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

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How can we improve the ecological values and social integration of existing urban open spaces by re-designing?

What would be the new digital methodologies to indicate this re-designing process, and how to integrate to landscape design?
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. ...
This paper aims to explore the algorithmic design thinking for the landscape by generative modeling approach in urban open space. Focusing on dynamic and reciprocal interactions between social (human movement), physical (hard-soft structures) and ecological (surface radiation and microclimate analysis) parameters.
In order to make the design computable, new methods arose out 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, Mitasova, Petrasova, & Harmon, 2016; Sanjuan & 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.
The Study Area

Istanbul / Kadıköy

Moda Square

sun exposure value // 11 days/hour
average radiation value // 6.6 Kwh/m²-day
average temperature values reaches // 28 degrees
The Study Area

Istanbul / Kadıköy

Moda Square
1. Data Gathering

Data

Area Boundaries
Buildings heights
Vegetation types-count
Vegetation location
Human usage patterns
Attraction Points
Epw Weatherfile

External Data
Field Observation
Map Restoration
Base map
Aerial Photo
1. Digitalization

Rhinoceros 3D - Grasshopper
Base model

Rhinoceros view

Grasshopper view

BUILDINGS MODELLING

Surface Modelling

1. STEP

3D BUILDING AREA PLANE

// OUTPUTS //
2. Defining Parameters

Rhinoceros 3D - Grasshopper

**Design Parameters //**
- Tree modelling
  - Tree types- Counts
  - Max-min sizes
  - Selection
  - randomization
  - Positioning

**Restrainting Parameters //**
- Microclimatic analysis
  - Solar Radiation
  - Buildings
  - Trees
  - Surface
  - Epw weatherfile
- Ladybug Add-on

**User simulation**
- Base model
- Build algorithm
- Predominantly usage axes
- Attraction Points (start-end points)
- Obstacles (trees,surface types)
- Seek force (to shaded areas)
- Quela Add-on
2 _ Defining Parameters

Rhinoceros 3D - Grasshopper

Design Parameters //

Tree modelling

Tree types- Counts
Max-min sizes
Selection
randomization
Positioning

Tree types
Melia azedarach
Ligustrum japonica excelsum

Total tree count
Existing: 25
Projected: min 15 – max 30

Selection randomization

Positioning - Point data
Defining Parameters
Rhinoceros 3D - Grasshopper

Design Parameters //

Tree modelling
- Tree types - Counts
- Max-min sizes
- Selection
- Randomization
- Positioning

Max-Min Size
2 _ Defining Parameters

Rhinoceros 3D - Grasshopper

Restraining Parameters //

Microclimatic analysis

- Buildings
- Trees
- Surface
- Epw weatherfile

Sun exposure
Wind Effect
Aspect etc.
2. Defining Parameters

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Restraining Parameters //

Solar Radiation

- Buildings
- Trees
- Surface
- Epw weatherfile

Solar radiation matrix
2 _ Defining Parameters

Rhinoceros 3D - Grasshopper

Restraining Parameters //

Solar Radiation

Buildings ○
Trees ○
Surface ○
Epw weatherfile ○

https://www.energyplus.net/weather-download/europe_wmo_region_6/TUR//TUR_Istanbul.170600_IWEC/all

Between 2003 – 2017 weather data

Analyse periods //

From mid June to mid September
At high noon (11 am – 4 pm)
Defining Parameters

Rhinoceros 3D - Grasshopper

Restraining Parameters //

- User simulation
- Base model
- Build algorithm
- Predominantly usage axes
- Attraction Points (start-end points)
- Obstacles (trees, surface types)
- Seek force (to shaded areas)

Human usage pattern
Simulation was run
By using Quela Add-on
Defining Parameters

Rhinoceros 3D - Grasshopper

Restraining Parameters

User simulation
- Base model
- Build algorithm
- Predominantly usage axes
- Attraction Points (start-end points)
- Obstacles (trees, surface types)
- Seek force (to shaded areas)

To mimic the behavior of the quelaas 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.
Rhinoceros 3D - Grasshopper

Defining Parameters

Restraining Parameters

- User simulation
- Base model
- Build algorithm
- Predominantly usage axes
- Attraction Points (start-end points)
- Obstacles (trees, surface types)
- Seek force (to shaded areas)

Recording the point data and converting to line data as walking pathways.
3 Constraints

Rhinoceros 3D - Grasshopper

Functions and Values //

Neutral Conditions // Tree Relations
- Tree type selection randomization value
- Tree max-min size values
- Tree cap min proximity function (to overlap max %30)
- Tree proximity max function (to design elements coexistence)

Neutral Conditions // Spatial relations
- Human usage axes and tree positioning function (to keep open predominantly usage axes)
- Movement area limiting function (to keep the design elements inside the site with 2 m pavement)

Main Condition
- Minimizing sun exposed area value
3. Constraints

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Functions and Values //

Neutral Conditions // Tree Relations

Tree type selection randomization value
Tree max-min size values
Tree cap min proximity function (to overlap max %30)
Tree proximity max function (to design elements coexistence)

These values defined with tree modeling stage.
3 Constraints

Rhinoceros 3D - Grasshopper

Functions and Values //

Neutral Conditions // Tree Relations
Tree type selection randomization value
Tree max-min size values
Tree cap min proximity function
(to overlap max %30)
Tree proximity max function
(to design elements coexistence)

Min proximity – caps overlap max %30
Max proximity – area boundary
3 _ Constraints

Rhinoceros 3D - Grasshopper

Functions and Values //

Neutral Conditions // Spatial relations
Human usage axes and tree positioning function (to keep open predominantly usage axes)
Movement area limiting function (to keep the design elements inside the site with 2 m pavement)
Inside area that close to maximum 2 m to reach the area boundary.

