Integrating Building Technology and Computation into Urban Design: A Contextual Approach

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Keywords: Data Analysis, Parametric Urban Aggregations, Optimization

ABSTRACT

In today's rapidly evolving world, cities experience continuous growth and transformation. Amid this progress, certain areas within cities often remain underdeveloped in comparison to others, leading to disparities and inequities. This project attempts to resolve these issues by using advanced technology and computation methods such as data mining and parametric design.

The proposed methodology aims to create context responsive urban aggregations by mapping open-source data such as population, public infrastructure and also subjective data (emotional data). This was done by referencing commonly used keywords on social media of individual expression related to a specific location. This ensures a holistic approach tailored to varying needs of different urban areas, thereby avoiding homogenized urban design.

The following project discusses a detailed insight into each step of the proposed methodology, using Chicago as a case example. The process initiates with a comprehensive data analysis and mapping of the chosen urban area, follows through a parametric design development and optimization stage.

PROJECT PROCESS- STEP 1: DATA ANALYSIS

The process begins by developing a better understanding of the chosen urban context. This is done by collating tangible contextual data such as demographics, traffic statistics, public amenities like farmer market, sport facilities, art installations, etc. The project takes Chicago, Illinois, USA as a case study. The city is considered for its varied density of urban fabric which is mix of the suburban, urban downtown typology with various stratas of socio-cultural and economical distribution. It therefore will suggest the accountability of the process as it will give a wide range of outcomes because of its diverse datasets. The above mentioned tangible datasets were accessed on Chicago Data Portal.[1] Similar open source big data can be used for computational analysis to identify emerging trends with respect to public infrastructure distribution.

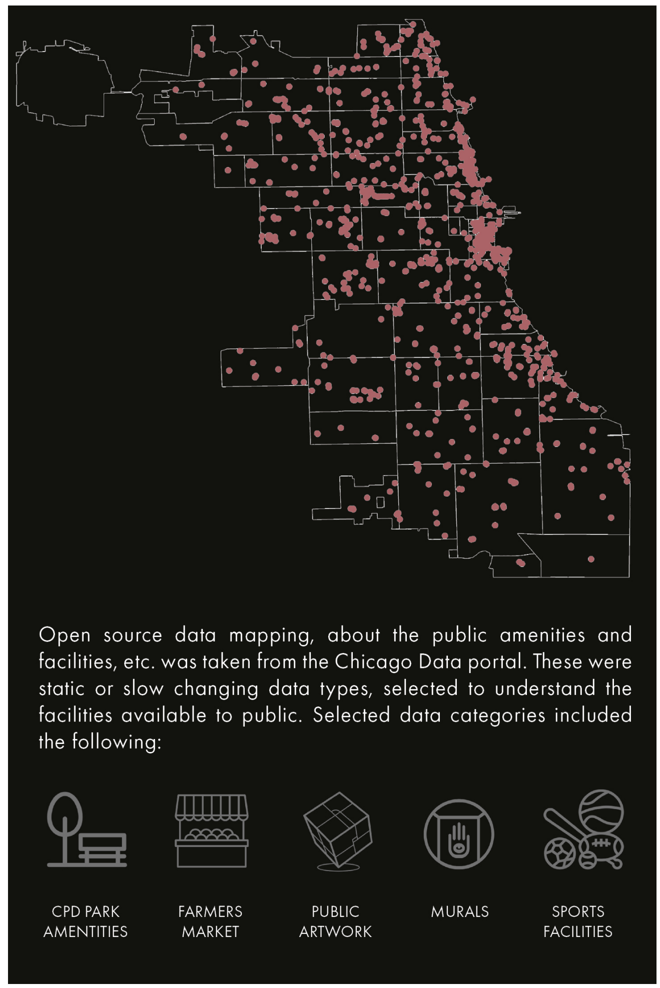

Figure 1. *Data Mapping* . Image credit: Anushree Parkhi, Urvi Varma

In the next step the identified trends are mapped geographically. Figure 1 shows the dataset mapping for Chicago (case example). This mapping is further quantified by assigning a geometric unit such as a rectangle as shown in Figure 2 (Top). The size of the rectangle is determined by the infrastructure distribution in different zones. Subsequently, the tangible dataset is layered by intangible aspects such as happiness index, livability, safety and shared experiences for different zones by zip code. Safety can be measured as the 'Crime Index' of a given space. Living comfort can be measured by the 'Livability Index', etc.[2] The numeric indexes are then inputted into the generated geometry as a third dimension. The generated rectangles are extruded based on this data to form a 3D geometry. Here the height represents the human experiences, higher the extrusion higher is the level of safety and community satisfaction. Finally, the areas requiring urban intervention are identified by colour variations. The rectangles obtained by the data mapping are then rearranged as shown in Figure 2 (Bottom) to allow dissociation with any existing human inhibitions pertaining to geographical locations and analyze the obtained data neutrally. The final geometry gives a set of visual data information which will be used as an input for computation of the built form. Figure 3 shows the deconstructed

