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Computational models for measuring spatial quality of interior design in virtual environment

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ABSTRACT

This paper presents a computational model designed to analyze and to assess quality of architectural space. The model consists of two parts: first part is a model of subdivided enclosed spaces, which is an approximation of spatial layout regarding the enclosure and the circulation path. Second part is a model of spatial quality assessment using three spatial parameters and two distinct approaches. The first approach of this assessment is visual distance and the second approach is viewing angle. The assessment valued by these approaches then combined to obtain spatial quality ranking of each of the subdivided enclosed space. Previous studies on spatial assessment showed the relationship between visual distance and spatial quality can be modeled through mathematical approaches. Our work proposes an improvement on the method of spatial mapping model and spatial quality assessment. Experiments have been conducted on interior design and we developed spatial evaluation using three parameters: visual openness, privacy and physical accessibility. Furthermore, we conducted a comparison study of privacy assessment on design variances. Finding shows some distinctive results on the assessment approaches that can lead to more elaborative spatial quality evaluation. The outcome on spatial quality assessment can facilitate spatial quality evaluation of interior design in early stages of design development.

1. Introduction

This study focused on the architectural space of interior design as a result of the arrangement of architectural elements. An architectural space is defined as the void between physical boundaries of the enclosures where its existence is independent of the user's presence. As an architectural space composed by its physical setting, we developed a model using superimpose technique to map this space into what we named as subdivided enclosed space. The mapping procedure follows the basic relationships between design elements and circulation paths using territorial lines approach as studied by Koile [1]. The benefit of this model is it offers a more elaborative object of assessments specifically relates with spatial quality parameters. In previous study of spatial quality evaluation [2,3], a single proxy usually used to represent object of evaluation (i.e. center of the room or any arbitrary point in the room). Some of earlier models have focus on spatial mapping mechanism and procedures [4] with less emphasize on the development of spatial quality evaluation.

Our spatial mapping model results in an array of points in an interior plan where each point has different spatial quality ranking that related with their relative position to the architectural elements. This model proposes a better analytic tool for spatial quality evaluation. The comparison of our model with previous works is presented in Table 1.

The spatial quality parameters used in this study are determined and intended to improve previous achievements. For example, Fischer-Gewirtzman and Wagner [5] and Pinsly et al. [6] analyzed spatial openness and visual exposure. Both parameters related with visual openness, which is bound for metric-based evaluation. Demirkan et al. [7] used distance measurement to analyze privacy in an interior space. We determine three spatial parameters for this study: visual openness, privacy and physical accessibility.

2. Architectural spatial quality

Architecture is experienced not just by attributes of its boundaries. The variability in the interior (enclosed space) and exterior (enclosure) comprise the essence of architecture. Several architects [8–10] as well as psychologists [11] have found that the

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Table 1
Comparison of models and methods.

	Gross method (1977)	Koile method (2001)	Sora method (2008)	Our method (2010)
Goal	Classification of enclosed space by its boundaries	Design representation by hierarchical territorial space	Quality of space by viewpoint and geometric elements	Spatial map that represents relationship of boundary elements and circulation space
Limitation	Only physical boundary forms a subdivided enclosed space, failed to accommodate center space, and no hierarchical attributes related to the space	Limit to the territorial spaces as a result of element, edge, and circulation model	Only to measure quality at arbitrary viewpoint position relative to the boundary element	Experimented on rectangular-based plan
State of the art	Enclosed space classification based on its boundary	Abstraction model of design representation	Spatial quality measurement based on viewpoint	Spatial map based on hierarchical relationship of boundary elements and circulation space
Result/Output	Numerical values that represents rank of enclosed space	Graphic representation of model	Numerical result of measurement	Layout of spatial mapping resulting in determination of subdivided enclosed space

experiences in the same space can vary with the changes in architectural design elements such as colors and transparency.

Another aspect of architectural space is that architects always compose space according to the boundaries and inter-relationships between the architectural elements and its planned activities. March and Steadman [3] used network graph to denote topological relationships between rooms – which room gives access to another, which room is adjacent to another. Péna [4] suggested that the matrix relationship of activities should be constructed to model adjacency of spaces regarding designated activities. Both studies had used basic mathematical model of spatial configuration in order to understand relationship between spatial design and activities.

