FINDING RELATIONSHIPS BETWEEN MOVEMENT AND TREE PATTERNS IN THEME PARKS

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Abstract. Tree planting in design practice is considered simply as void fillers or view blockers. However, for a sustainable design, creating places using trees need to be reconsidered. Going beyond traditional tree plantings in urban environments, an application of computational methods in landscape architecture for the management of the complex system is needed. While computational methods have been extensively applied to buildings, less has been applied to trees. The goal of this paper is to investigate how the presence of trees affects human movement and find out if computational methods can be used for recommending tree planting patterns. We analysed the tree planting patterns in renowned theme parks as an initial research categorizing tree planting patterns, using an agent-based analysis for simulation, and comparing the results of the average agent counts in theme park plans without trees and those with trees. We noticed there was a clear distinction between tree planting pattern types and the change in agent counts supporting the qualitative theory in landscape architecture. The result of this research can guide theme park designers as well as urban park designers when deciding which tree planting patterns to implement for the purpose of controlling pedestrian movements.

Keywords. Tree planting pattern; agent-based analysis; theme parks; pedestrian movement.

1. Introduction

The way trees are planted in cities mean nothing to people because they are not planted to form places; instead, they are planted along roads or in parking lots instrumentally not interactive with people. However, according to a Norwegian architectural theorist, Christian Norberg-Schulz, a landscape is one of the components that make up an existential space. Existential space
lies between the perceptual space and the cognitive space in a list of five space concepts (in the order of growing abstraction: physical space, perceptual space, existential space, cognitive space, and geometrical space). The existential space indicates a complex space where human interact with the environment experiencing the immediate perception and schemata or an image that the environment creates. In this sense, landscapes—as masses and spaces—determine, and perceptually and schematically influence the paths taken by the people (Norberg-Schulz, 1971).

Keeping in mind that landscape is one of the components of existential space and that people interact especially through their movements, the current situation of landscape architecture in practice should be examined. Trees are planted along the roads linearly or planted around the buildings as buffers. However, tree planting patterns should be utilized for the control of movements in a complex space. Control of the movement means areas, where people need to gather, should gather, and that areas, where people need to walk on, should walk on. However, to apply the tree planting patterns for the control of movements, we need information on how different kinds of tree arrangement patterns influence the movements in a complex system.

In this research, we investigated how the presence and the arrangement patterns affect agent movements by comparing the simulation results from plans without trees and the results from plans with trees. To do so, we first categorized different types of tree planting patterns from literatures and used an agent-based analysis from a space syntax theory to compare the analysis results from the plans with trees and without trees. After the agent-based analysis, the sub-regions in plans were categorized according to the tree arrangements to see whether if there is a pattern between tree planting patterns and average agent counts. For this paper, theme parks are chosen as research sites because, unlike the cities, theme parks are designed to create a spatial identity and to persuade people to walk around. In other words, the tree planting patterns in theme parks are supposedly designed to control the movements in a complex space (Clavé, 2007).

2. Research background

2.1. TREES AS STRUCTURE

According to Christopher Alexander et al (1977), trees have a crucial meaning to humans often representing dreams, power, and perseverance. The trees that people love create special social places: places to be in, pass through, and dream about or draw. And these trees are arranged in different patterns:
an umbrella (a single, low-sprawling tree), a pair (two trees forming a gateway), a grove (several trees cluster together), a square (an enclosed open space), and an avenue (a double row of trees lining a path).

Alexander further adds trees should be planted to form an enclosure, avenue, square, or an umbrella since trees and people have a complex interactive symbiotic relationship where people need trees and trees need care from the people, and thus trees need to form places where people occupy, pass through, and rest to be taken a good care of (Alexander et al., 1977).

Further supporting Alexander’s work, Gang Chen (2011) has published a book that lists a number of spatial arrangements that affect human movements (Figure 1).

![Spatial arrangements](image)

*Figure 1. Basic spatial arrangements (redrawn from Chen, 2011).*

Chen (2011) lists centralized, clustered, linear array, curved and straight, and radial spatial arrangements. Each of these spatial relationships create a distinct sense of place for the people. For example, in the centralized organization, the tree in the centre plays a role of a dominant space acting as a focal point. In another case, in the linear organization, people are encouraged to move along a straight line and have access to a powerful perspective view (Chen, 2011).

Theoretically, from Alexander et al (1977) and Chen (2011), it is clear that trees create spaces with enclosure and identity depending on what kind of pattern they are planted as. However, it is unclear how these tree patterns influence human movements in a holistic bounded system.

### 2.2. COMPUTATIONAL RESEARCH AIDING LANDSCAPE DESIGNS

Application of computational methods in architecture has been ongoing for a long time simulating human movements inside buildings and proving how spaces influence people’s movements. In contrast, the application of compu-
tutional methods in landscape architecture field has been slow because trees do not have definite and solid characteristics like walls in buildings, and because, in practice, landscape architecture requires more heuristic knowledge when designing. However, researches exploring ways to design landscape quantitatively are recently on a rise and are becoming more diverse.