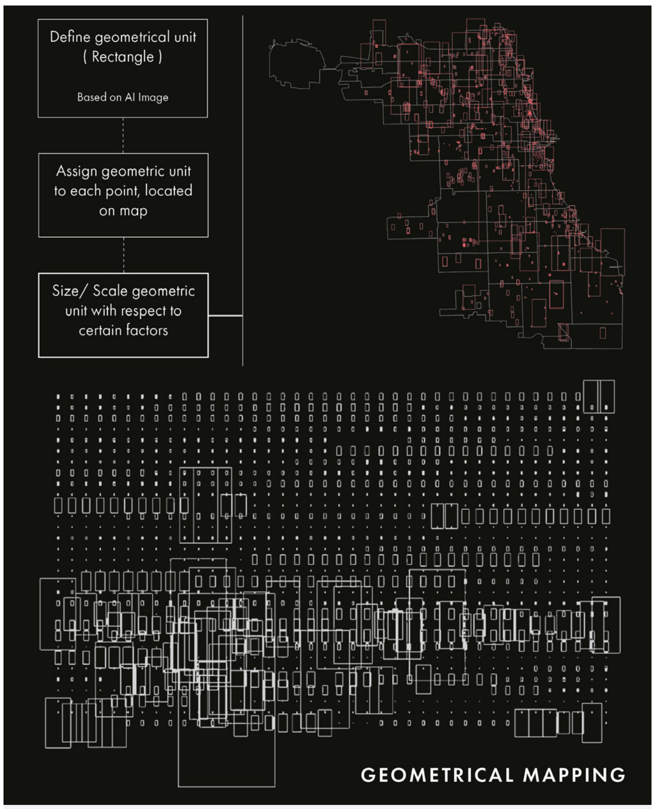

Figure 2 (Top) *Geometric Mapping* (Bottom) *Deconstructing Physical Map.* Image credit: Anushree Parkhi, Urvi Varma

graphical data mapping of Chicago.

PROJECT PROCESS- STEP 2: MODULE DEVELOPMENT AND AGGREGATION FORMATION

The next stage involves the design of modules which can then be multiplied, replicated and modified to create context-specific aggregations. Three basic architectural elements, a line, volume and plane are used to create varying spatial enclosures. Different arrangements of the line in the form of a column beam; and the plane in the form of a slab help generate different volumes as shown in Figure 4 (Top). Some of these would be open, some semi-open and some entirely closed. The varying degrees of openness can be used for varying functions within the space. Open modules can be used as spaces for open markets, play areas, etc. While enclosed modules would allow for functions such as co.-working spaces, art galleries, etc,. as depicted in

