

Voxel Sequence: An Analysis of Kengo Kuma's Prostho Museum

Kuma's Prostho Museum was analyzed in incremental phases to properly evaluate spatial relations found between different operational systems within the structure. Emphasized by a gridded-system, Kuma designed the museum to reflect the traditional Japanese building set for children known as the Cidori assembly. Because the museum undergoes a series of sheared volumetric subtractions both internally and externally, the spatial organization of this museum were broken down into the following systems to evaluate: Roof, Massing, Enclosure, and 3D-Frame.

Spatial relations between the evaluated systems share an interconnected relation between coordinates related to the Cidori assembly that Kuma designed. Interrelationships between these systems were first hypothesized and then analyzed by the team to evaluate unique optimizations of both space and energy utilization. An evidently gridded organizational system was examined in 2D with a 500mm sequenced array of lines in the x and y axes, within which overall volumetric boundaries appeared to be strictly adherent. Deriving these evaluations from the generalized grid-system of the museum, complex relations were tested throughout this analysis period to evaluate integrations discovered between the systems within Kuma's design.

Each system was evaluated in the terms of voxel architecture. A voxel represents a value on a regular grid in a 3D space, which can also be interpreted as a coordinate within a 3D space. Therefore, the synthesis of these systems was derived from a shared coordinate system within the grid system that was evaluated, analyzed, and optimized. The shared coordinate system observed is referenced as a voxel sequence here on out.

The overall organizational grid examined was through a voxel sequence of cubic volumetric in the x, y, and z axes, but parametrically limited to the maximum extent of initial boundaries defined by the precedent. Unique spatial relations were then formulated between the other building systems which share similar trends, discussed in detail below.

The 3D-frame system was initially evaluated to determine constrained parameters that which the massing, roof, and enclosure systems will embrace from it. Constrained parameters of the frame system observed in this study include optimal horizontal member distances in relation to its vertical member distances. From this, the other systems and their associated linkages to the voxel sequence of which it derives can be optimized accordingly. The notion of a voxelized organizational system (intersection and volumetric) became the determinant and parametric order in defining the massing, roof, and enclosure systems. The 3D-frame system is the material manifestation of the order itself operating as an interior/exterior threshold and intermediate spatial skin system.

While each building system is strictly determined by a voxel coordinate order, the dialogue between each is non-sequential. This is seen most evidently in massing/roof system as they are parametrically defined by points within the voxel sequence. However, the interrelationship and connection of these points to produce implicit surfaces provide a subtractive boundary upon which the 3D-frame system is terminated from the exterior in a perceptually defiant manner. The interior enclosure system is also defined by a voxel sequence and produces yet another subtraction of the 3D-frame system.

Initially defined by voxel arrays, the 3D-frame system can be seen as a sequence of lines in the x, y, and z axes that are divisionally contingent on parametrically defined site boundaries and also by the previously mentioned subtractive orders. Subsequently, the 3D-frame system's 500mm cubic voxel can paradoxically be both a determinant and a byproduct.

In analyzing the parametric optimization of these integrated systems, relations were identified between different surface areas and volumes. Parametric optimization explores the relationship between expansion and contraction of the voxel sequence, as both singular volumetric conditions and point conditions. Additionally, it explores their respective aggregation within and about serial subtractive boundaries. Sequential distribution of the coordinate system is determined by the maximization and minimization of the horizontal-to-vertical member ratio. Thus, modifying contingent massing points of determinacy in each axis, each unitary voxel, and ultimately the spacing and size of the Cidori 3D-frame members.

In order to optimize a space's designed output, the minimum amount of surface area of the space is compared to its maximum amount of volume produced from it. Therefore, minimized optimization was evaluated in our processes to determine the most sustainable design types observed. This minimized output was then compared to its maximized counterpart. These optimization patterns, which compare and contrast in design, are displayed in the diagrams of our study. From this first step in this optimization process, one can proceed to more rigorous steps associated with complete-design optimization and metadata analysis.

Since the 3D-frame system shares voxel relations with the massing, roof, and enclosure systems, efficiently designed systems can then be derived from its initial 3D-frame optimization. This latter portion of analysis is considered to be variation analysis. Detailed variation analysis extends past the time constraint of this class, which could lead to academic breakthroughs in the concepts of spatial symmetry and its synthesis with sustainability.

Variation analysis has potential to bridge gaps between the academic world and the professional world when addressing sustainable design. This was observed by our group as we went through the optimization phase, realizing the importance it has on real-world applications. The optimization parameters used and identified in this study should be revisited in future works and revised, as needed, to make a more versatile optimization processes that flexibly integrate many systems into one comprehensive variation analysis tool. By doing so, these re-tuned optimizations can then be integrated into different software systems that professional practitioners can use in the field to produce better-designed spaces.

When designing buildings, site areas and air-rights associated to that site are factors in determining the volumetric space of its intended structure. These are related factors to those observed in our optimization analysis. It is just one of many paths this project can take in future years, when relating optimized voxel architecture to sustainable designs which are oriented around geometrical symmetries.