10

ENVIRONMENTAL PARAMETRICS 2
A SYSTEMIZED AGGREGATION WITH GENERATIVE GROWTH MECHANISM IN SOLAR ENVIRONMENT

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).

Figure 1
Fully aggregated model in response to solar vector.
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 (Bohnacker 2012). The concept of systematic architecture has been widely used on structural concepts, module systems, and space organization. In 1950s, in Philadelphia, Louis Kahn and Anne Tyng proposed City Tower, a synthesized space system that uses tetrahedron structure modules as a basic rule set for the floor slabs and three-dimensional space at multiple scales for the entire building (Figure 5). This is a seminal example of earlier systematic architecture with a rule set.

Our system design also offers the possibility of diverse morphological transformations by connecting and modifying the geometry of the components in different ways. Early studies show diverse transformations and assembly possibilities using identical geometric components during the aggregation. For example, a tetrahedron aggregation study shows the assembly mechanism in a linear growth model (Figure 6) and the TetraGO project demonstrates the multi-directional growth and divergence mechanism in the module system of the elongated octahedron during the aggregation (Figures 7, 8). The former study worked with a single path growth based on a generative algorithm known as L-System. The latter project applied asymmetrical modules which result in
more diverse possibilities of assembly by using the Diffusion Limited Aggregation algorithm. Both studies represent the synergy between component systems and generative algorithms as an integrated rule set.

1.4 MINIMAL SURFACE AGGREGATION

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 Taichung 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 enacted 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 sun 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.

Figure 5
DLA simulation in solar vector environment.

Figure 6
Five Platonic solids are the tetrahedron, icosahedron, dodecahedron, octahedron, and cube. The 13 Archimedean solids are the truncated tetrahedron, truncated icosahedron, snub cube, snub dodecahedron, rhombicosidodecahedron, truncated icosidodecahedron, truncated cuboctahedron, icosidodecahedron, small rhombicuboctahedron, truncated cuboctahedron, cuboctahedron, truncated cube, and truncated octahedron. The cube and truncated octahedron are the only Platonic and Archimedean solids, respectively, that tile space.

Figure 7
Tetra octahedron density study to evaluate the total number of center point of 3m radius geometry in 15 X 15m cube.
2.3 MORPHOLOGY
The form of the truncated octahedrons 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 condition, 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 Geographic Information System (GIS). Specifically, the potential sites are office buildings in New York City that are under fifteen-story heights with leftover air right 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 circumstance 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 switchback 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 criterion. 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.

AKNOWLEDGEMENTS

The research was developed as part of the Master of Architecture Program at University of California, Berkeley. The large portions of research were conducted as part of digital design seminar and design studio under supervision of Assistant Professor Kyle Steinfeld at University of California, Berkeley. The project was awarded Sandy Hirshen Prize in 2014. All figures copyright of the authors and KL'IP.
Figure 17
Renderings of the applications on sites.

Figure 18
Applications of aggregation in different parameters.

Figure 19
1:30 scale physical model.
REFERENCES


DONGIL KIM

Dongil Kim is a Director of KL’IP architecture and research office. He is the recipient of the Jhon. K Branner Fellowship 2015 which allows him to develop his design theory “self-formation” through year-long research and travel funded by University of California, Berkeley. Dongil has won many international architecture and urban design competitions and his projects have been introduced in many publications. He is currently a graduate student in Master of Architecture at University of California, Berkeley where he received T.Y Lin Prize and Sandy Hirshen Prize. He has practiced at many international firms including Morphosis Architects in Los Angeles and REX Architecture P.C. in New York. Prior to his professional experience and studies in the US, he received undergraduate degree in architecture with distinction and first thesis prize from the Kyung Hee University in Korea.

SEOJOO LEE

Seojoo Lee is a Founding Director at San Francisco based architecture and research office KL’IP. Previously, her professional works include practicing at Pritzker architecture prize winning offices such as Richard Meier in New York and Morphosis Architects in Los Angeles. Seojoo won several international design competitions and her award winning design projects were published and exhibited in many cities. Seojoo is currently pursuing a Master of Architecture at University of California, Berkeley where she is a recipient of a Merit-Based Full-Tuition Scholarship and a Design Workshop Prize in Practical Construction in 2014. She was invited to join at the Institute of Computational Design at the University of Stuttgart as a visiting scholar. She graduated with a Bachelor degree in Architecture from Kyung Hee University in 2008.