For example, in urban greenery research field, there is a research that identified locations that are spatially available for potential tree planting based on satellite images (Wu et al., 2008) as well as a research that prototyped decision support system for sustainable urban tree planting programs for micro-management of the urban forest canopy (Kirnbauer et al., 2009). In addition, there are researches where a graph theory is used to investigate the connectivity of patches of green fields to recommend the location of urban greens for a higher habitat connectivity value (Galpern et al., 2011; Hepcan, 2013). However, these researches only deal with the tree and green patch placements in relation to other environments, not examining the existential relationship between human and trees.

There recently was a research on the usage of space syntax theory for planting design in urban parks. In Mahmoud and Omar’s research, the authors investigate how space syntax techniques can be incorporated for predicting the social structure of the proposed space and assess design alternatives at a pedestrian movement level (Mahmoud and Omar, 2015). The authors use the visibility graph analysis to assess the design alternatives of tree planting and computationally illustrate which alternative is better. Our research used a similar method used by Mahmoud and Omar (2015), but with a different purpose where the goal is to see whether if there is a noticeable relationship between tree planting patterns and human movements.

3. Methodology

3.1. TREE PLANTING PATTERN CLASSIFICATION

While Alexander et al (1977) and Chen (2011) both classified tree planting patterns, the terms used are different. For instance, Alexander called a tree pattern where one tree stands as an ‘umbrella’, while Chen called it a ‘point’. The terms are organized in Table 1 along with the corresponding diagrams. As illustrated, a ‘pair’ planting pattern is considered similar to a linear planting pattern, so it included in the linear/avenue category, and similarity a ‘centralized’ pattern, where a large tree stands in the middle with small trees around, is categorized as a pattern that encloses a space—circular and square. In this paper, the most planting patterns shown in the first column of Table 1 are used.
Table 1. Tree planting patterns.

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Point/Umbrella</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td>Point</td>
<td>Umbrella</td>
<td>A single tree</td>
</tr>
<tr>
<td>Linear/Avenue</td>
<td><img src="image2.png" alt="Diagram" /></td>
<td>Pair</td>
<td></td>
<td>Two trees forming a gateway</td>
</tr>
<tr>
<td></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>Linear</td>
<td>Avenue</td>
<td>A double row of trees lining a path</td>
</tr>
<tr>
<td>Centralized/Square/Circular</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td>Circular</td>
<td>Square</td>
<td>An enclosed open space</td>
</tr>
<tr>
<td>Cluster/Grove</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td>Cluster</td>
<td>Grove</td>
<td>Several</td>
</tr>
</tbody>
</table>

3.2. DATA COLLECTION

The purpose of this research is to computationally find out how the presence of trees and the tree pattern types influence the way human move through space as Alexander et al (1977) and Chen (2011) have mentioned. In this particular research, the four representative theme parks of Walt Disney (Tokyo Disneyland, Disneyland Paris, the Magic Kingdom at Walt Disney World, and Disneyland California) were investigated because theme parks are designed to create social space and induce movements (Clavé, 2007).

The trees in the middle of the streets—the trees located near the buildings that do not directly interact with the pedestrians are not considered in this research—were plotted onto CAD maps of the theme parks marked using a small square as Mahmoud and Omar (2015) have done (Figure 2).

![Figure 2. Plotting the trees into CAD map (linear/avenue type).](image6.png)
After plotting the trees, the tree clusters were categorized into different tree planting patterns according to the categories: cluster/grove type, linear/avenue type, point/umbrella type, centralized/square/circular type.

3.3. AGENT-BASED ANALYSIS

For the analysis, we used an agent-based analysis tool in DepthmapX 0.30 which is based on a visibility graph from a space syntax theory. DepthmapX 3.0 is developed by Tasos Varoudis based on the theories suggested by Alasdair Turner and Bill Hillier. The agent-based analysis was first proposed by Turner and Penn (2002) with a visibility graph as its foundation. For our research, 1000 agents were randomly placed throughout the CAD maps. We first confirmed whether if tree plantings in theme parks have a structural role in terms of their influence on agent movements by comparing the results of agent-based analysis between a plan with and without the trees. When the difference was confirmed, we investigated whether if there is a relationship between planting pattern types and the change in the average number of agents at a spatial node identified by the tree planting structures (Figure 3). Lastly, we determined which patterns increase the average number of agents and which decrease it.

![Image](image.png)

*Figure 3. Counting the average number of agents.*

4. Results

When the agent-based analyses were implemented on four theme park plans without the trees and plans with trees, it showed a clear difference in terms of the average agent count. Overall, the plans with trees showed more distribution of agents than those without. We were able to conclude that trees play a significant structural role on how space is occupied. After this confirmation, we categorized each occurrence of tree planting patterns into those that
increased in the number of agents going from a plan without the trees to a plan with the trees and those that decreased.

