Reflecting Time in Computer-aided Landscape Design and Analysis: Developing an Application for Modelling Seasonality and Resiliency in Small Scale Landscapes

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Abstract: Time is a vital factor to any landscape design. Landscape design solutions "rely on transformation, growth, decay, flow, and settlement to produce evolving solutions" (WALLISS et al. 2014). Although there have been advances in large-scale scenario modelling and analysis, the evolving nature of landscapes are hardly reflected in the way landscape architecture uses CAD in small-scale designs.

The timely attention of the discipline to urban resiliency accentuates the importance of acknowledging dynamics of landscape systems in design process. Plants, as living matter of designed landscapes, change through time and are affected by seasons and extreme environmental conditions. Although there are local nuances to the parameters that can affect a planting scheme through time, many aspects of it can be parameterized. In this regard, I developed an application in Processing programming language that addresses the influence of time-related factors such as seasonality and environmental changes on planting design. Accessible large databases such as USDA plant database and the literature in ecological rules for urban planting resiliency (HUNTER 2011) are incorporated into this rule-based CAD tool for designing resilient landscapes.

This paper provides a brief review of landscape resilience and the current use of CAD in small-scale landscape design. In addition, it explains the underlying rule-based ecological theory in the process of the application development. Lastly, it demonstrates the application developed as an example of this parametric approach to landscape design. The interactive app shows the resiliency of a planting scheme under different extreme environmental scenarios, bloom resiliency, and the colour palette of the planting scheme throughout a year. This parametric tool has both design and educational purposes and is applicable in design analysis, facilitating user-engagement, and long-term maintenance and monitoring of small-scale landscapes.

Keywords: Time, data visualization, processing, resilience, urban landscape, landscape apps

1 Introduction

This paper is part of an on-going research agenda on use of information technology and CAD tools for designing resilient urban landscapes. While the broader research explores both social and environmental aspects of landscape resiliency in multiple scales, here, the paper focuses on resilient planting design in small-scale landscapes and provides an example of simulating resiliency in a planting scheme. The length of this paper does not allow for in-depth discussion of landscape resilience or the use of CAD in landscape architecture. However, a brief review on these two subjects has been included to draw a theoretical foundation for the application development. Another essential theoretical base is research on resilient urban planting (HUNTER 2011). Here, the criteria mentioned for response and functional diversity in planting design are incorporated into the application design.

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The application is written in Processing programming language. Processing is a Java-based language with the focus on new media and digital arts (BOHNACKER 2012, SHIFFMAN 2012). The databases used for the sample experiment include USDA plant data and the plant data provided in Hunter (2011). The application shows the changing landscapes through focusing on the factors that influence the plants long-term endurance in general and the ecosystem service they provide for pollinators in particular. In this regard, I have focused on the change in the plants through different seasons/months of the year and severe environmental conditions.

2 Landscape Resilience, Time and CAD Tools

2.1 Landscape Resilience: Matter of Scale and Time

The concept of resilience has received much attention in urban planning and design in the recent years. This attention specifically revolves around cities (WALLACE & WALLACE 2008, WU & WU 2013). It is believed that the shocks that today's cities may face are different from those in the past in terms of their scale and pace due to globalization and climate change. Rapid depletion of natural resources and the increasing frequency of extreme ecological events have been mentioned among the factors that make resilience a timely focus (ERAYDIN & TAŞAN-KOK 2013).

Resiliency is a term introduced by HOLLING (1973) in the context of ecological science. In his article "Resilience and Stability of Ecological Systems", he emphasizes the importance of focusing on change rather than constancy and qualitative features rather than quantitative ones in studying systems; in particular, ecological systems. Since then the term has been expanded in terms of both its notion and application in many studies that address social-ecological systems.

Since different disciplines have touched on the idea of resilience in their specific contexts, there are many different definitions of the concept. Cumming (2011) provides two definitions of resilience. The first one defines resilience as the ability of a system to absorb changes, self-organize and increase its capacity for learning and adaptation. The second definition is based on system identity. Here, resilience is defined "by quantifying identity and assessing the potential for changes in identity" (CUMMING 2011, 13).

Focusing on *change* is the shared part of many definitions of resilience. Resiliency measures how a designed system responds to gradual or abrupt *changes* such as a hazardous events (FIELD et al. 2012). Change is defined within the factor of time and we can analyse the resiliency of a landscape through studying its *change* during a year or under severe environmental conditions (specific moments in time).

