A SYSTEMIZED AGGREGATION WITH GENERATIVE GROWTH MECHANISM IN SOLAR ENVIRONMENT

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ABSTRACT
The paper demonstrates a work-in-progress research on an agent-based aggregation model for architectural applications with a system of assembly based on environmental data acting as a driver for a growth mechanism. Even though the generative design and algorithms have been widely employed in the field of art and architecture, such applications tend to stay in morphological explorations. This paper examines an aggregation model based on the Diffusion Limited Aggregation system incorporating solar environment analysis for global perspective of aggregation, the geometry research for lattice systems, and morphological principles of unit module at local scale. The later part of this research paper demonstrates the potential of a design process through the “Constructed Cloud” case study, including site-specific applications and the implementation of the systemized rule set (Figure 1).
1 INTRODUCTION

1.1 GENERATIVE DESIGN
Generative design is a design methodology in which the output is generated by a set of rules or algorithms, normally implemented on the computer. In the early 1970s, Prof. Ralph L. Knowles at the University of Southern California implemented an external factor, a solar vector data, as the main principle for the design rule set in The Solar Envelope project where all adjacent neighbors are capable of solar access. While the early project was operated manually, generative design process using a computational method has been triggered to mediate a rule set between humans and the environment factors in this fast changing and unpredictable contemporary period.

1.2 GENERATIVE DESIGN IN COMPUTATIONAL ECOLOGIES
Parametric design and generative algorithms have been investigated in architecture as a way to integrate environmental factors into the design process. Morphosis Architects integrates technologies into high-performance skin systems that minimize solar heat gain while maximizing glare-free daylight by using parametric design technique in the Phare Tower project. Also, the Concept_Face_C project (Banke 2013) demonstrates a form generation toolset that use the analysis and simulation of daylight conditions and indoor comfort to drive the form in early design phases. However, such recent applications of parametric design with environmental data still tend to stay on envelope design or frozen morphological moment even though generative algorithms are more suitable for responsive and adaptable real-time outcomes. Therefore, this research investigates a reciprocal design process by a generative algorithm that involves a decision making process, enabling positive impacts on both human and the environment.

1.3 SYSTEM MAKING AND GEOMETRY
A system design is a set of interacting or interdependent components forming an integrated whole (Bohnamer 2012). The concept of systematic architecture has been widely used on structural concepts, module systems, and space organization. In 1950s, in Philadelphia, Louis Khan and Anne Tyng proposed City Tower, a synthesized space widely used on structural concepts, module systems, and space organization. In 1950s, a seminal example of earlier systematic architecture with a rule set. A system design is a set of interacting or interdependent components forming an integrated whole (Bohnacker 2012). The concept of systematic architecture has been widely used on structural concepts, module systems, and space organization. In 1950s, a seminal example of earlier systematic architecture with a rule set. The idea of minimal surface aggregation is an advanced system design that produces continuous surface via duplicating, reversing and rotating the modulated minimal surface. Toyo Ito’s Techo Chung Opera House demonstrates an application of minimal surface aggregation system in large scale architecture. The independent aggregation modules not only become a unified component, but also demonstrate the whole system of building. As a result the assembly logic can be applied to the component system design to control both individual and collective logic of morphology simultaneously.

2 METHODOLOGY

2.1 DATA RESPONSIVE DIFFUSION LIMITED AGGREGATION SYSTEM
Data responsive generative design is initiated by a generative algorithm, Diffusion Limited Aggregation (DLA)—an algorithmic model of fractal growth that produces dendritic forms that was introduced in 1981 by Witten and Sander. In the DLA model, a sphere surrounds an attraction point at the center, a growth starts from the sphere surface, and then a seed from the surface wanders around randomly until it is attached to a branch of the existing cluster. Finally that seed becomes a new agent to attract the following seed. This process repeats creating a divergent aggregation. Because the DLA system can be grown toward exacted directionality and parameters, it offers a possibility for the user to set a rule and operate it systematically. In this project, the DLA system is driven by environmental data, especially solar factors, and the sunlight direction toward an attraction point which circumscribes the possible growth surface of seed on a sphere. As the agent can only grow within a certain volume determined by solar analysis, the framework of the cluster will be developed toward specific direction (Figure 5). As a result, the environmental-data-driven DLA system provides an aggregation system that is adaptable to the solar conditions.

