering indoor, outdoor, semi-indoor and semi-outdoor spaces. The research on constructing semi-indoor spaces was presented in a conference paper.

By identifying different navigation spaces such as indoor space, semi-indoor (i.e., top-bounded), semi-outdoor (i.e., side-bounded) and outdoor space pedestrian seamless navigation between indoor and outdoor can be facilitated. In this regard, available navigable spaces are identified considering size of a pedestrian and the available spaces in Figure 16. Based on this, a various navigation queries can be performed finding an optimal route for pedestrians in different navigation scenarios. Thus, weather conditions, physical boundaries as well as pedestrian access rights and preferences can be considered for effective indoor-outdoor navigation.

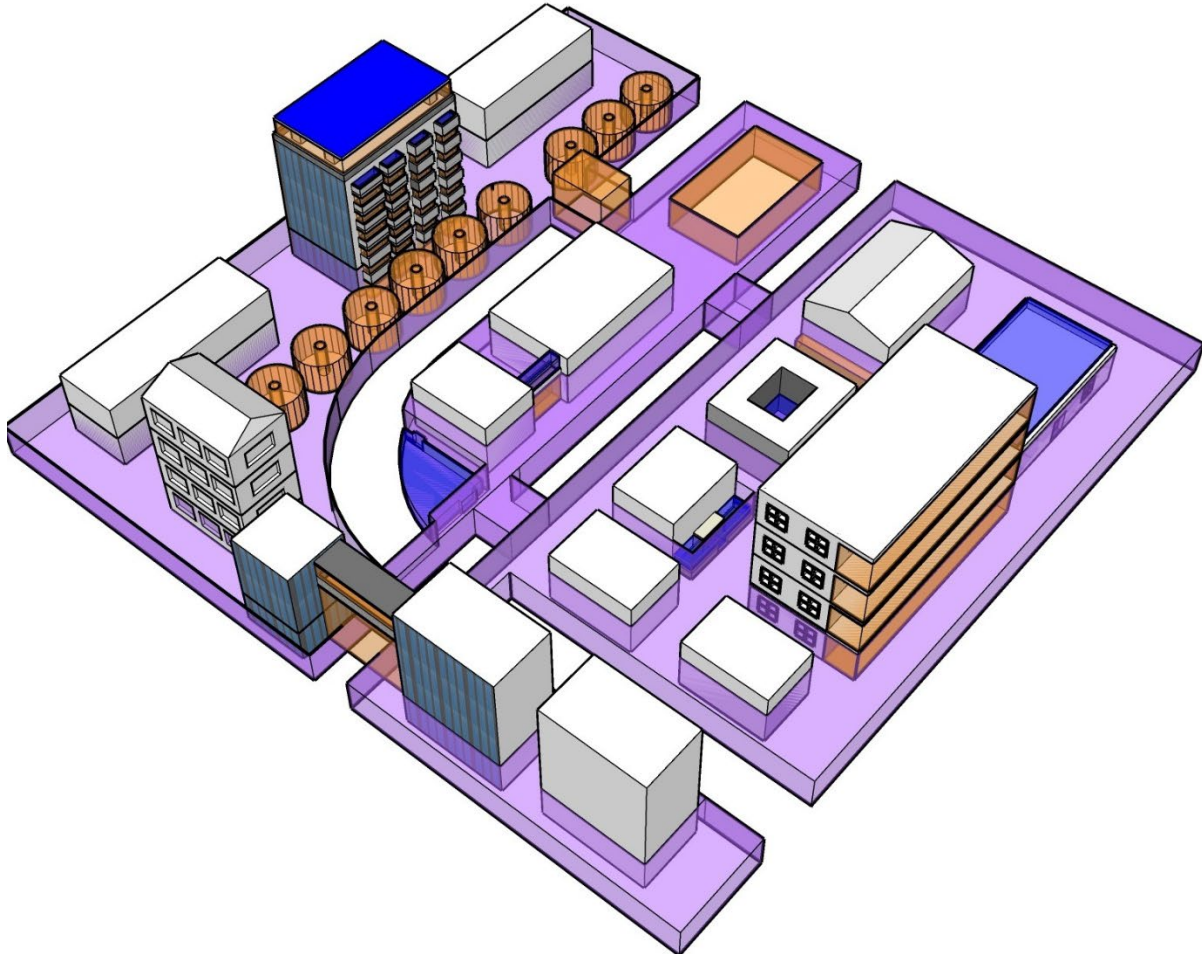


Figure 16: Identification of navigable indoor and outdoor space (white – indoor space; light brown – semi-indoor; blue – semi-outdoor; purple - outdoor)

Milestones

- Structuring of Indoor Information: partially completed
- Space subdivision FSS: algorithms for automatic subdivision of BIM-like mesh models are completed
- Paths for navigation for different users (November 2018): **postponed for 2019, replaced with extending the space subdivision concept for outdoor.**

Conclusions

The project is progressing according to the plan with few small deviations on the conceptual part. A summary of the completed developments is given below:

- Two data sets prepared: one point cloud (F&R NSW) and one BIM (Red Centre Building)
- Algorithms for space subdivision of BIM models
- Tools to create navigation network and a path, based on the subdivision
- Tools for exporting subdivision to IndoorGML

- Tools for importing BIM model in RDMS (PostGIS)
- Database schema for IndoorGML-LADM and corresponding implementation

Publications within this project

Alattas, A., S. Zlatanova, P. van Oosterom, Ki-J. Li, 2018, Improved and More Complete Conceptual Model for the Revision of IndoorGML, In: 10th International Conference on Geographic Information Science (GIScience 2018), Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 114, Dagstuhl, Germany, pp. 21:1-21:12, 2018.

Alattas, A., P. van Oosterom, S. Zlatanova, A. Diakit , J. Yan, 2018, Developing a database for the LADM-IndoorGML model, 6th International FIG 3D Cadastre Workshop 2-4 October 2018, Delft, The Netherlands, pp. 259-276

Ghawana, T., Aleksandrov, M., and Zlatanova, S.: 3D Geospatial Indoor Navigation for Disaster Risk Reduction and Response in Urban Environment, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-4, 49-57, <https://doi.org/10.5194/isprs-annals-IV-4-49-2018>, 2018

Yan, J., Diakit , A. A., and Zlatanova, S.: An Extraction Approach of the Top-Bounded Space Formed by Buildings for Pedestrian Navigation, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-4, 247-254, <https://doi.org/10.5194/isprs-annals-IV-4-247-2018>, 2018