Although there are several studies on landscape resilience, the link is missing to connect these studies to design decisions at small scales. In order to see different components, relationships, processes and feedbacks necessary for assessing resiliency of a landscape system, landscape architects should pay attention to the different nested scales. Many of the research studies on landscape resilience, though, only reflect upon the large scales (which is definitely necessary) and rarely address the local interactions (CUMMING 2011). This occurs because many landscape architecture projects happen at small-scale and practitioners in different levels of construction industry become more and more interested in incorporating the idea of resilience into their design (ASLA 2014).

2.2 CAD for a Dynamic Design

Here, the gap is the lack of principles and tools for designing resilient landscapes at small scales. Our design approach in small-scale landscapes focuses more on static scenes, even when we consider factors that are more dynamic. This is mainly because design is considered as the embodiment of the ideas and analyses in a fixed form, while the reality of landscapes are much dynamic and evolving.

Another contributing factor to inability of the landscape architects to reflect the changing nature of the landscape in the design process is the way that the discipline uses CAD. Computer-aided design started in architecture and caused a major paradigm shift in the way it is conceived and represented (VARDOULI 2011). Early in the history of computer-aided design, Yona Friedman emphasized how CAD can produce a "repertoire of possibilities" for the users to choose and allow them to see and correct the design errors. Errors can be determined based on quantitative rules in the context of design; e. g. size of the structure in an architectural design project. According to Freidman, the main potentials of CAD lie in its educative and adaptive nature and its ability to produce different design alternatives in a transparent process based on certain design rules (VARDOULI 2011). This rule-based participatory approach to CAD was faded away in mainstream design for years and it has come back strongly in recent decades as the idea of generative or parametric design.

Parametric design takes place through defining constrains/parameters of design and their relationship/dependency. Parametric tools are interactive; users can change the value of parameters (BIER 2013, STEINO et al. 2013). They can instantly visualize the change in the system and thus provide a high level of detail even in early stages of design. In the context of parametric tools, the designer will actually be able to design the rules rather than the object of design. From the simple rules, complex configurations can emerge and time-related parameters of design can help to trace the design through time.

Parametrics has been explored vastly in architecture, urban design and planning fields. Landscape architecture has been slow to embrace new technologies to expand design processes and techniques (WALLISS et al. 2014), and parametric design is not an exception. The discipline's use of parametric design has been influenced by the conceptualization and application of the parametrics in architecture, which is more focused on finding optimized forms. This happens because "landscape design solutions rely on transformation, growth, decay, flow, and settlement to produce evolving solutions" (WALLISS et al. 2014). The need for a distinctive approach for the use of parametric design in landscape architecture is apparent considering the differences between the two fields. The changing aspects of the landscapes require a more dynamic use of parametric design.

This paper focuses on planting as one dynamic aspect of landscape design. This aspect has been chosen for two additional reasons. First it can be easily parameterized and second, the large datasets showing the characteristics of many different plants are available online.

3 Design with Data: An Experiment of Planting Design with Processing

3.1 Urban Planting: Resiliency under Climate Change

Plants, as the living matter of designed landscapes, change regularly through the seasons. They also are affected by warmer average temperatures and extreme environmental conditions due to climate change. Although there are local nuances in their change or growth pattern through time, general rules exist that can help us to achieve a general understanding of the resiliency of the planting schemes.

There is a line of research that calls for adaptation strategies to buffer ecosystems against uncertainty resulting from climate change. Many adaptation strategies are concentrated on urban planning solutions for "sea-level rise, heat island effects, health impacts, and water treatment", while strategies for urban planting are limited (HUNTER 2011, 174). Hunter (2011) provides a rule-based approach to urban planting resiliency through rating the plant species based on ecological criteria for plasticity, functional redundancy, response diversity, and structural diversity. Ecological resilience is defined as the ability of maintaining ecosystem function under environmental disturbance and depends on both functional redundancy and response diversity. While functional diversity is defined as "the number of species contributing to an ecosystem function", response diversity deals with "the range of reaction to environmental change among species contributing to the same ecosystem function" (ELMQVIST et al. 2003; HUNTER 2011, 174).

As an example, Hunter (2011) points to a planting design with the goal of support for generalist pollinators. Here, functional redundancy can be achieved through having overlapping bloom times. For response diversity, the overall species that provide nectar should be flexible to the environmental variations such as both drought and flood events (HUNTER 2011, 175). The rule-based approach of Hunter (2011) adaptation strategies and the availability of large plant databases helped my experiment of parametric urban planting design with Processing programing language.

