Visualization of the spatial distribution of light and heat by graphical representation for the improvement of the quality of indoor environment and energy efficiency

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MIKI Yasuhiro (Ph.D. in Engineering), Head, Building Environment Division, Housing Department

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1. Introduction

In recent years, an increasing number of attempts have been made to improve both the quality of the indoor environment and energy efficiency in buildings.

Particular attention has been paid to the method of ensuring temperature and brightness at the required time and place by allocating air conditioning and lighting equipment locally in areas where they are insufficient, taking into account the effects of heat and light from the outdoors. Such methods can reduce energy consumption for the space as a whole while ensuring comfort for people.

However, an understanding of the relationship between the indoor environment formed by such methods and energy efficiency has been inadequate so far because it has been necessary to grasp the relationship in a two-dimensional distribution (cross-sectional or planar contour map) (Figure 1). Thus, in order to facilitate the understanding of the relationship between the indoor environment (elements related to light and heat radiation) and energy efficiency, this study attempted to visualize the spatial distribution of three-dimensional light and heat environment in the indoor space, both locally and in the entire space, through a graphical representation using visual cognition.

2. Graphical representation using visual perception of local distribution

The representation of light and heat by radiation could be a vector representation consisting of arrows extending in various directions from the surroundings because light and heat of different intensities are incident at a point in space from different directions. Still, it is difficult to display the various directions in a clear, three-dimensional manner (Figure 2, left). In this study, directions were narrowed down to the six basic directions of an architectural indoor room: up and down, left and right, and back and front. In addition, to make it easier to grasp the intensity of light and heat in different directions, an isometric diagram was used, which clearly shows the

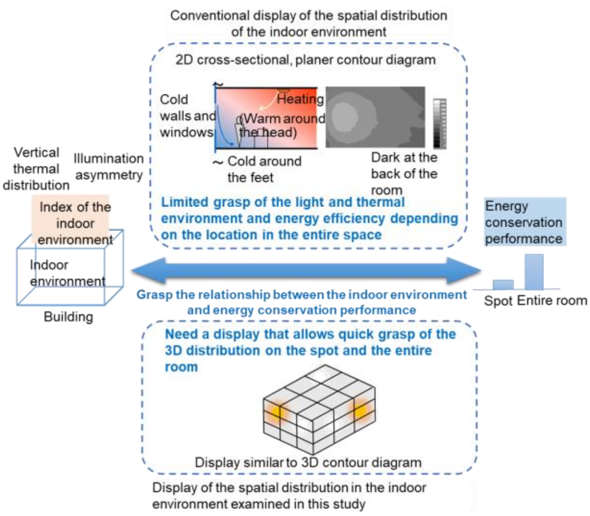

Figure 1: Necessity of graphical visualization of three-dimensional distribution

coordinate positions of the space and makes it easy to see the whole picture. However, since the simultaneous representation of vectors in six directions makes it difficult to intuitively understand the aspect of light and heat (Figure 2, center), the representation of a cube with surfaces that would easily express the brightness and color of light and heat were considered appropriate. However, a normal cube can only show three surfaces, and the convexity as a perceived figure is inverted (Figure 2, right). Therefore, a method to arrange the surfaces in a discrete manner was devised. Figure 3 shows how the discrete arrangement is organized by linking it to the theory of visual cognition. First, when the six surfaces that make up a cube are slightly discretized at the same spacing, the overlapping edges create depth perception using pictorial cues as higher order visual cognition (Figure 3, left). However, in a small discrete, it is difficult to see the surface at the back and cannot be perceived as the shape of the surface that makes up the cube. On the contrary, if the six surfaces are made into a large discrete with the same spacing, the depth perception of the back three surfaces

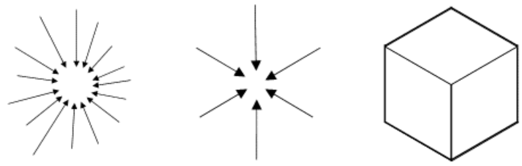

Figure 2: Limit to the three-dimensional representation of local light and thermal radiation

