Generative Landscape Modeling in Urban Open Space Design: An Experimental Approach

S. Elif Serdar[1], Meltem Erdem Kaya[1]

[1]Istanbul Technical University, Istanbul/Turkey · s.elif.serdar@gmail.com

Abstract: This paper aims to explore the algorithmic design thinking for the landscape through a generative modeling approach to urban open space. Focusing on dynamic interactions between spatial dispersion of hard-soft surfaces, shadow elements like tree locations and their impacts such as micro-climatic condition changes with human behaviors, were the primary inputs of the process. Using a case study from Turkey/Istanbul-Kadıköy, the reciprocal relations between social (*human movement),* physical (*hard-soft structures*) and ecological (*surface radiation and microclimate analysis*) parameters were studied, and how these relations formed the design was shown. The modeling process was defined in 4 algorithmically associated stages: firstly, field observations were conducted to collect data on vegetation and user behaviors, for site digitalization. After that, algorithmic parameters were defined in the second phase; and design constraints, as the first initiator of the interactive process, were identified. At the last stage, by the evaluation of all parameters with constraints, final design set-up was originated via a Quadtree algorithm. During these phases, user simulation data, surface radiation and outdoor microclimate analysis findings were shown for comparison. Therefore, this study underlines the importance of the data for landscape design, and its process, rather than the final design solution.

Keywords: Generative landscape design, simulation, algorithmic landscape design

1 Introduction

Design paradigms recently have an agenda that is based on ecological and environmental concerns. The dynamic, operational and even physical aspects of this situation have brought the landscape to the center of design generation, including architecture and urbanism practices (REED 2018). Especially the dramatic increase of the population in urban areas and its reflections on structural density has been highlighting the urban heat ısland effect and mitigation strategies. This subject can be considered in all scales from a building to the urban whole with the incorporation of landscape design. Such that the emergence of landscape as a new instrument for today's cities can be seen as a medium to understand urbanization and urban life through the landscape (CORNER 1999, WALDHEIM 2016).

Also, new openings have led investigations of the social examination of human interaction and their impact on the environment. However, rapidly increasing environmental awareness and the changing relationships between man and nature have been reflected in design patterns and directed to produce more efficient processes. This situation forced the designers to look for new methods (KALAY 1987). Simultaneously with these innovative ideas, developing technologies and digital production methods have been started to emerge as new ways that meet the designers' expanded perceptions. In order to make the design computable, new methods arose to parametrize the design via CAD programs. These systems have attractive effects in terms of defining parametric design over constraints because many design alternatives can be generated with several modifications (JABI 2013). Therewithal, one-step further, algorithmic coding and iterative process-based design methods make it possible to generate more complex design variations from a set of design rules and parameters (PETRAS,

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MITASOVA, PETRASOVA & HARMON 2016, SANJUÁN & RAMIREZ 2016). The algorithms are designed to produce these alternatives within the framework of design rules (*constraints*) and to achieve the optimal scenario – called generative systems.

From this point of view, this study focuses on how urban open space can be designed by algorithmic thinking considering ecological and social behaviors. It aimed to produce an experimental model on the parameterization of landscape design by putting on user behaviors and microclimatic conditions into its center. Despite the fact that urban open spaces were shaped by anthropogenic effects, they have reciprocal relations between urban social life because of their physical and ecological values. As mentioned by GEHL (2011), user activities in urban open spaces are shaped by the conditions of the physical environment. Such that, users can choose to spend time in or decide to pass through the area based on climate comfort values and spatial design (GEHL 2011). The studies which were focused on urban pedestrian usage indicate that optimum temperature which is a part of the climatic condition value is seen as a component affecting the behaviors and outdoor activity types of the users(CHEN & NG 2012, YIN et al. 2012). In this context, the project aimed to parametrically identify, the complex structure of the interrelated design matters of the urban landscape and obtained as a model that produces spatial relations.

