Topology and Semantic based Automatic Indoor Space Subdivision from 2D Floor Plan

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Abstract. As indoor space becomes wider and more complicated, the need for indoor space information is increasing. In Korea, since 2013, indoor spatial data are being constructed based on IndoorGML, an international standard for indoor navigation in Open Geospatial Consortium (OGC). When building an indoor spatial data based on IndoorGML, it is necessary to divide space appropriately in order to construct more sophisticated indoor network. In this paper, we proposed the indoor space subdivision algorithm to consider the most important connectivity when building indoor spatial data in IndoorGML standard.
Keywords. Indoor, Space Syntax, Subdivision, IndoorGML

1. Introduction

As indoor space becomes wider and more complicated, demand for indoor spatial information is increasing. In Korea, since 2013, indoor spatial data have been constructed based on IndoorGML, an international standard for indoor navigation OGC. IndoorGML assigns one node to one room (physically closed space), but it is not enough to construct an Indoor network by this alone. This is because it is difficult for user to accurately search for a destination when several semantics such as a dining room, a front door, and a kitchen are mixed in a space. Also, if there is only one semantic (ex., corridor) in a large space, a network created with only one node is inefficient because it does not correspond to the shortest network (Khan A 2013). So it is necessary to divide space appropriately in order to construct more sophisticated indoor network. (Diakité A A 2017). In this paper, we proposed a new indoor space subdivision algorithm using topology and semantics from architectural floor plans to consider connectivity when building indoor spatial data in IndoorGML standard.

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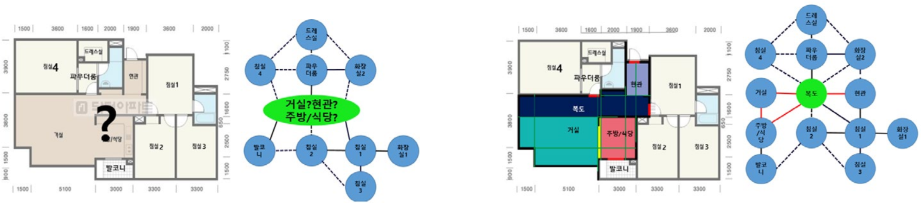
2. Related work

Previous, indoor space for indoor navigating has been divided into physical and conceptual units. However, recent studies (Kang 2015, Zlatanova S 2013, Lee 2012) have divided space by semantics (function) of the space for navigating efficiency. Enactment Provisions on Building Space Information in Korea have stated that space should be divided when characteristics of space are clearly distinguished (ex., in the case of a train station, the gate, etc.) We could derive semantics from the text of architectural floor plans, and extract topologies from the geometry of them through space syntax analysis.

2.1. Indoor space subdivision

Ahmed S (2012) and Lewis R (1998) have shown the possibility of space subdivision considering semantic elements by using the text of floor plans. Lewis R (1998) has divided space into vertical lines of the equidistant axis of the text if there is more than one text in the closed space. Ahmed S (2012) has divided space and merged it with the surrounding area until there is only one piece of text in the space, however, spatial information other than text was not used. Diakité A A (2017) and Lin Z (2017) have suggested the criteria and priority -including geometry, topology, and semantic information of space - of indoor subdivision for IndoorGML data. However, in their criteria, the definition of connectivity was not verified and text was not used.

The text extracted from the architectural drawing reveals the semantics of space, the meaning and function of space. Therefore, if several semantics such as dining room, entrance, kitchen, etc. are mixed in one detected space, it should be distinguished in the process of indoorGML-based data. Figure 1 shows the possible results of dividing an interior space by text.



(a) (b)

Figure 1. Dividing Indoor Space by Text: (a) An original floor plan and IndoorGML diagram; (b) The divided floor plan and IndoorGML diagram

2.2. Space syntax

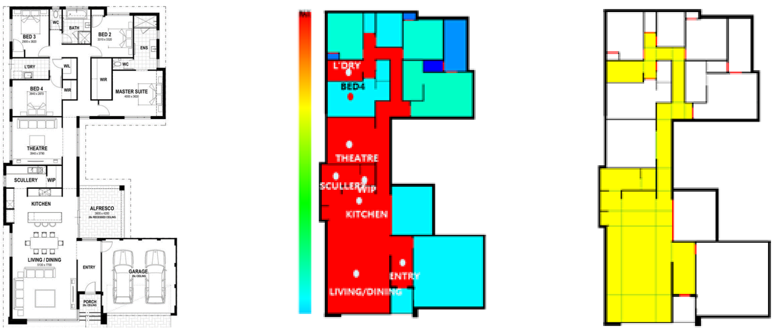
Choi (1996) has argued that the space syntax analysis which Bill Hillier (1984) proposed, space has already shown its validity and reliability based on several previous studies. He (2007) has also argued that if the space syntax is used from the preliminary stage of the building plan, it would be possible to predict traffics and the space utilization from floor plans. Hiller, Hanson, and Graham (1987) were able to extract functions of farmhouses by analyzing their floor plans without room name. Choi (1996) found that the relative spatial depth tended to be low in the living room and corridor of the house. We are trying to find a space with potential connectivity based on variables of space syntax, the integration value of which is the inverse of relative spatial depth.