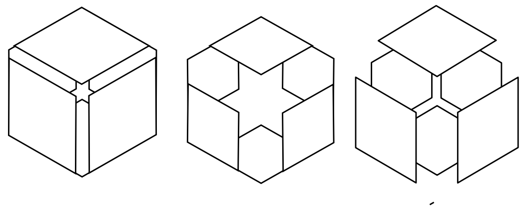

Figure 3: Representation by discrete arrangement of cubic surfaces

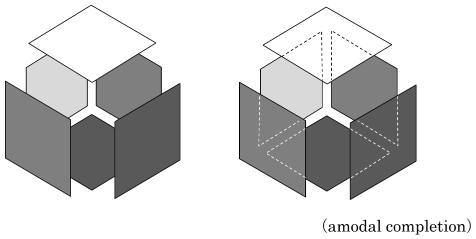

Figure 4: Local depth perception using light and dark surfaces and amodal completion

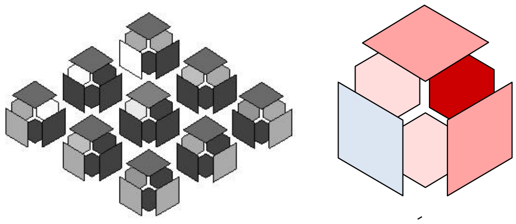

Figure 5: Display of multiple localized light and heat

becomes less, and they are not easily perceived as a cube (Figure 3, center). Therefore, the best way to display the image is to create a large discrete on the front three surfaces and small discrete on the three surfaces at the back (Figure 3, right). As an example of light, Figure 4 (left) shows different shading on the surfaces according to the amount of incident light. Here, amodal completion occurs in which the surface that is hidden behind another surface is perceived as an existing surface, and the entire surfaces including the back three surfaces are visible, and together with the pictorial cues provided by the overlapping of edges and shading of the surfaces, cubic shape is perceived as a depth that is not inverted. The three front surfaces with large hollow walls are filled in by the three back surfaces, and the pictorial cues similarly provide non-invertible depth perception. In the isometric view, an object with the same size at the back is perceived as relatively large, so the group of the three surfaces at the back is a little smaller than the group of the three surfaces at the front, but they do not seem strange. From these, the entire surfaces from six local directions are perceived, and the local distribution can be intuitively grasped. Figure 5 (left) shows the example of this representation of the light environment expanded into a layer of horizontal surface with multiple points. Figure 5 (right) is an example of representing the local thermal environment.

3. Attempt to graphically representing light and heat environment in a space as a whole

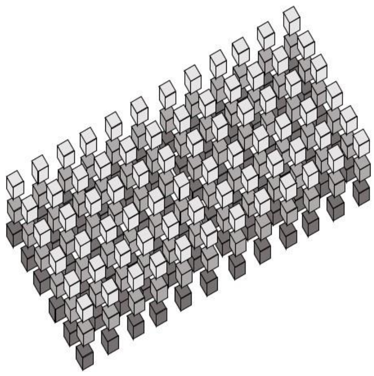

Figure 6: Trial display of the light environment of a space as a whole

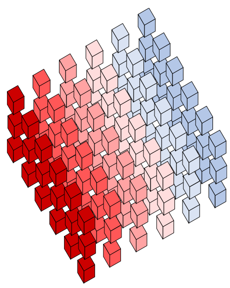

Figure 7: Trial display of the thermal environment of a space as a whole

When the displaying the light and heat environment in a space as a whole in the isometric diagram shown in Figure 5 (left), the multiple layers create overlaps in a cube itself, which depletes the perception of depth. Here, the study devised and tested a cubic representation of the entire space for the light and heat environment as scalar quantities. A method was devised that allows us to partially see and grasp surfaces even when each cube overlaps in the entire space because of the characteristics of the axonometric diagram that gives an overview of the entire space and the distortion of the displayed cubes. Figure 6 and Figure 7 show trial representation of the light and thermal environment, respectively. It is possible to grasp through the space that, for the light environment, the brightness declines as it approaches the floor from the ceiling, and for the thermal environment, the temperature changes from the wall to the back of the room.

4. Summary

This study is a groundbreaking attempt to visualize the three-dimensional depth of an interior space with a two-dimensional graphical representation. The study will be continued to create practical graphical methods.

☞For more information:

1) Graphical Representation of Light Field by Discrete Arrangement of Cubic Surfaces Using Visual Congition, Technical Papers of Annual Meeting, Japan Society for Graphic Science Lecture, pp. 9-10, Nov. 2020.