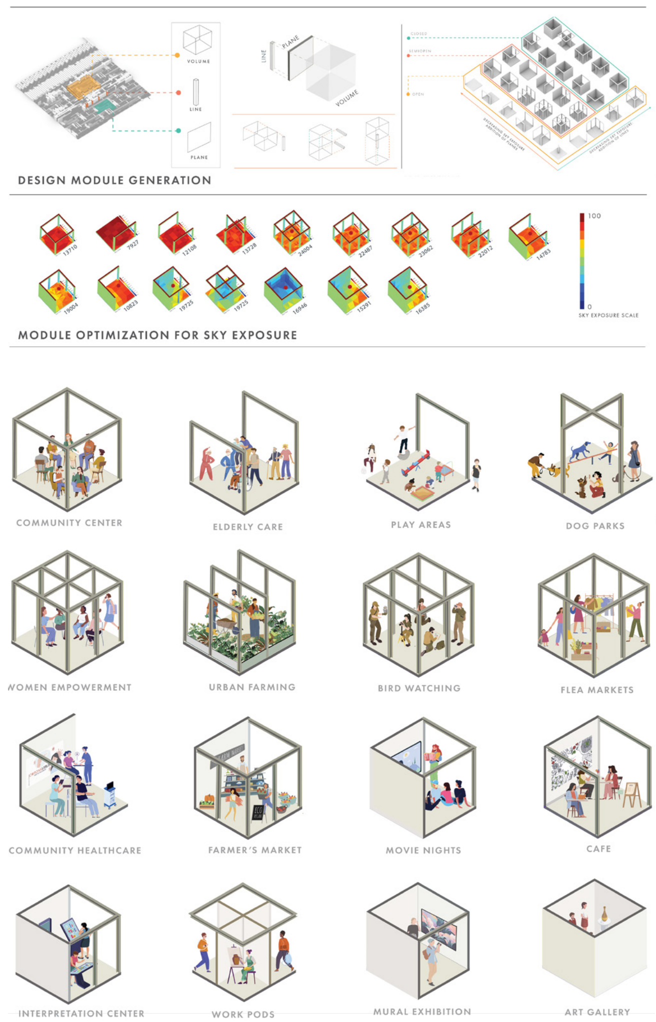

Figure 4. (Top) *Module Design*, (Middle) *Module Selection*, (Bottom) *Variable Functions* Image credit: Anushree Parkhi, Urvi Varma

Figure 4 (Bottom) The function to the modules are assigned based on the identified needs from the data collected in step 1. From the generated options a few are selected based on their relative openness and sky exposure, as indicated in Figure 4 (middle). The selected modules can be combined to form varying aggregations using parametric computation. The number of modules and type of modules in each aggregation are based on the parameters obtained from the visual data mapping. Figure 5. shows the procedure to compute an aggregation and indicates