2 Study Area

Moda square located in Kadıköy was chosen as the site for the modeling process. Kadıköy, as one of the largest districts of İstanbul, on the Anatolian site, between 41° East Latitude and 29° Longitude (KADIKÖY BELEDIYESI 2019). Moda takes attention from its dense urbanized structure with its vibrant and vivid neighborhood culture. In this respect, the "Moda Square" offers the appropriate environmental and social significance for the model generation. It can be observed that people use this place like a park rather than a square. The presence of vegetative elements in the area give people more reasons to spend time here, but the spatial configuration can be discussed. Considering that the average sun exposure value of Istanbul in the summer is approximately 11 days/hour, and the average radiation value is 6.6 Kwh/m²-day with the average temperature values reaches 28 degrees, it was observed that the use of open space is related to the microclimatic structure of the area (ENERJI ENSTITÜSÜ 2011, METEOROLOJI GENEL MÜDÜRLÜĞÜ 1988-2017).

3 Modeling Process

In the modeling process, the new open space design was created with associative steps: data gathering, algorithmic examination of their relations optimization and utilizing vectors that shape the surface pattern to design. These steps underline the parameters and conditional relations that guide the operations rather than discussing the rigid presence of the design itself. The workflow of this modeling approach was identified in four main phases that are shown in figure 1.

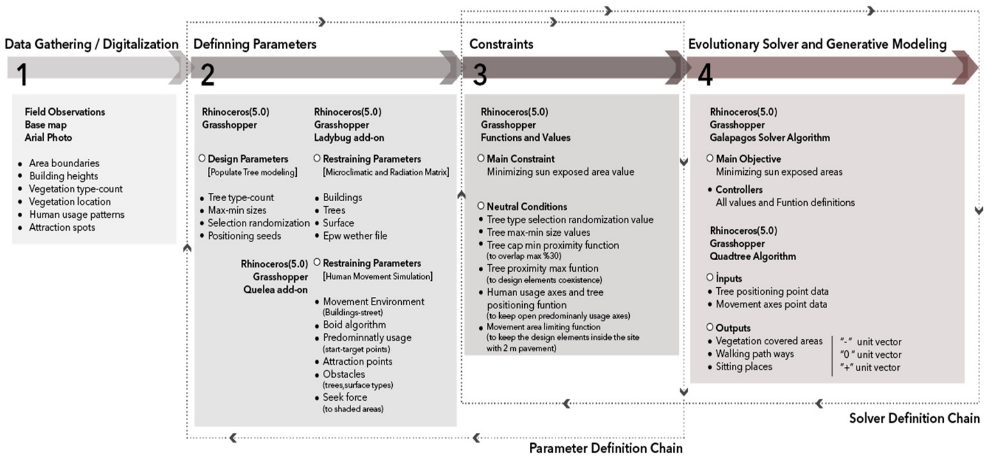

Fig. 1: The workflow of the modeling process mainly follows a linear flow, but also includes cyclical interactions between steps

3.1 Data Gathering and Digitalization of the Site

In the first phase, the field observations were conducted to collect data for digitalization and modeling process. This data was combined with a 1\1000 master plan of the Kadıköy Municipality and an aerial photograph of the site to draw the most precise boundaries via Rhinoceros (5.0). Also, to spatialize these data as roads and surrounding buildings of the area were modeled in an algorithmic way in grasshopper associated with Rhino. Additionally, vegetation and user behaviors of the area were scrutinized. In this manner vegetation types, counts, sizes and positioning data, with attraction spots and predominantly used behavior patterns were investigated.

3.2 Parametrization of Model

In this paper, the design layout followed these steps: defining object-oriented modeling parameters, specification of their constraints and producing the generative design. These constraints determined how to construct or modify these objects, which were created from the points. Besides, the algorithmic point-based elements were shaped by design parameters, and modified by the restraining parameters, via rhinoceros (5.0) and the grasshopper plugin. The expected outcome here was to investigate how to adapt the algorithmic system to landscape design in an urban context. Thereby, it was aimed to measure how the physical, social and ecological outputs of this model affect each other, and to use them as vectors that shape the surface in the appropriate scenario. For this reason, two different parameter groups which constraints rely on were created and altered as results. These can be called *design parameters* and *restraining parameters*. This reciprocal inputs and outputs of the modeling process are shown in figure 2.