Our model of enclosed spaces is the elaboration from previous study with the advancement of having a map configuration of what we named as subdivided enclosed space inside a set of interior space. We advice each area of subdivided enclosed space expresses distinct spatial quality that is significant for spatial quality analysis and further conceptual design elaboration.

3. Mapping the interior by virtual agent

The concept of spatial quality mapping by previous works referred to the preposition that on an enclosed space or interior space, the hierarchy of the space can be mapped by the strength of influence of its boundary elements [12–15]. A study of spatial mapping has been conducted by using number of solid boundaries to classify enclosed spaces [13], combining concept of territory space to map strength influence of boundary elements into enclosed space [1] and recently, used distance model to classify hierarchy of enclosed space [14].

Our model began with the classification of enclosed space [15] where there are six defined architectural spaces: by linear elements (column), by single vertical plane (i.e. wall), L-shaped space, parallel space, U-shaped space and four planes to define full closure of space. The basic enclosed space category we used for this research is L-shaped space (Fig. 1).

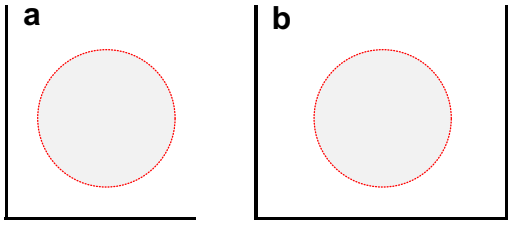

Fig. 1. Diagrammatic model of enclosed space, a) L-shaped space; b) U-shaped space.

Following the basic classification of enclosed space, our model of spatial mapping is based on the visual perception and position of the virtual agent. Therefore, the rules for generating spatial mapping are taking account the detected objects by virtual agent. Our method of enclosed space detection is based on the hierarchical structure of the space as previously been studied. On this model, the hierarchy of enclosed space is as follows:

1. L-shaped space; defined by two non-collinear solid boundaries.
2. Circulation space; defined where it has territorial space of circulation gate (i.e. door).
3. Attractor space; defined where it has territorial space of other architectural elements at the boundary such as openings.
4. Subdivided space; defined as result of the rules of spatial mapping.

As result of this concept, we determined an interior space as a unit analysis. An interior space is a space that comprises of enclosures, enclosed space and circulation path. We named this area as bounded area (Fig. 2).

A bounded area comprises of rectangular-type arrangement of enclosed spaces that depend on the configuration of architectural elements at its enclosure. We employed procedural rules by considering relationship between bounded area and its circulation path. The bounded area may enclosed by opaque boundaries (walls), openings (windows or doors) and other architectural elements. A circulation path is a circulation connector inside the bounded areas. Circulation gates such as door and path form a circulation space inside the bounded area.

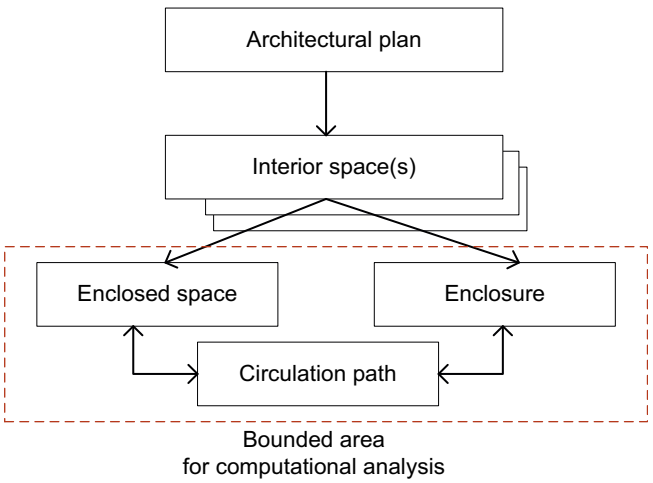

Fig. 2. Unit of analysis.