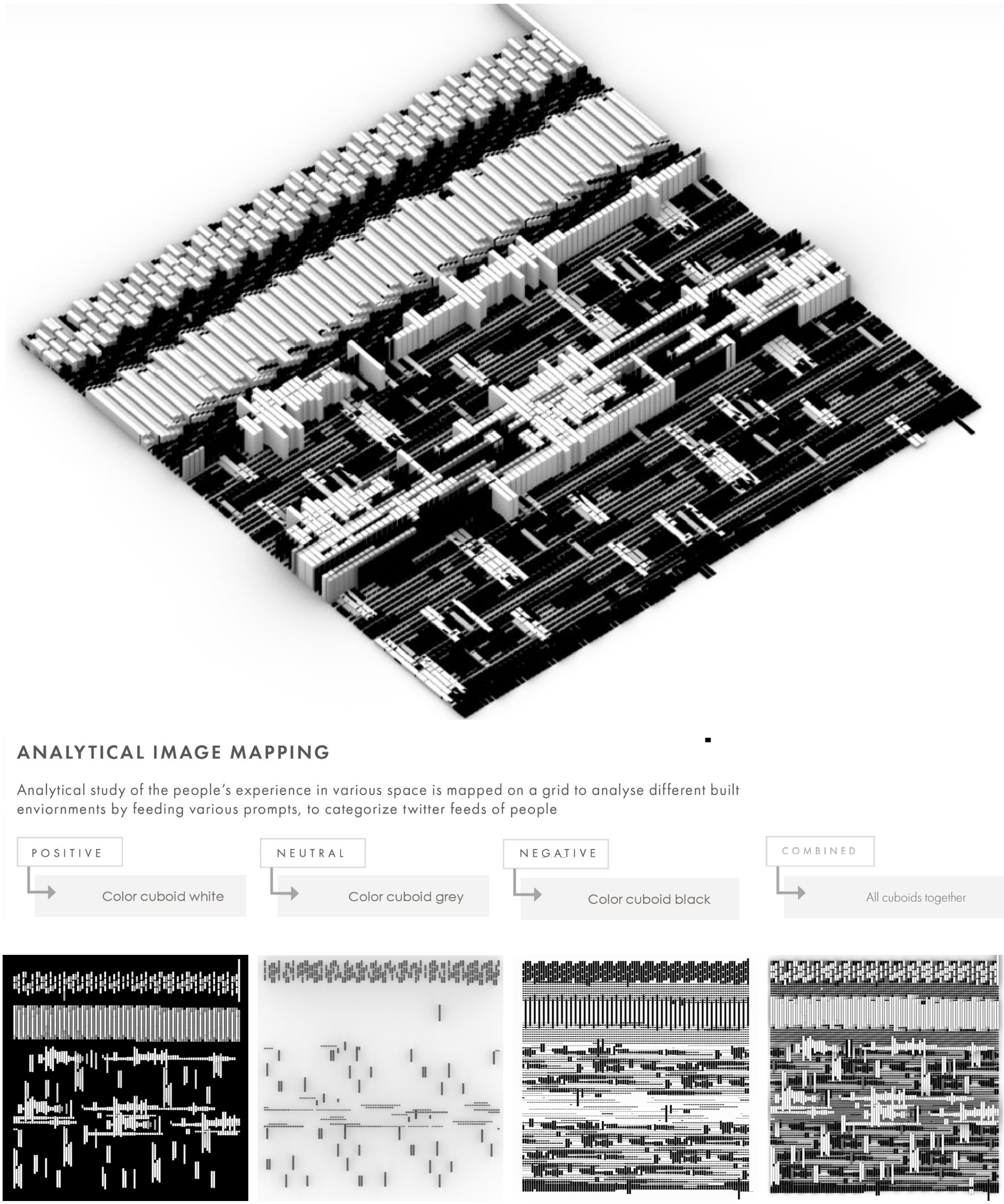

Figure 3.(Top) *3d Visual Data Analysis*, (Bottom) *Separated 2d Layers of Visual Data Analysis*. Image credit: Anushree Parkhi, Urvi Varma

