Parametric Planting Design: Algorithmic Methods for Resilient Communities

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Abstract: Parametric applications in landscape architecture are gaining traction as designers realize the full potential of script-based analysis in various stages of design. Planting design is one realm of parametric landscape architecture that is traditionally done manually with books, websites, or other research on hand, thereby keeping its application within the grasp of landscape designers. This discussion proposes a method of using algorithmic design to analyze and specify plant species based on four different measures. Further, it is possible to expand this method in the form of a browser-based program for non-designers to take part in resilient landscape planting.

Keywords: Algorithmic design, resiliency, planting analysis, interactive tool

1 Introduction

The origin of computation-driven landscape analysis and design is often attributed to Carl Steinitz's 1966 land evaluation and the SYMAP print of the Delmarva Peninsula (STEINITZ 2014). Subsequent decades brought advancements in processing power and user interface, allowing a variety of software to gain traction in the design field including Photoshop, AutoCAD, and specifically for landscape architects, LANDCADD (ERVIN 2020, MACDOUGALL 1984). ERVIN (2020) also describes the rise of optimization software and use of algorithmically-generated landscapes in response to the formation of the internet (ERVIN & HASBROUCK 2001). As such, the success of spatial design computer applications has led to at least a partial reliance on digital workflows in the design process, if not a large portion of the work.

In an effort to explore emerging landscape architectural frontiers, designers echoed Steinitz' experimentation and began programming new tools for greater flexibility in their work (CANTRELL & MEKIES 2018). Development of programs continued with some tools being codified as permanent sub-tools, such as Grasshopper within the 3D modelling software Rhino.

General investigations of parametric landscape design problems can exist in the form of blog posts (GENERATIVE LANDSCAPES), online videos, and academic papers (SERDAR & KAYA 2019). Commercial tools have also been created and added to aid in the digital landscape design process (LANDKIT). Notable built projects include Eda U. Gerstacker Grove by Stoss Landscape Urbanism at University of Michigan, where student desire lines, drainage, and parametric bench profiles were incorporated into an algorithm to generate a site model that responds to and supports the pedestrian experience (REED 2018).

Journal of Digital Landscape Architecture, 8-2023, pp. 301-309. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-740-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537740032.

2 Existing Research

While parametricism in landscape architecture is an ever-expanding area of study, limited research has been conducted on the use of algorithmic workflows regarding ecological factors including species selection and planting location.

A thesis by Roasliina Luminiitty (2021) from Aalto University examines parametric planting design's integration in the landscape design progress. LUMINIITTY (2021) analyzes prior software used for landscape design, as well as more modern investigations into algorithmic landscape architecture. The paper offers a detailed explanation into the components of parametric planting design and offers a framework for digital planting design workflows, which can be expanded further with the inclusion of measurements and real-world data to inform the final result. Parametric patterns can be tailored for design continuity and be ecologically developed by an algorithmic plant selection process to create a holistic planting concept.

OLIN Lab's Tech- and Eco Labs have also developed research into digital workflows for planting design. The process utilizes AutoCAD, Rhino, Grasshopper, Python, LandFX, and Adobe Suite products to derive functional planting plans for use in a landscape architecture office setting (AREVALO 2020). The process is broken down into four parts: (1) Investigating plants as living material, (2) Speculating and experimenting with parametric components, (3) 3D Spatial and aesthetic analysis, and (4) Seasons and time. AREVALO (2020) states that this workflow was successful for the office-side design process, but documentation was still prepared manually, which requires work by a landscape architect.

LandKit is a Grasshopper plug-in developed by LANDAU Design+Technology that creates custom components in Grasshopper for users to more effectively design fundamentals including with specific components called TopoKit, PavingKit, and PlantKit (LANDKIT). What sets PlantKit apart from other parametric planting tools is that it does not automatically assign species to the plants it generates, but rather establishes certain plant typologies to be determined later by the user. The plant typologies refer to similar sizes, environmental considerations, and biodiversity, which gives the end user more agency when specifying species and accounts for regional climate variations.

