Abstract

This study suggests a new spatial network models (SNMs), called the space-connector model, for improving the representation of the relations between spaces. Previous models had shortcomings of not being able to express the differences in the spatial connection relations between spaces: e.g., the differences in the type and size of openings and as the differences caused by whether a wall is solid or transparent. A new notation for representing these differences is proposed.

Keywords: space-connector model, spatial relation, space analysis, space syntax

1 Introduction

There have been many studies on the representation and analysis methods for the relations between spaces. The representation is called a spatial network model (SNM). Many studies on SNMs stemmed from the space syntax (Hillier et al. 1984). Common SNMs include the node-edge map (Biggs N. et al. 1984), the convex map (Hillier et al. 1984) and the convex-edge map (Hillier et al. 1984).

These methods have a great strength in representing spatial relations in a simple form. However, none of these can represent the types of connections: i.e., whether the spaces are connected by an opening or a door, or by a glass door or a solid door.

The objectives of this study are to develop a new SNM for overcoming the limitations in spatial analysis of previous SNMs by allowing description of physical or geometrical properties of space connectors.

2 Previous Studies

This section reviews a theoretical background of this study including the definition of spatial relation, types of existing SNMs, and quantitative space analysis methods using the SNMs.

2.1 Spatial network

Spatial network represents the topological relations between two spatial objects. A spatial network model is a graphical or non-graphical representation of a spatial network. Spatial network models are used in various quantitative space analysis methods including space syntax analysis (Hillier et al. 1984), traffic forecast, traffic line analysis, and structural analogy analysis. Among them, space
syntax is the most commonly used space analysis methods for spaces in buildings. A detailed description on space syntax and its analysis methods is provided below.

### 2.2 Types of spatial network models

The three most commonly used SNMs in architecture are the node-edge model, the convex model, and the convex-edge model as described in Introduction. This section describes them in more detail. Table 1 compares these three SNMs. Both the convex model and the convex-edge model represent the shape of a space as a polygon whereas the node-edge model represents space as a node. The difference between these two models is whether there is an edge that explicitly represents the relation between spaces. The node-edge model, the convex model, and the convex-edge model are all limited in representing geometric properties of space although modelers can represent the size of space by the size of a node or a polygon and the distance between spaces by the length of an edge. Edges cannot represent whether space is connected by a door or a window, whether the door is closed or open, wide or narrow, or transparent or opaque. For example, the apartment plan in Figure 3 comprises a hinged door between the master room and the hall, a sliding door between the entrance and the hall, and an invisible partition between the living room and the hall. The sizes of doors are different. The door between the master room and the balcony is transparent while other doors are opaque. These properties cannot be represented in the traditional SNMs although they have a significant influence on the perception of a space and the behavior of residents.

This study proposes a new spatial network model, called the space-connector model, to reflect the differences between the connection types and their properties in the spatial network analysis. Next section describes the space-connector model in detail.

<table>
<thead>
<tr>
<th>Simplest example of graphic representation (relation between two spaces)</th>
<th>Node-Edge</th>
<th>Convex</th>
<th>Convex-Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space</td>
<td>Node</td>
<td>Convex polygon</td>
<td>Convex polygon</td>
</tr>
<tr>
<td>Relation</td>
<td>Edge</td>
<td>Abutment of boarder lines</td>
<td>Edge</td>
</tr>
<tr>
<td>Representation of the geometric properties of space</td>
<td>(x)</td>
<td>(O)</td>
<td>(O)</td>
</tr>
<tr>
<td>Representation of the properties of relation</td>
<td>(x)</td>
<td>(x)</td>
<td>(x)</td>
</tr>
</tbody>
</table>
3 Space – connector model

This section describes the space-connector model. The space-connector model consists of space and connector. Definitions of space and connector used in the space-connector model are described below.

3.1 Representation of Space

Architectural space is not just a three-dimensional Euclidean space bounded by walls, but also a place confined by the psychological interaction between a person and the surroundings. Space in the space-connector model also does not just mean a physical place, but also an abstract psychological space. That is, space is categorized by its usage as well as physical partitions in the space-connector model. Based on this definition, Figure 1 shows the differences in interpreting the boundary of space in the existing SNMs and the space-connector model. In Example 1 in Figure 1, an L-shaped space (e.g., an L-shaped exhibition space) is defined as one space in the space-connector model and the node-edge model while the convex model interprets them as two spaces. It’s because space in the convex model is defined based on the visibility of space and, thus, space is defined as the “fewest number of fattest convex shapes” in convex model or convex edge model (Hillier et al. 1984).

Example 2 is an opposite example. In case of a living room-dining-kitchen (LDK) plan, there is no physical boundary between the three spaces, but the space-connector model and the node-edge model defines them as three different spaces whereas the convex model view this configuration as one space. The difference between the space-connector model and the node-edge model is that the space-connector model distinguishes that the three spaces are connected by an invisible boundary whereas the node-edge model cannot represent whether the three spaces are bounded by a solid wall or an invisible boundary.

