Complex, flexible, virtual environments based on a four dimensional grid

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A projection-based virtual reality system combines a cubed grid with the perspective of the user to represent high-dimensional spaces.

As virtual reality (a computer-generated physical environment that simulates the real world) evolves, demand increases for structures that are not restricted to 2D or 3D spaces. These self-imposed constraints challenge the developers of computer graphics. Nevertheless, mapping information to complex grids in virtual reality is valuable to engineers, artists, and other users because interactive navigation is then internalized. In other words, the interaction engages the user to maneuver the environment to gain further knowledge of, and experience with, complex spaces.

Current work in higher dimensions (those involving four dimensions and above) involves change over time, or database swapping, which forces users to destroy the relationships they seek to investigate. Although both mathematicians¹ and artists suggest the possibility of higher dimensional spatial modeling, they have not seen virtual reality as a malleable spatial structure. However, combining design principles and virtual reality in these higher dimensions generates complex and more integrated environments.

In the past, designers have become familiar with how projections affect 3D objects in two dimensions. I postulate that it is possible to gain familiarity with variations that occur while moving through higher dimensions² if such dimensions are reflected on a recognizable structure that is affected by perspective.

To make four dimensions visible, a shadow of a tesseract (cubes in four dimensions) grid is assembled in virtual reality. By tracking the orientation of the user’s hand, the result becomes a 3D structure of surfaces that self intersect as the grid rotates in four dimensions.

To see the grid and enhance the relative position of its cells, a 2D texture is assigned to all semi-transparent surfaces of the tesseracts. The texture arrangement creates a superposition of colors and images. The image intersection and superimposition is familiar because of similar phenomena in the real world, specifically when shadows, reflections, and imprints are used to understand and navigate space. In the real world, patterns and forms inscribed on a grid are used for measurement and continuity. Thus, the same design principles used for designing 2D and 3D worlds are used for navigation in higher dimensional grids.

Interaction with the 4D structure is facilitated by using body motion (see Figures 1 and 2). Human limbs move as a whole but also move independently so the degrees of freedom of an arm and hand, for example, control the projection of a 4D rotation. The motion of the user becomes an articulated point-of-view, and the higher dimensional grid references the user’s position relative to it. In other words, the user learns how motion inputs affect the grid, thus recognizing a correlation between the input and the transformations.

The application operates in the CAVE®, a multi-person, room-sized virtual reality system, or in other similar systems such as the configurable wall (C-Wall), a single wall version of the CAVE. The Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago designed both systems, which allow multiple users move around in a structure physically

Figure 1. The tracked wand rotates the four dimensional (4D) plane, which results in the stretching the cells of the tesseract grid.

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Figure 2. The user navigates the grid by aligning walls that share the same orientation.

while also allowing them to interact virtually by maneuvering a tracked sensor in each hand.

The idea of higher dimensional spaces holding more information than three dimensions challenges current assumptions about design and architecture. Such a possibility opens up a world to language and space that exists only as a reaction to body actions.

The creation of higher dimensional space is a design challenge in electronic imaging just as the rendering of three dimensions into two dimensions was a challenge in the past. However, advancements in computer graphics further connect mathematics with higher dimensional space. Consequently, designers within electronic imaging are developing complex structures that use as many dimensions as needed to represent various complicated situations.

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References