The creation of these products is testament to years of dedicated research into accurate and efficient planting algorithms, for use in a landscape architecture office. The development of different algorithms and tools has taken off regarding landscape design and will continue to bring new and improved iterations into the field. However, this computation-driven analysis is mostly locked behind software with intense learning curves and high price points. With the goal of simplifying communication between designer and computer, parametric application developers should also strive to lower the barrier of entry for the use of these tools.

3 Digital Equivalents to Planting Design Concepts

Before attempting to develop any parametric tools, it is critical to understand the concepts behind existing ecologically sound landscapes. Traditional landscape design practice includes researching native or naturalized plants in a specific region, while placing them in a pattern corresponding to a design intent. This varies from project to project, but is generally the format of the planting design strategy. Many different categories of planting information exist for each plant, and can be addressed through different ways to fit the project's goals.

Qualitative information exists as a subjective rationale in landscape design. This may include aesthetic considerations, natural plant communities (dependent on location and ecosystems), and features included on a site and how the site functions as a whole. In the digital realm these cannot be quantified, though studies have investigated various methods to evaluate landscape perception (KARMANOV 2009). Use of qualitative data or input is still important, however, as it establishes "the meaning individuals or groups ascribe to a social or human problem (CRESWELL 2014). Use of this type of information can be presented in the setup of a project, or change with user preferences.

Quantitative information is a numerical type of data representation where all possible results are accounted for, and often presented numerically. In landscape architecture, common uses of quantitative data are found in climate data, topography, and geotechnical properties. Data can also be extracted from the site itself through analysis tools and simulations, unearthing underlying layers of data otherwise hidden.

Planting for a Post-Wild World (RAINER AND WEST 2015) describes the structure of a designed landscape through a series of layers: a structural layer, groundcover layer, seasonal filler layer, and dynamic filler. The clear distinction between individual plants work together to form the identity of a garden which can establish character even before more complex design motifs take place. Additionally, thinking of plants in a binary manner lends itself to digital applications where a machine must be programmed to receive input and output information in a highly controlled manner.

RAINER AND WEST (2015) also signify the importance of employing ecological strategies within plantings to promote resilience in plant communities. "Resiliency" is a commonly used term referring to the ecological health of a landscape and its ability to recover after periods of distress (RAINER & WEST 2015), but it also can be interpreted as a human community's ability to recover from a disturbance (FLINT 2010). Given the difficulty of evaluating a multifaceted concept such as resilience, we can instead look at establishing environmentally sound starting points (namely regionally accurate plant spreadsheets) in order to generate resilient planting communities.

Software for this algorithm process utilizes the Grasshopper tool in Rhinoceros 3D. Because this software allows for algorithmic design approaches, a single input can trigger a variety of subsequent processes and analyses, culminating in an algorithm-derived final product.

Preparation for this tool included development of a plant list extracted from eastern Nebraska nursery stock listings to ensure success in the Nebraska landscape. In total, 198 unique species and 80 cultivars or varieties were identified and constructed in a spreadsheet with important information such as mature height and width, shade tolerance, salt tolerance, drought tolerance, bloom timings and color, nativity to Nebraska, and hardiness zone range. All plants were parsed based on their landscape function: overstory conifer, overstory deciduous, understory conifer, understory deciduous, perennial, tall grass, groundcover, and annual.

4 Algorithm

4.1 Grid

A site's surface can be divided into a grid of any size, though standard 1-, 2, and 5-foot squares work best. The grid allows for easy analysis of site features such as elevation, edge proximities, and sun exposure. The ideal scale for this depends on the overall scale of the site, with smaller sites requiring a higher level of detail. The ideal resolution for a 7,000 sq. ft. (650 m^2) site can be 2 feet, while larger sites may need 5-foot resolution to minimize computing time.

4.2 Plant and Environment Scoring

A surface in Rhino is referenced in Grasshopper where four analyses take place: 1) Elevation, 2) Shade, 3) Salt intensity, and 4) Structure proximity (Fig. 1). The interplay between environmental factors plays a large role in identifying a "best fit" species for a particular location on a site (CZAJA et al. 2020). Elevation analysis takes note of local high and low points on the site, and corresponds with low points requiring less drought tolerant plants and high points requiring more drought tolerant plants. Shade analysis looks at sun exposure on the site from existing buildings and trees to accurately place plants with regards to sunlight hours. Salt tolerance measures look at a point's distance from paving surfaces or curves to account for road salt accumulation in winter months near the planting surface peripheries. Lastly, structure proximity refers to the distance between a plant and a structure, preferring slow growth nearer to the structure to reduce risk of root damage to the foundation.