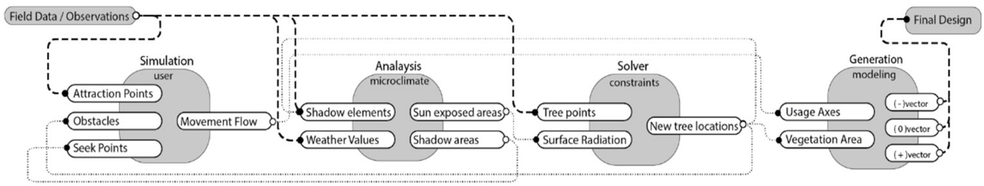

Fig. 2: Inputs and Outputs relations of modeling process via grasshopper definitions

3.2.1 Design Parameters

One of the main components of the site vegetation, trees were algorithmically defined as design parameters in the modeling process. Obtained from observations, the existing plant species, numbers and approximate locations in the area were identified, listed and drawn digitally. Two types of tree species (Melia azedarach, Ligustrum japonica excelsum) was chosen, which are mainly located in the area and respond to ecological and social functions (bordering, shadowing). Then, the selection randomization values of tree types, counts, and max-min sizes were connected with numerical data to define relations. Also, the criteria for positioning of trees were described with more holistic assessments and constraints.

3.2.2 Restraining Parameters

In order to make seen, and control, the spatial interactions of the design inputs, constraints were connected to the social and ecological values. We aimed to get the social data from human movement simulation, and the ecological data from microclimatic analyses. The modeling intended to explore how design solutions affect open space usage behaviors. Therefore, the human simulation was created with Quelea, which provides an intuitive interface for agent-based design as one of the add-ons of grasshopper (FISHER 2015, HELBING & MOLNAR 1995). Birth points of the simulation units (*queleas*) with their target points were selected to create predominantly usage axes, and attraction points were identified to represent cafes and some other places of interests. Also, a mimic of the behavior of the queleas as people in the open spaces, such as walking around, was provided with *wonder force*, and making shaded areas more preferred as walking axes was defined with *seek force*. In addition to these point data and additional forces, the simulation was created based on swarm behavior rules from the Boids algorithm with *separation, alignment* and *cohesion forces* (REYNOLDS 1986).

Additionally, to analyze the climatic factors such as surface solar radiation and urban microclimate matrix which are important factors that affect human movement in the field especially in the summertime were defined via Ladybug, one of the add-ons of Grasshopper. By the instrumentality of this plugin and its' collection of software for environmental design usage, EnergyPlus Weather file of Istanbul was included in the algorithm (ROUDSARI & MACKEY 2013). These measure data about rainfall, wind, humidity, temperature values, obtained between 2003 and 2017. The urban microclimate analysis was run to provide a surface mapping of conformity assessment. The boundaries of high sun-exposed areas were specified as unsuitable. Moreover, the solar radiation matrix was conducted to be able to make the outputs as constraints. As a result of this analysis, the design surface was transformed into the 1x1m matrix. This matrix was included in the fitness function for the optimization of the shaded-sun exposure regions in the range of 18-21 °C, which are suitable outdoor temperatures (CHEN & NG 2012). These mentioned simulations were run at four times: first, while space was empty, second at the existing situation, third when the configuration created by the evolutionary solver, and then the design surface was generated.

3.3 Constraints

Constraint-based systems consist of design models that are formed by the interactional structure of variables such as parametric systems. The main difference here is that parametric systems' relational solutions need to be determined as a procedural string by the designer. However, constraint-based systems do not need a causal order; they can define problem, expression and solution by itself (SAPOSSNEK 1991). In this study, the parameters were defined to create the design that controlled with the rules in a constraint-based system. Constraints determined the rules of how design and restraining parameters interact. For modeling decision, the main constraint was to minimize the sun-exposed areas of the surface. Other constraints were about the implementation of fundamental design decisions such as; type selection values, counts, sizes, and maximum proximity distances of tree units. Besides these, other constraints which allow the design elements to move only within the site boundary and define the predominantly open usage axes were determined too. The primary condition here was fastening to the fitness function outcome. On the purpose of obtaining the values assigned by other constraints, the alternatives of design parameters were being tested while the solver was running.