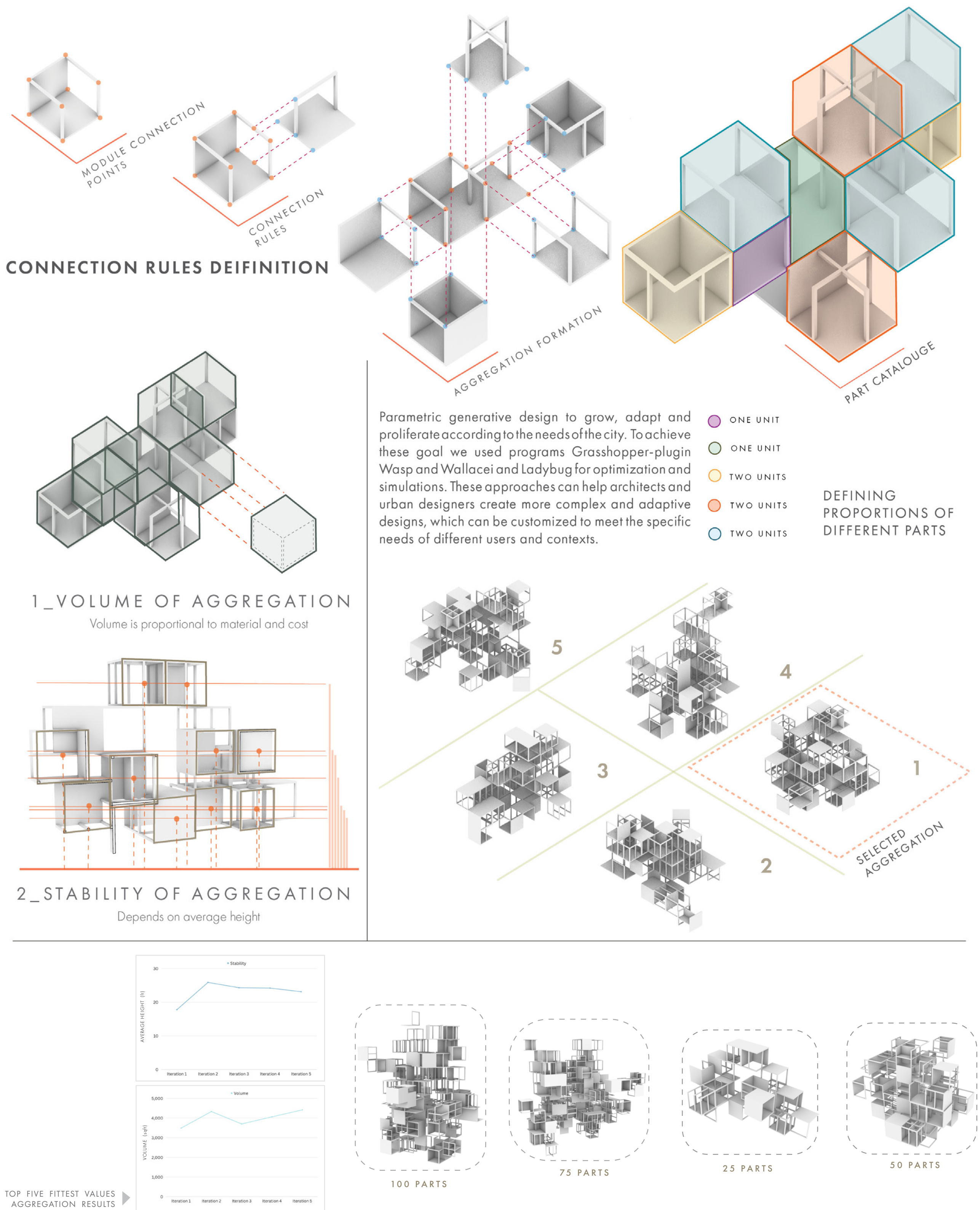

Figure 5 (Top) *Rules for Connection,* (Middle Left) *Aggregation Optimization* (Middle Right) *Top 5 Optimized Aggregations* (Bottom Left) *Optimization Result Graphs* (Bottom Right) *Aggregation with Varying Numbers of Modules* Image caption: Anushree Parkhi, Urvi Varma

various possibilities generated using Grasshopper with plug-in Wasp.[3]

Combination of modules are determined by different connection criteria as shown in Figure 5 (Top). For example, two adjacent modules can connected along their vertical/horizontal edges or their corners. The number of modules within each aggregation are determined by the infrastructure distribution data derived in the first step. As shown in Figure 5 (Bottom Right) the number of modules within each aggregation can be varied to form modules of 25 parts, 50 parts, 100 parts and so on. Moreover, parameters that define the number of modules of a certain type (open, close, etc.) In the given aggregation are derived from the requirement generated for the specific location.

PROJECT PROCESS- STEP 3: AGGREGATION SELECTION AND OPTIMIZATION

From the infinite aggregation variations generated in the previous step, one aggregation is chosen by optimization. Criteria for the optimization are defined by the designer. In the considered case study, structural and cost efficiency were the focus areas as shown in Figure 5 (Middle Left). Wallacei for Grasshopper was used to optimize the aggregations for stability index and material volume.[4] Top five fittest solutions are plotted on the graph in Figure 5 (Bottom Right).

PROJECT PROCESS- STEP 4: SITE SELECTION AND AGGREGATION ORIENTATION

Once a final aggregation has been selected, the next step involves refining its design further depending on the site. First, the site is identified using the data driven study as shown in Figure 6 (Left). The example project identified the area around the Aurburn Park in Chicago demonstrating the need for further infrastructural development. The placement of the selected aggregation is determined by optimization studies for site specific constraints such as. orientation, solar gain, etc using Ladybug plug-in for Grasshopper as shown is Figure 6 (Right).[5] Further the aggregation can be refined to develop program specific spaces and adding details. This step is important as it also helps to recognise an architect and urban designers' human centric sensitivity in design preventing the entire process to be directed by a machine as shown in Figure 7 and 8.

Figure 6. (Left) *Site Selection* (Right) *Aggregation Orientation* Image credit:Anushree Parkhi, Urvi Varma

PROJECT OUTCOMES

Figure 7. *Axonometric View of Aggregation as Urban Intervention* Image credit:Anushree Parkhi, Urvi Varma

Figure 8. *Series of Different Spaces of Community Engagement* Image credit:Anushree Parkhi, Urvi Varma

PROJECT

The project gives an overview of how the power of technology and data can be harnessed to create context responsive and need specific urban interventions. It highlights reliability on data based approaches for accountable design by integrating simulation models to validate obtained results. Various Grasshopper based plug-ins like Ladybug, Honeybee and Wasp helped in simulating human comfort conditions for the obtained aggregation. The results established that computationally generated design models can be responsive to human comfort. Although the process is driven by data and computation it takes into account designers instincts and creative sensitivity. The described methodology would help to achieve an equitable allocation of the urban spaces in the cities. The project proposes an utopian vision where context specific aggregations proliferate across the city to bring balanced growth in the urban realm. Each aggregation is a representative image of the community and motivate communities to work towards upliftment of the neighborhood. Figure 9 shows the proliferation of varying aggregation throughout the city of Chicago. In this manner the proposed methodology integrated technology and computation to develop human centric urban design.