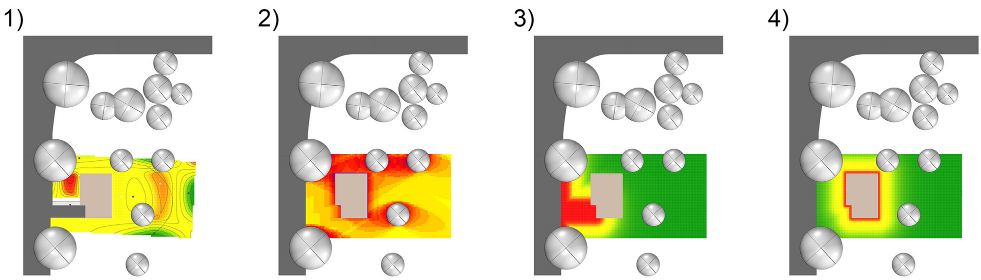

Fig. 1: 1) Elevation, 2) sun exposure, 3) salt intensity, and 4) structure proximity for a sample site

The "environmental scores" (elevation, sun exposure, and salt intensity) of each potential planting spot on the site are compared to each "plant score" of a particular plant typology (Fig. 2). The difference between the "environmental score" and "plant score" determines the resiliency of the proposed plant, with a lesser difference resulting in higher probability of resilience. It is possible for the algorithm to compare all 278 plants for every potential location, though it would leave too many options available for the user and result in an unclear direction. Parsing plants into specific landscape structures provides opportunity for a better structured landscape (RAINER & WEST 2015).

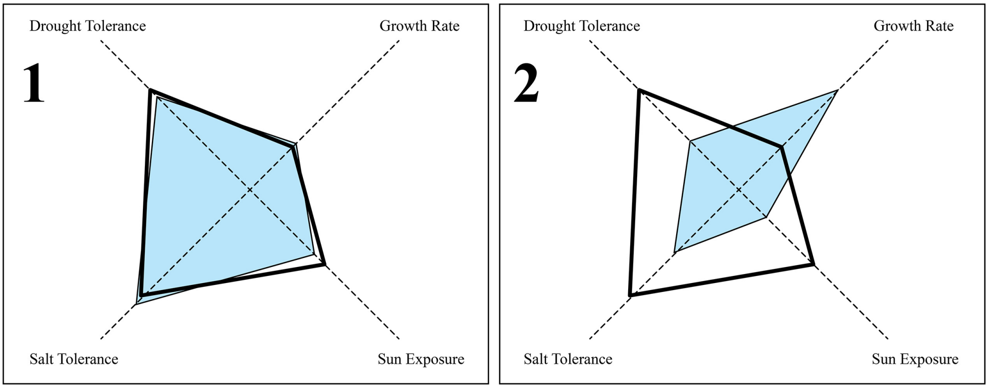

Fig. 2: Evaluation of environmental scores (thick stroke/no fill) compared to plant scores (thin stroke/fill). Comparison "1" is a closer match and likely more resilient than Comparison "2", therefore Comparison "1" is recommended

4.3 Flexibility

The uniform analysis and subsequent visualization of a landscape allows for a variety of planting regimes to occur. Planting locations can be derived from the algorithm itself, or decided by a user making informed decisions from the data.