3.4 Generative Modelling and Evolutionary Solver

The generative principle represents the creation of the most appropriate solution from the 3D spatial alternative configurations, by using numbers instead of lines as inputs (STAVRIC & MARINA 2011). In other words, for the derivation of alternatives, it is necessary to have specific parameters and rules which are interrelated. Therefore, it describes a complex problem-solving process that complies with design practices too. This method can be used for multi-faceted problems that need to be considered as a whole in many disciplines of design including landscape. It is noteworthy that it has recently been used effectively in the design of urban landscapes. The renovation of Eda U. Gerstacker grove of Michigan University is exemplary for generative design usage in landscape design practice. In this project the topographic structure of the design area was hybridized with the sitting function, which is part of the social life, working together with the surface flows and drainage system. Surface run-off and sun exposure areas were controlled by generative modeling techniques, while social and environmental relations were constructed (REED 2018). In this study, the context of the generative system was to achieve a surface design that minimizes the radiation and unifies the social relations of the field. For this purpose, at first parametrically identified constraints were processed as the next step, then these parameters were evaluated by the fitness function of Grasshopper, *Galapagos*. As a result of the solver, final configuration of tree units with their shaded areas and movement pattern data from simulations were included in the last stage as vectors to form the surface. Subsequently, the topological relations of all these point data were transferred with the spatial data structures with a matrix on the surface via the Quadtree, which is called the 4-tree technique. In this way, depending on the density of point data, a hierarchical surface fragmentation was provided by dividing the surface into sub-grids (SAMET 1995). Then, finally, these diversified grids were classified hierarchically according to the surface usage functions. It started from the most intensive usage (predominant axes) towards sitting areas and vegetative surfaces where the movement was gradually decreased. Therefore, the surface strategy of the smallest unit was created like a continuous line with 0 z-vector, while the sitting units were created as elevated blocks inside the shaded area boundaries with 0.5 z-vector force.

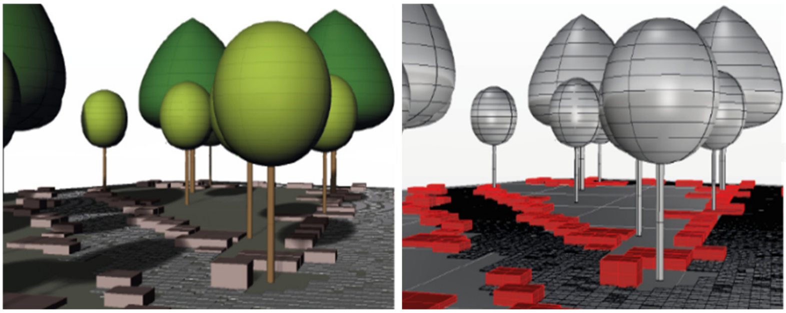

Fig. 3: The generated design surface has different features like sitting walls, vegetation patches, and walking pathways

4 Results

After the evolutionary solver and generative surface modeling processes, the environmental conditions were examined. It was seen that both the surface radiation and the micro-climatic temperature values decreased. In the current case, the region with the highest radiation value is still covered with a hard surface; however, this algorithmic model was run to configure the tree orientation according to the sun for minimizing the exposure. Also, the space alternatives were screened in terms of human movement simulation for 30 seconds at four different times. The interest of attraction points was maximum when the area was empty; though, the current spatial situation caused limited interaction by dividing into two regions. Despite this, the generated new open space structure intensified human usage, while strengthening the relationship with the environment. These inferences in the process chart were shown as the surface radiation, climatic comfort matrix, and user behavior patterns of the area were compared with four different situations: while space was empty (1); the current situation (2); the configuration created by evolutionary solver (3) and with this final composition site's morphology created by a generative algorithm (Figure 4).

