A Shape Grammar for Space Architecture –
II. 3D Graph Grammar Approach

Proposed paper is a further development of ideas sketched in previous study on Shape Grammars for Space architecture. Composing new shapes from a set of generic elements is continued in 2 and 3-dimensions. A number of specific problems arise with this attempt. Originally, the Generative Grammars have been developed as a string rewriting procedure i.e. they operate in 1-dimension. The Stiny’s Shape Grammars overcome that constrain by using points and lines in plane situated more or less freely. Later, a similar approach was applied in 3D extensions of Shape Grammars. The problem of such approach is that basic rule in Generative grammars – the concatenation couldn’t be simply transferred into multidimensional case.

We choose to develop a rule-driven generative systems based on the Graph Grammars. The Graph Grammars have been invented in early seventies (the same period the Shape Grammarians have emerged) in order to generalize Chomsky string grammars. The main idea was that of extending concatenation of strings to a “gluing” of graphs along a common substructure. The Graph Grammars has a number of applications in chemistry, biochemistry, economics etc. beside primary use in computing science. Most of their applications use an abstract interpretation of the term ‘graph’ not directly associated to any objects in Euclidian space. We do not find a previous usage of Graph Grammars formalism in the Shape Grammars paradigm developments.

In presented framework the Graph Grammars are used to generate topology of spatial skeleton (frame) consists of axes and nodes. Since topology itself is not enough to define particular shape a certain metrics should be applied. We choose an approach compiled from theoretic crystallography and space point-group theory. By appropriate symmetry point-group operation on axes connected toward certain node their directions will be defined. There are rather strict packing conditions for realistic space modules that must be met. These conditions can be accomplished only by a limited number of arrangements of very few symmetry operations; these are inversion through a point, the twofold screw rotation and the glide reflection. Some space groups are mathematically legitimate, but physically impossible so far.

The other problem a following higher dimensions are physical constrains applied on node elements in order to keep membrane hypothesis assumption admitted in previous paper. A particular approach based on symmetry of cutting planes is applied.

Working on axes is familiar in the architectural workflow as well for the design process (and thinking) in aerospace engineering. By formal point of view a special attention is paid on keeping a context-free implementation of our framework for Spatial Shape Grammars. The strictly context-free system is easier to implement in software.

On the other perspective, described approach is related to methods applied in structural chemistry, crystal growth, theoretical urbanism and population dynamics – all that fields have features of growth with spatial constrains. All that make possible to explore construction sequences and usability dynamics of space architecture superstructures by methods already in use in urban planning theories.

In conclusion, a discussion is opened about the role of higher order symmetry operations as a source of new morphology.