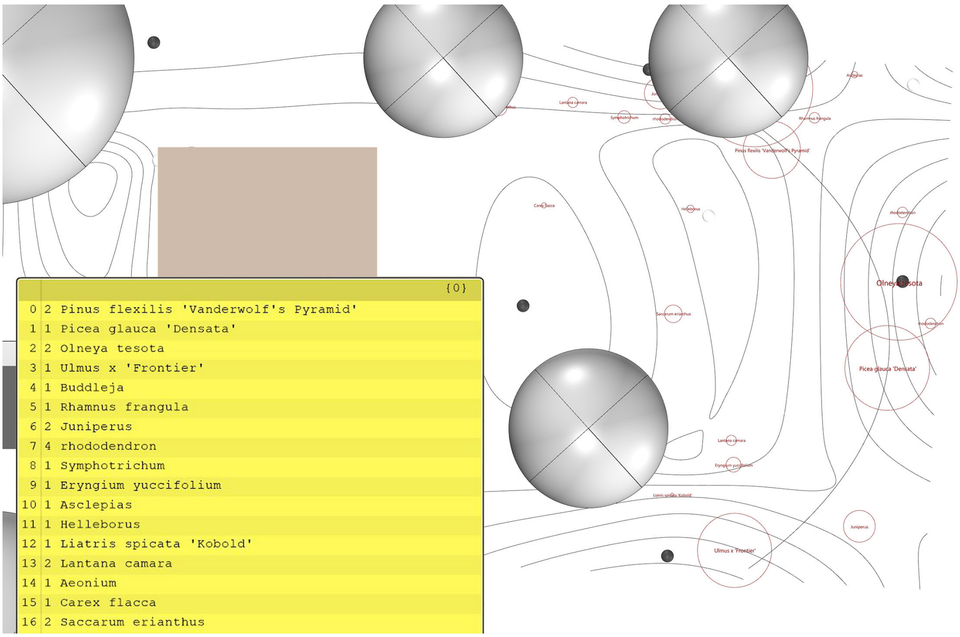

Fig. 3: Preliminary results of the tool based on an attractor curve with size decreasing as distance increases. The tool is able to total the amounts of various species and compile it into one list.

Algorithm-derived planting plans can be applied in a few ways, provided a distinction is made for the specific plant typology being used in each spot (overstory, understory, tall grass, etc.). Grids, attractor curves, and random points are options when considering automatic planting proposals (Fig. 3). Further exploration in parametric design tools such as Grasshopper may offer informed layouts with emphasis on user comfort and more complex designs.

The user may defer to stylistic choices based on a desired theme (naturalistic landscapes, English gardens, etc.). For manual placement of plants, collections of points can be projected onto the site surface and analysis be drawn for those, where inputted plant patterns and sizes are matched to the "best fit" plant for that location. The variability of planting styles allows for highly unique landscapes designed by the end user. To aid in this process, planting pattern diagrams were developed to demonstrate the core principles of various landscape styles. A few selected styles being presented to the user show successful patterns easily replicable from an amateur designer's perspective and increase the appearance of legible design intent.

5 Algorithm to Browser-based Tool

This algorithm can be interpreted as a backend process for a planting design tool intended for people inexperienced with landscape design. Given that the tool is able to suggest planting strategies from topographic information, it is possible to derive this information from other sources using real-world data and leave the user with freedom to focus on designing their space. Further, incorporating heterogeneous (containing structure and hierarchy, biodiverse) landscape design in homeowner-designed landscapes improves landscape perception (KHACHATRYAN et al. 2020). These positive attributes prompted the idea of a browser-based tool that can aid in the creation of a homeowner's landscape design.

Translating a Grasshopper script to a programming language is a fairly straightforward task, given that Grasshopper is in essence a visual coding language. Python and Javascript are popular programming languages capable of creating interactive maps, ones which users could use to select site boundaries in their respective regions. An application programming interface (API) allows for communication between two or more computer applications, such as an individual computer requesting data from a large online database. Integration of OpenStreetMap (OSM) and United States Geological Survey (USGS) API allows for up-to-date interpretation of landscapes with OSM providing location data, and USGS providing elevation data.

OpenStreetMap is a free, open-source online mapping service that uses volunteer-provided information to gather location data, along with deriving maps from Bing aerial imagery and other mapping techniques (OPENSTREETMAP). Overpass API is a resource for an application to request read-only data in a variety of formats for any particular use due to the open-source nature of the service. To obtain specific site data, a bounding box is drawn over a map and coordinate boundaries are established. The software requests any road and building geometry intersecting or within the boundaries from Overpass, which can be interpreted and shown in the map view.