3. Methodology

In this chapter, we propose an indoor space subdivision algorithm based on geometrical information, topological information, and semantical information.

3.1. Geometric and semantic feature extraction

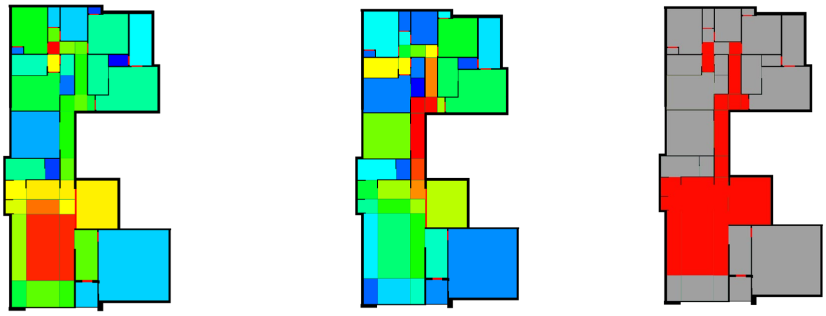
From floor plan image (Fig. 2-a), we can extract polygon features enclosed by wall opening through floor plan analysis (Jang et al. 2018). Text its relative position can be extracted by OCR.



(a) (b) (c)

Figure 2. Space syntax analysis and S-partitioning (a) A raster floor plan.; (b) a visual representation of the Integration(3) value.; (c)Subspaced Floor Plan

After extracting geometric features, space syntax analysis is performed to obtain Integration values of spaces (Fig.2-b). Especially, Integration (3) is a variable considering pedestrian zone (Choi 2005). The red polygon which has a high degree of Integration (3) could be a candidate of a connectivity nodal space. There are also several text points, meaning mixed semantics in a space. It should be divided into several polygons topologically and semantically while maintaining the existing geometry. Thus,we performed S-partitioning (Peponis 1997, Lee 2006). We defined the borderline of the partition as an imaginary line extending from the wall line until it met another wall line. We added some rules to this by making only convex polygon while avoiding making too small subspace helps to minimize exceptions when interpreting results(Fig.2-c).



(a) (b) (c)

Figure 3. The Result of Space syntax analysis (a) Integration(3) of Subspaced Floor Plan; (b) Integration of Subspaced Floor Plan (c) Sum of Top 25% Integration(3) value and Top 25% Integration value.;

The fact that some subspaces have topological or semantical connectivity is an important information that can be used to place connection node of the IndoorGML data. To look more closely at the candidate of connectivity nodal space and extract the right subspace where the connected node would be made, we performed space syntax analysis again on the whole floor plan (Figs.3-a,b).

3.2. Finding final nodal subspaces by semantically difining the space

Finally, from results obtained from space syntax analysis, we selected the subspace with Integration (3) and integration value of upper 25% Generally, if the degree of integration is 1.7 or more, the space is considered to be highly integrated. If it is 1.0 or less, the space is considered to be isolated space (Hiller B 1984).

We adjusted this threshold to the top 25% range to fit the subspaced floor plans. It can be changed depending the floor plans. Sum of the two results is obtained and considered be the candidate of connection nodal spaces (Fig. 3-c). In this process, subspaces are merged or segmented while existing geometric information is maintained. In the next step, the previously obtained semantic information (text) is spatially joined to each subspace (Fig. 4-a). This means it is labeled. This semantic information also informs the connectivity information of the space (ex. porch, entry, lobby, corridor, staircase, etc.). We gave a new attribute 'corridor' to the unlabelled connection spaceAdding nodes for a network.

(a) (b)

Figure 4. Topologically and semantically defined space (a) semantically defined subspaces.; (b) divided connection space

Finally, the space is divided geometrically, topologically, and semantically. However, we still do not have enough IndoorGML data since there is only one node in the connection space. Khan(2013) has insisted that expressing the long corridor as one node is too abstract. Therefore, it is necessary to divide it to achieve better navigating performance. We basically followed the door semantic based partitioning algorithm for corridor (Li 2016) but modified and added some steps to include geometrical and semantical information (Fig. 4-b).

4. Conclusion

In this paper, we proposed an indoor space subdivision algorithm to consider the most important connectivity when building indoor spatial data in IndoorGML standard which is oriented for indoor navigation. We tried to divide the space more practically and suitable for indoor navigation using all information we could draw on the floor plan's geometric information, topology information from spatial analysis, and semantic information from text. Based on the topology information found through space syntax analysis, it is possible to improve indoor navigating efficiency by appropriately dividing the indoor space and designating essential nodes for the IndoorGML data.

In the space syntax analysis, the threshold used to extract the subspace with high connectivity can vary depending on the floor plan. This means that topology information is dependent on geometric information. The subspaces generated by s-partitioning are subjected to spatial analysis. When interpreting the results, the problem of how to set the R value of the Integration can be solved by considering the actual physical size and the number of sub-spaces. We were able to get semantic information of the space from the text only. We analyzed semantic information to classify space with connectivity and used it to construct the network. Future studies are needed to obtain semantic information by symbol detecting.

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