As a result, these could be obtained: tree positioning was generally reasonable, and spatial effects of the area were enriched. However, scale randomization could be considered with locations because they were uninformed, and some of them stayed too close to the edges defined as pavement. Because of the boundary shape of the area, surface units could not be regulated as the most accurate way; besides this, considering the positioning, surface segmentation generally was consistent.

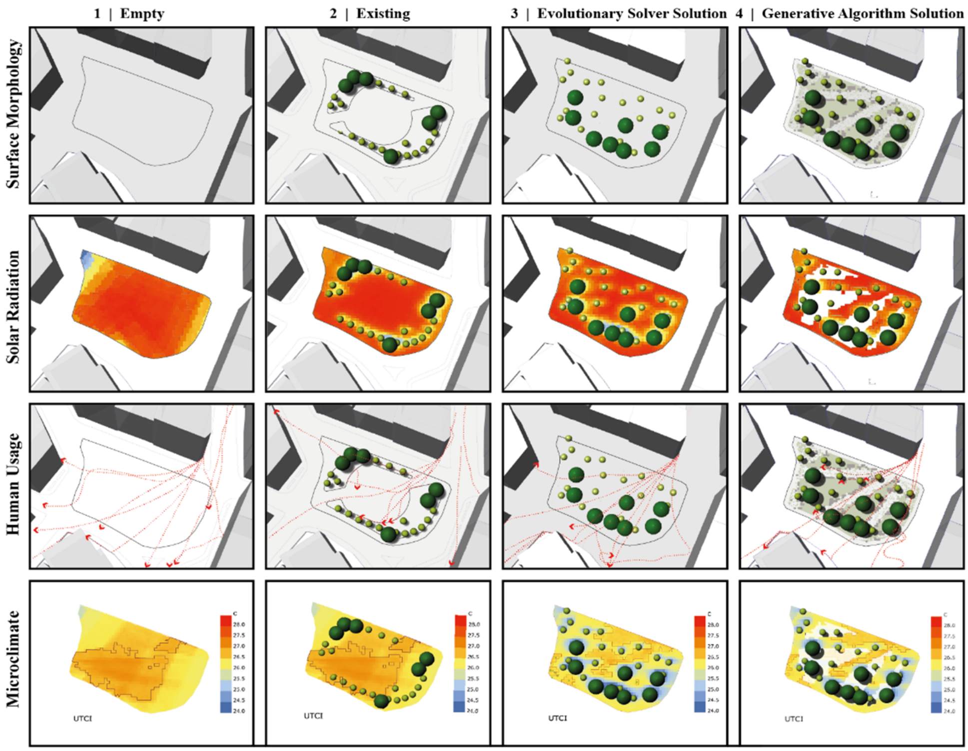

Fig. 4: The process chart shows the analysis, and simulations results at four (4) different design solution

5 Conclusion and Discussion

This model was created corresponding to the constraint-based design; however, it was aimed to be a generative model with a series of parameters that were integrated to obtain a design result. In this way, a digital model has been created to generate design alternatives. The design and restraining parameters that were included in the modeling process were specified as tree characteristics; human motion patterns and sun exposure surfaces with heat-oriented climate comfort matrix. Although these parameters can describe the conditions that provide the appropriate environment for the creation of landscape design, the model can be developed by defining more and detailed parameters. This model was intended to be produced in a single and integrative definition so that the ways inputs and outputs affect each other can be seen instantly. To this respect, while this study proposed a design outcome, it tested the effects of landscape elements on the spatial structure in an urban context by the instrumentality of the algorithmic design process. Also, for future works, the following are outstanding: 1) The tree features, which were used as the design parameters, can be introduced into the model in a way that carries all the characteristics of the field. 2) A model can be developed with more detailed and variated microclimatic analysis outputs. 3) New definitions can be developed through ecological cycles by evaluating the material properties of the design surface. 4) In order to make the simulation more consistent, input data which were collected from the location-based observations can be used as more statistical and recorded data.

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