The National Map (TNM) is a project by the USGS's National Geospatial Program to consolidate downloadable products into one location for all public and private use (UNITED STATES GEOLOGICAL SURVEY). The TNMAccess API allows developers access to multiple datasets, and will use the highest resolution dataset for the desired location request. To obtain accurate elevation data, the Elevation Point Query Service returns the elevation in requested units at a specified latitude and longitude. Coordinates from the initial OSM bounding box can be used to create a rectangular array of coordinate points and sent as a request to TNMAccess, where surface analysis can begin. Once a site is selected, the user can demarcate structures, roads, and potential barriers to plants that are present but not recorded to cull any areas incapable of supporting plant life.

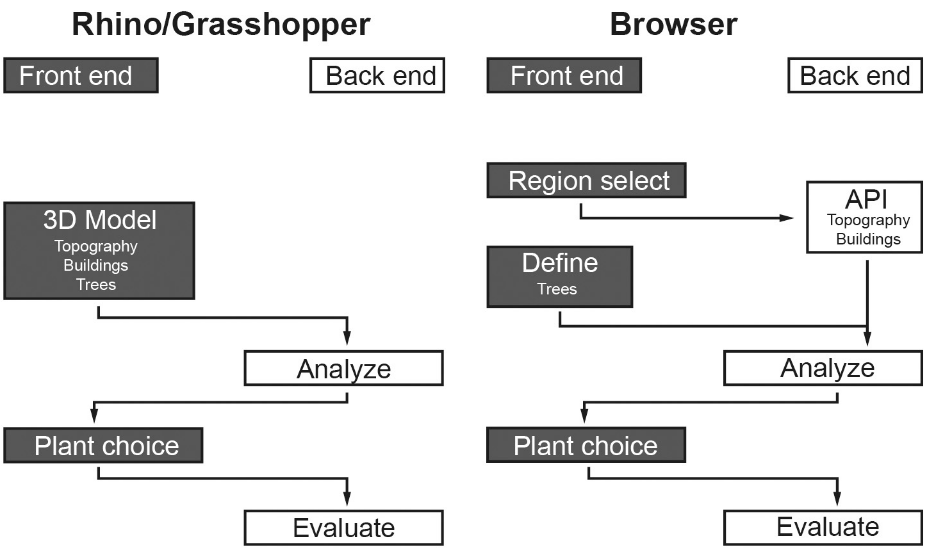

Fig. 4: Comparison of workflows between Grasshopper and a browser-based program. The Grasshopper model requires more inputs and higher skill to work, while a browser-based.

The development of a user interface or user experience (UI/UX) can lower the barrier of entry to individual landscape design. User interface is considered the format in which users see and operate the software, which should contain simple and concise language to explain the concepts at play in landscape design such as elements of analysis, plant environment descriptions, and list of results provided by the algorithm. This is considered front end development: the side that the user is allowed to see. All the user's inputs are relayed to the back end of a software to be analyzed before a response is sent back to the front with a clear visual result (Fig.4).

User experience is the act of using the software and experiencing it through various steps to produce a valid result. The flow of this process includes clear language to describe what each component is and how it changes the result. This includes the language and response of any analysis performed by the application. The goal of this experience is to provide the user with a simplified approach to landscape design, performing site-specific landscape analysis in the back end to produce a tailored result for further consideration.

6 Discussion

The creation of a digital planting tool geared towards the general public provides an accessible platform that can elevate the ecological diversity and architectural quality of typically underutilized landscapes. The use of this proposed process does not necessarily end with the individual user in a single-family home setting, but can be applied in a broader application for use in community organizations and people interested in improving the landscape of their community spaces.

While the project does accurately complete the task of planting design, it performs mainly as backend development with complex inputs. Further exploration into user interface and user experience front end could improve the clarity of language and process of the tool, and ultimately may be able to compile a custom document regarding maintenance and further resources for the end user for future planning. Further back-end analysis of landscape can increase the accuracy of the results regarding unique species preferences, or the variable shade from vertical layers of vegetation.

Certain limitations apply to the accuracy and scope of an accessible planting tool, with datasets needing to be researched and formatted to a uniform spreadsheet. One approach to expanding this process into a United States-wide resource would be the use of the Federal Highway Administration's Ecoregional Revegetation Application (ERA). This resource is a compiled list of plant species and related information found in ecoregions across the entire United States, including Alaska and Hawaii (STEINFELD et al. 2007).

Through this framework, it is possible to begin the development of a tool that brings informed, site-specific planting information to the general public.

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