ENDNOTES

1. "City of Chicago: Data Portal: City of Chicago: Data Portal." Chicago. Accessed October 10, 2023. https://data.cityofchicago.org/.
2. "Navigation." CMAP. Accessed October 10, 2023. https://www.cmap.illinois.gov/data/data-hub.
3. "Wasp." Food4Rhino, July 29, 2023. https://www.food4rhinocom/en/app/wasp
4. . https://"Wallacei." Food4Rhino, May 17, 2022. https://www.food4rhino.com/en/app/wallacei.
5. . "Ladybug Tools." Ladybug Tools | Home Page. Accessed October 10, 2023. https://www.ladybug.tools/.

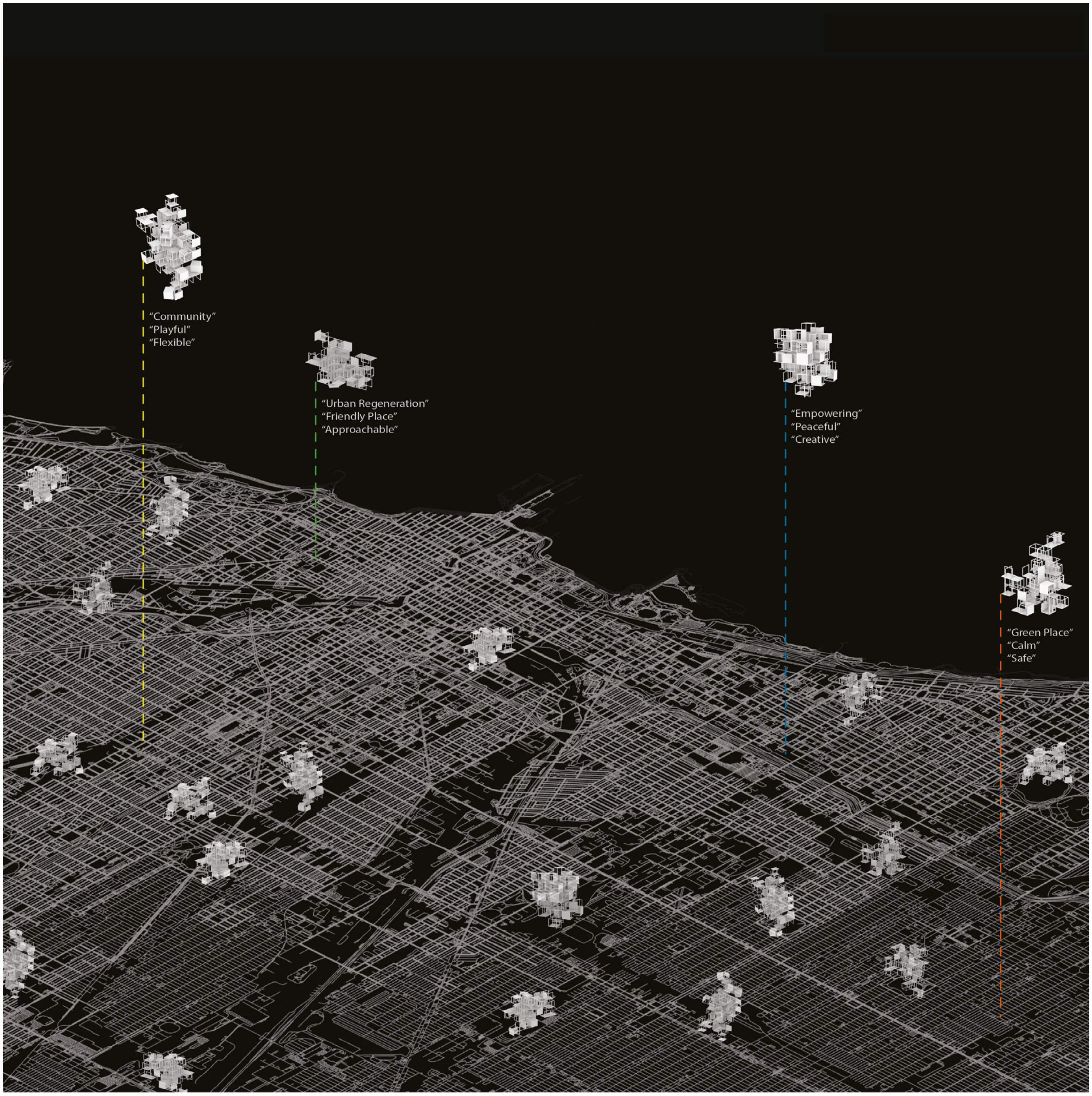

Figure 9 *Urban Proliferation*. Image credit:Anushree Parkhi, Urvi Varma

PROJECT