The main planting pattern types that decreased the number of agents were the cluster/grove and the linear/avenue types (Figure 4a and 4b) where the area of warm colours decreased from when there are no trees planted to trees planted. From the agent-based analysis, we can suspect that the reason why cluster/grove type and linear/avenue type decreases the number of agents is because the cluster/grove type blocks the views of the agents and the linear/avenue type narrows a path thereby decreasing the visibility, and thus the number of agents passing by. Meanwhile, the planting patterns that increase the number of agents are the point/umbrella and the centralized/square/circular types (Figure 4c and 4d) meaning that they gather agents.

For the graphical visualization (Figure 5), the percentage differences are averaged for each planting types and represented as bar graphs. We can see that the cluster/grove planting pattern type influenced the number of agents the most negatively, then the linear/avenue type; meanwhile, the point/umbrella planting pattern had the least influence. The reason might be because the agent-based analysis is based on the visibility graph so the point/umbrella planting patterns have a minimal impact on the sightlines.
Figure 5. The average percentage differences for each tree planting patterns.

5. Conclusion and contribution

The goal of this paper was to investigate how the presence of and the arrangement patterns of the trees affect agent movements. In this particular research, we analysed renowned theme parks as an initial approach to answering this question because theme parks are designed to create a spatial identity and to persuade people to walk around controlling the movements. For our research, we categorized different types of tree planting patterns identified in the literature and used an agent-based analysis. When we compared the results of the agent-based analysis on theme park plans without trees and those with trees, we noticed that trees had the tendency to distribute the agents more. This result was as expected, since agent-based analysis is based on a visibility graph, and with more obstacles (trees), it means that there are more diversity in the lengths of sightlines. When the areas with tree patterns identified previously were listed in the order of percent difference, we were able to see that cluster/grove and linear/avenue types influenced the agent count the most where the point/umbrella type influenced the agent count the least. This is also possible because point/umbrella type is minimal on its impact on sight lights of the agents.

A surprising finding was that there was a clear distinction between tree planting pattern types where two types (cluster/grove & linear/avenue) decreased the agent counts while other two types (centralized/square/circular & point/umbrella) increased the agent counts. In the theory of landscape architecture, cluster/grove planting patterns are used to block views while linear/avenue planting patterns are used to make people move linearly. Furthermore, centralized/square/circular patterns and point/umbrella planting
patterns are to gather people. The results from this research where it was only dependent on the agents and the algorithm created by Turner and Penn (2007), it clearly reflects how the theories in landscape architecture can also be replicated computationally. While, it is understandable for the cluster/grove and linear/avenue patterns that they decreased the number of agents, because they do interrupt the sight lines of the agents, this research result should be reinvestigated on how point/umbrella and centralized/square/circular types actually had increased agent counts because for these patterns, people gather not due to sight lines but psychological reasons. One possible reason might be because cluster/grove and linear/avenue types distribute agents that other places must have increased in the number of agents. Still, using agent-based analysis for tree planting design is shown to be effective from the results.

The result of this research not only can guide theme park designers when making design decisions regarding the tree planting pattern to control pedestrian movements, but it is also applicable for places where inducing human movement in an open space plays a big part. A main reason is because, although we used the arrangements from tree planting patterns, from the agent analysis point of view, the trees are simply considered as obstacles where it can be anything from a bench to a trashcan. For example, the finding from this research can be used when designing shopping malls or even traditional markets in city centres; for areas where many people are expected to pass through, a linear/avenue or a cluster/grove obstacle arrangements should be implemented, for areas where people are expected to not pass through often, a centralized/square or a point/umbrella obstacle arrangements should be implemented. Nevertheless, choosing the trees as obstacles is appropriate since there are no other ‘obstacles’ that can be placed in the manner how trees are placed. Our research demonstrates that trees can be used to create space as well.

6. Limitations and future works

One of the limitations of this research was that it was limited to an agent-based analysis in two-dimension and neither tree shapes nor the psychological effects of trees were taken under considerations. The trees were simply represented as a square. Space syntax is based on the visibility analysis developed by Bill Hillier; it is extensively used for buildings where a wall is usually straight. However, applying space syntax in an urban park with trees, we expect there will be differences. Next step in this research is to investigate the nature of space syntax theory around trees adjusting space syntax to be used in exterior space. How different tree shapes (crown shape and
height) influence our sight lines should be taken under considerations, because currently, in this research, the trees are simply represented as a pole indicating that the research result may not have anything to do with the psychological benefits of trees. Giving weight to the places with certain tree patterns would definitely provide more meaning and depth to the agent-based analysis.

Furthermore, it would have been really supportive if we were able to compare our simulated results to real observations but to verify the analysis results, we would have to observe a site for a long time where a site begins as a site without the trees to a site with trees.

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References

Hepcan, Ş.: 2013, Analyzing the pattern and connectivity of urban green spaces: A case study of Izmir, Turkey, Urban Ecosystems, 16(2), 279–293.