2.2 LATTICE SYSTEM FROM TRUNCATED OCTAHEDRON
The DLA model constructed using solar data is developed by exploring geometry studies in Platonic solids and Archimedean solids. Among the eighteen solids (Figure 6), the geometry of truncated octahedron offers a high degree of density because the distance from a center point of one truncated octahedron cell to another is relatively shorter than other solids (Figure 7, Figure 8). Furthermore, truncated octahedron each of which consists of six squares and eight regular hexagons can assemble into zero gap tessellation and the lattice system that is generated by connecting the centers of the truncated octahedron becomes the fundamental lattice system of the DLA model. Therefore, the DLA system with a lattice system of truncated octahedron results in a stable growth structure with high density.
2.3 MORPHOLOGY
The form of the truncated octahedron is optimized via a process of evolvement and degeneration in order to improve its function and the connection between neighbors in DLA lattice structure. In detail, one truncated octahedron unit is surrounded by fourteen neighbors by touching six square faces and eight hexagonal faces, and the six square faces are positioned farther from the center of the truncated octahedron so that during transformation they are fixed to maintain the maximum volume, but the hexagonal faces become alienated from their neighbor (Figure 9). With regard to six possible outlets out of fourteen faces, two squares among six are degenerated to secure sufficient passages for sunlight between the DLA structure layers, eventually four squares are selected as outlets to connect to neighbors (Figure 10). The geometry results in four outlets and six surfaces by merging vertices of a unit. Then the four outlets become an inner space, a circulation or termination of the unit depends on the surrounding conditions, resulting in an asymmetrical form that diversifies possibilities of assembly in aggregation. As the new form is optimized into minimum number of faces, six faces, each surface is capable of exposing to maximum amount of sunlight, moreover the alienated faces offer cavity space between units, which allows sunlight to passing through multiple layers in the lattice system (Figure 11). Due to these transformations, the truncated octahedrons have been converted into different geometric forms, resulting in maximum surface area exposure for the ultimate amount of sunlight within the multiple layers of the DLA structure (Figure 12). Thus, the aggregation system has achieved varying morphology at global scale, and still remains as a unified form underlined by the lattice system.

3 APPLICATION
3.1 BACKGROUND
The project “Constructed Cloud” showcases a specific application of the methodology in the previous session. The growth mechanism is driven by a parameter defined by the Geographical Information System (GIS). Specifically, the potential sites are office buildings in New York City that are under fifteen-story heights with leftover air rights in restriction of reconstruction. An area of seed growth within a sphere of the DLA system is circumscribed by the range of the sun vector, whose direction is perpendicular to the designated volume and the area that is capable of daylight inflows for at least three hours per day. Then the data-responsive aggregation system is operated according to the specific environmental conditions.

3.2 LOCALIZED CLUSTER SYSTEM
After the DLA model along the lattice structure of the truncated octahedron is constructed, it is grouped into several looping clusters in order to achieve structural and functional qualities on large scale from the independent integrated systems in unit scale. Each cluster can function as one or any combination of circulation, ventilation, occupiable space, utility, vegetation, space separation, or visual connection. As a result, one cluster distributes the functions of among its units (Figure 13).

3.3 MULTI-DIRECTIONAL ORIENTATION
One unit is shaped into an asymmetric form after transformation, consequently, the clusters within the DLA model are capable of creating different configurations depending on circumstances by rotating, mirroring, or duplicating units as a rule of minimal surface aggregation. Therefore, the various configurations enable the unit within each cluster to a range of different directions (Figure 14).

3.4 SPACE ORGANIZATION
The aggregated model is placed on the lattice system of the truncated octahedron, so the unit spaces of each cluster are accessible from the same floor level and circulation stairs. These spaces contain a skip floor type office (4 modules), a trail type office (6 modules), a lattice type office (6 modules), a ring type office (8 modules) and a switch-back type office (6 modules) (Figure 15, 16).

3.5 PARAMETERIZE THE RULE SET
This rule set operates from the site selection process, generative algorithm to systematic design, and we have shown that the rule set can be parameterized into the selected volumetric spaces and adapted to different physical urban context and environmental conditions (Figure 17).

This work-in-progress research project aims to explore an environmental-factor driven generative design process that highlights the reciprocal relationship between architecture and environment. Also, in response to the Anthropocene, the employment of systematic design in generative algorithm enables adaptable and responsive parameters in diverse environmental criteria. In this paper, the Diffusion Limited Aggregation (DLA) system as a generative algorithmic language serves as a self-sun-oriented aggregation model within limited volumetric parameters with a global perspective. The geometry of the truncated octahedron was used as a unit of the lattice system in the DLA aggregation. The relationship between the truncated octahedron units bring about a transformation of geometry that results in 4 outlets and 6 surfaces by the process of evolvement and degeneration. The generated form is shaped as a collection of multi-oriented units that can adapt to diverse directionalities of evolvement. Also, the cavity space in the aggregation allows solar access for all units. The outcome of the aggregation represents not only the continuity of surface on aesthetic level, but also the connectivity of volumetric spaces on spatial level (Figure 18, 19).

5 FUTURE WORKS
The project focused on the daylighting directionality as an actuator of Diffusion Limited Aggregation. Future researches can include different environmental actuators such as thermal or acoustic data, additionally other generative algorithms including L-system, Cellular Automata, Flocking or Evolution can serve as a basic aggregation rule set as well. Furthermore, it is interesting to explore geometry different from truncated octahedron...
as a basic unit for the lattice structure and also the possibility of combining two or more geometric types.

Lastly, this project tried to aggregating basic geometric elements into complex forms. The reversed process, in which complex structure in Physics and Biology is broken down to simple elements, can also be potential area to research.

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Figure 14
System module skeleton model.

Figure 15
Cluster models with outer surface system.

Figure 16
Cluster models with inner lattice system.

Figure 17
Applications of aggregation in different parameters.

Figure 18
Renderings of the applications on sites.

Figure 19
1:30 scale physical model.
REFERENCES


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