3.2 Representation of Connector

In the space-connector model, connector represents the relation between spaces. It connects or separates spaces. The connector for architectural space is categorized into doors, windows, virtual connector (an invisible boundary between spaces). (Table 2). In the space-connector model, a door is a connector type that can be opened or closed and that people can walk through. A window is a connector type that may be opened or transparent, but the initial design goal is not for letting people walk through it. In the space-connector model, if a window is opaque and sealed, the window is regarded as a part of a solid wall, not as a window. A virtual connector is a connector type that does not divide space physically, but by usage. In the space-connector model, the physical size, the transparency, and the opening direction and type of a connection are also considered. The physical size of a connector has the influence on the pedestrian flow and openness to another space. Especially, the width of connector influences to the convenience in passage of spaces and the number of people...
who can simultaneously pass. The transparency of a connector influences the visual openness between spaces and the perception of the other spaces, and, thus, the direction to move and the cost of travel.

Table 2 summarizes the types and symbols of connectors. A connector is represented as a think box-like shape except for the virtual connector. The virtual connector is represented as a broken line. The physical size of a connector is represented as the width and the depth of the connector box. The transparency of a connector is represented as the darkness of the box. The brighter the box is, the more transparent. The opening direction and type is represented using a small dot that represents a hinge. The next section describes how a space-connector model can be built using these symbols in detail using an example.

Table 2. Connector types and properties

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type</th>
<th>Expression</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector</td>
<td>Door</td>
<td></td>
<td>A door physically separates a space, but it represents a relation that a person can move and pass through.</td>
</tr>
<tr>
<td></td>
<td>Window</td>
<td></td>
<td>A window is possible to see through and open, but it represents a relation that passing through is not possible.</td>
</tr>
<tr>
<td></td>
<td>Virtual Connector</td>
<td></td>
<td>Virtual connector represents a relation that it does not physically divide a space but does by usage or meaning of the space.</td>
</tr>
<tr>
<td>Physical size</td>
<td>Width</td>
<td></td>
<td>The width of a connector means horizontal width of a door, window or virtual connector.</td>
</tr>
<tr>
<td></td>
<td>Depth</td>
<td></td>
<td>The depth of a connector means thickness of a wall surrounding a door, window or virtual connector, or length of a hallway. If a hallway connecting two spaces is determined to have additional function in addition to being a passageway, it may be regarded as a separate space rather than a connector.</td>
</tr>
<tr>
<td>Transparency</td>
<td>Shade</td>
<td></td>
<td>Transparency is represented by transparent rate. Black and white are used respectively for being opaque and transparent.</td>
</tr>
<tr>
<td>Opening directions and types</td>
<td>Hinged</td>
<td></td>
<td>In case of hinged doors or windows, square dot represents a knob and opening direction.</td>
</tr>
<tr>
<td></td>
<td>Sliding</td>
<td></td>
<td>In case of sliding doors or windows, square dot represents a knob and opening direction.</td>
</tr>
<tr>
<td></td>
<td>Bidirectional hinged</td>
<td></td>
<td>In case of bidirectional hinged doors or windows, two square dots are at the center facing each other.</td>
</tr>
</tbody>
</table>
3.3 Creating a Space-Connector Map

Figure 2 is a simple example for illustrating the basic steps to create a space-connector map. A space-connector map is an instance of the space-connector model. The first step is to choose a plan to analyze. The second step is to extract interior lines from the chosen plan. The third step is to add connectors.

Figure 2, Steps to create a space-connector map

Figure 3 is a slightly more complex example of a space-connector map than the one in Figure 2. Outdoor space is open to limitless space and, thus, connectors such as outside windows or entrance that are connected to outdoor space are ignored. The differences between the plan and the interpreted space-connector map are that while spatial boundaries and space connector types are implicitly defined in the plan, the space-connector map explicitly defines spatial boundaries and connector types. Division between the hall, the living room, the kitchen and the entrance in Figure 3 are such examples.

Figure 3, Example of a space - connector map
4 Conclusion

Spatial models are not just a visual representation of spatial relations and their properties, but also a reflection of the philosophical view on space. This study began in need for a new spatial network models (SNMs) that allow us to express the properties of the connections between spaces: whether space is divided by a solid door or a transparent door, and so on. These are all critical factors to consider because they affect the behavior of space users. For this objective, existing spatial network models were reviewed and a new spatial network model, space-connector model, was developed to complement the shortcomings of existing models. Space-connector model consists of ‘spaces’ and ‘connectors’. Space is categorized by usage and as well as by physical boundaries. Connector is an element that connects spaces. Examples include doors, windows, the virtual connection, and walls. The virtual connection separates spaces by not a physical boundary but by the usage of space.

The greatest advantage of space-connector model is that the properties of connectors can be expressed. The transparency, the dimensions, and the opening directions can be represented in the model.

The results showed that the space-connector model could distinguish the difference between the spaces separated by the virtual connection and the spaces separated by solid walls. The results also showed a potential for applying the space-connector model in other analysis methods such as Isovist and traffic line analysis by adding the weight of each connector to the analysis equations.

Reference


BENEDIKT ML, 1979, “To take hold of space: isovists and isovist fields” Environment and Planning B 6 47 – 65