With 3 main predominantly usage axes, emerge acceptance, tree positionings was restricted to keep open usage pattern.
By using **Galapagos Grasshopper Evolutionary Solver**, and constraint functions that defined.

- **Evolutionary Solver and Generative Modelling**
  - *Rhinoceros 3D - Grasshopper*

**Constraint Function**

**Controllers**
- Tree positioning point data

**Main Objective**
- Provide tree constraints

**Galapagos Solver Algorithm**

**Controllers**
- All values and function definitions

**Main Objective**
- Minimizing sun exposed areas

**Quadtree Algorithm**

**Inputs**
- Tree positioning point data
- Movement axes point data

**Outputs**
- Vegetation covered areas
- "-" unit vector
- "0" unit vector
- "+" unit vector
- Walking path ways
- Sitting places

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Optimizations
Evolutionary Solver and Generative Modelling

Rhinoceros 3D - Grasshopper

Constraint Function

Controllers
Tree positioning point data

Main Objective
Provide tree constraints

Optimizations
By using "move function" that defined via tree constraints.
Evolutionary Solver and Generative Modelling

Rhinoceros 3D - Grasshopper

Galapagos Solver Algorithm //

Controllers
All values and Function definitions

Main Objective
Minimizing sun exposed areas
4  Evolutionary Solver and Generative Modelling

Rhinoceros 3D - Grasshopper

Quadtree Algorithm/

Inputs
Tree positioning point data
Movement axes point data

Outputs
Vegetation covered areas
Walking path ways
Sitting places

" - " unit vector
"0 " unit vector
" +" unit vector
Sitting area
''+'' vector force
Walking pathways
''0'' vector force
Final Design Plan
Findings
### Findings

**Design Surface**
Consist of boundaries that shaped by roads.

**Solar Radiation Matrix**
Sun Exposure depends on only sun rays and building positioning.

**Usage pattern**
Spread around the Side
Recorded 30 sec.

**Microclimatic Analysis**
(with wind and sun exposure direction)
Open space feeling Condition value

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Surface % Impermeable</th>
<th>Surface Radiation % Direct Sun Exposure</th>
<th>Human Usage Pattern</th>
<th>Area Microclimatic Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evolutionary Solver Algorithm</strong> Surface</td>
<td>95</td>
<td>34</td>
<td>Limited with center of the design surface.</td>
<td>High</td>
</tr>
<tr>
<td><strong>Generative Algorithm</strong> Surface</td>
<td>34</td>
<td>26</td>
<td>Spreaded, environmental interaction is high.</td>
<td>High</td>
</tr>
<tr>
<td><strong>Existing Surface</strong> Surface</td>
<td>68</td>
<td>47</td>
<td>Limited with center of the design surface.</td>
<td>High</td>
</tr>
<tr>
<td><strong>Emtv Surface</strong> Surface</td>
<td>100</td>
<td>75</td>
<td>No unit inside the area.</td>
<td>High</td>
</tr>
</tbody>
</table>

**Existing Surface** Surface
% 68 impermeable. 904 m²
Tree count 24
T1 | 6
T2 | 18

**Surface Radiation**
maximum % 47 of the area was directly sun exposed

**Human usage pattern**
Environmental interaction is high and also because of the fractality of designed area usage interaction is high.

**Area microclimatic condition**
open space usage is high %12 of the area’s degree higher than 27°C

Users could reach only impermeable surfaces.
Findings

Existing Situation

Impermable Surface // % 68
Microclimatic effect // %33
higher than 27° C
Solar Radiation // % 47
directly sun exposed
Social Interaction // Low
environmental interaction is low, but 4 unit is inside the area.

Generated Situation

Impermable Surface // % 34
Microclimatic effect // %12
higher than 27° C
Solar Radiation // % 26
directly sun exposed
Social Interaction // High
environmental interaction is high, and also 4 unit is inside the area.

Tree count 24
T1 | 6
T2 | 18

Existing Situation

Tree count 26
T1 | 8
T2 | 18

Generated Situation
Findings

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

While this study proposed a design outcome, it was tested the effects of landscape elements by the instrumentality of algorithmic design process.

This model was intended to be produced in a single and integrative definition so that it can be seen instantly how inputs and outputs affect each other.

Parameters that used in the model, can describe the conditions that provide the appropriate environment for the creation of landscape design; however, the model can be developed by defining more and detailed parameters.

However constraints and rule functions works, tree positionings and identified usage areas creation should be defined more precisely because one tree and also some sitting areas were located too close to the edge and sidewalk.

Future Works

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.

A model can be developed with more detailed and variated microclimatic analysis outputs.

New definitions can be developed through ecological cycles by evaluating the material properties of the design surface.

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.

Generative design stage should be consider to create different method to achieve more soft design lines.


https://www.zaha-hadid.com/masterplans/kartal-pendik-masterplan/


[5] https://big.dk/#projects-arc


[13] https://putihanime.com/noticifications/push/cpaer/lock/index.html?subid_short=1178a7be6662ba7eab5193207343609190&ip=3%3Ff3%3Emelio%3C% %4f%3cyf%3dyf%3eA0d0d4d4a4a599be8a8c2889875e54b9


[18] https://uni-weimar.decodingspaces.de/courses/introduction-to-computational-urban-modeling-and-simulation/

Thank You !