World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:17, No:06, 2023

A Computational Framework for Decoding Hierarchical Interlocking Structures with SL Blocks

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Abstract : This paper presents a computational solution for designing reconfigurable interlocking structures that are fully assembled with SL Blocks. Formed by S-shaped and L-shaped tetracubes, SL Block is a specific type of interlocking puzzle. Analogous to molecular self-assembly, the aggregation of SL blocks will build a reversible hierarchical and discrete system where a single module can be numerously replicated to compose semi-interlocking components that further align, wrap, and braid around each other to form complex high-order aggregations. These aggregations can be disassembled and reassembled, responding dynamically to design inputs and changes with a unique capacity for reconfiguration. To use these aggregations as architectural structures, we developed computational tools that automate the configuration of SL blocks based on architectural design objectives. There are three critical phases in our work. First, we revisit the hierarchy of the SL block system and devise a top-down-type design strategy. From this, we propose two key questions: 1) How to translate 3D polyominoes into SL block assembly? 2) How to decompose the desired voxelized shapes into a set of 3D polyominoes with interlocking joints? These two questions can be considered the Hamiltonian path problem and the 3D polyomino tiling problem. Then, we derive our solution to each of them based on two methods. The first method is to construct the optimal closed path from an undirected graph built from the voxelized shape and translate the node sequence of the resulting path into the assembly sequence of SL blocks. The second approach describes interlocking relationships of 3D polyominoes as a joint connection graph. Lastly, we formulate the desired shapes and leverage our methods to achieve their reconfiguration within different levels. We show that our computational strategy will facilitate the efficient design of hierarchical interlocking structures with a self-replicating geometric module.

Keywords : computational design, SL-blocks, 3D polyomino puzzle, combinatorial problem
Conference Title : ICDGPCG 2023 : International Conference on Digital Geometry Processing and Computer Graphics
Conference Location : Montreal, Canada
Conference Dates : June 15-16, 2023