3.2 Visualizing Resilience in Processing

Focusing on the Hunter (2011) example of designing a garden with the goal of support for generalist pollinators, I created a sample planting scheme in Processing. Based on the discussed criteria of response diversity, we need to know in which month we will have the species in bloom and if there is enough overlap in bloom time. Changing the colour pallet of the planting scheme due to the species' different bloom times and colours is also important in terms of the aesthetic design decisions. Here, we're not limited by a fixed scene and can design the landscape with its changing nature. The response diversity of the planting scheme also depends on its functionality under severe environmental conditions. Three extreme conditions are considered: flood, drought, and extreme heat event.

Input Data

The application reads two CSV files. The first CSV file has the information for the plants' locations (the centre x and y), maximum size (diameter) and their associated ID. The sample planting scheme include trees and bushes. This file can be easily exported from an AutoCAD file of a designed planting scheme. Each ID is associated with a specific plant species that connects the first CSV file to the second. The second CSV file has all necessary information on the characteristics of the plants including bloom time, bloom colour, drought resistance, flood resistance and associated temperature hardiness. The base for second CSV file is retrieved from USDA Plant database (http://plants.usda.gov/). The related tags on the USDA plant database include flower colour, bloom period, drought tolerance, and moisture use. The associated hardiness zones and the exact bloom start and end month have been added from Hunter (2011) paper for this specific sample of the plant data. The bloom colours have been translated to hex keys. The bloom start and end months range from 1-12 represent the months of the year. The hardiness zones are listed from 1-9. The number of the hardiness zone in which the plant can survive represents its tolerance to temperature variation and is labelled as heat tolerance. The heat tolerance is added to the USDA plant database and is represented with the range of 0-3 where 0 represents no tolerance and 3 represents maximum tolerance. Drought tolerances are listed as none, low, medium, high which are respectively represented as values 0-3. The same range is used for moisture use.

Algorithm

The code checks the first CSV file and draws the plants relatively on the screen based on each plant centre location and maximum size (diameter). Then it searches on the second CSV file for the related characteristics for each ID. Based on the user input in the slider for different months of the year, each plant colour might turn to green (have leaves without bloom), grey (without leaves) and particular colour (the bloom colour when it is in bloom). When any of the extreme environmental conditions button is pressed the application checks for each plant tolerance to the related extreme event such as heat tolerance, flood tolerance and drought tolerance. If the value is 0 (no tolerance), the colour will change to black to represent the plants that may fail under that environmental condition.

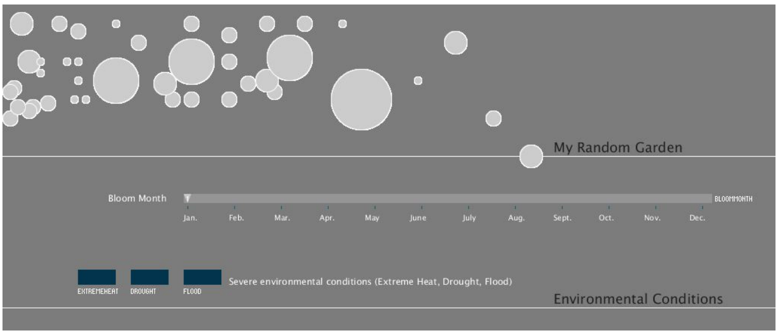

Fig. 1: The application shows the species in January. The slider can be changed to see bloom time and colour in different months of the year.

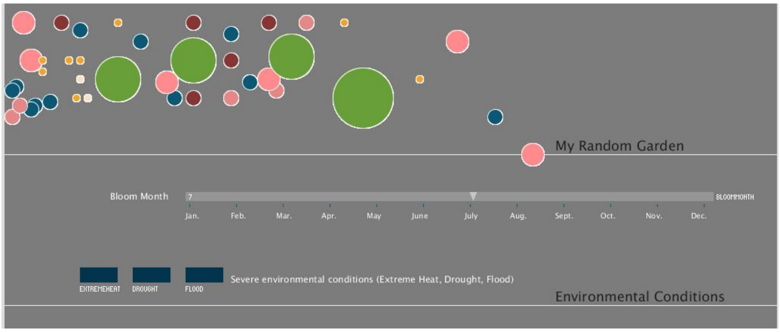

Fig. 2: The application shows the species in bloom in July. Bloom colours are shown based on the hex keys associated for each plant ID.

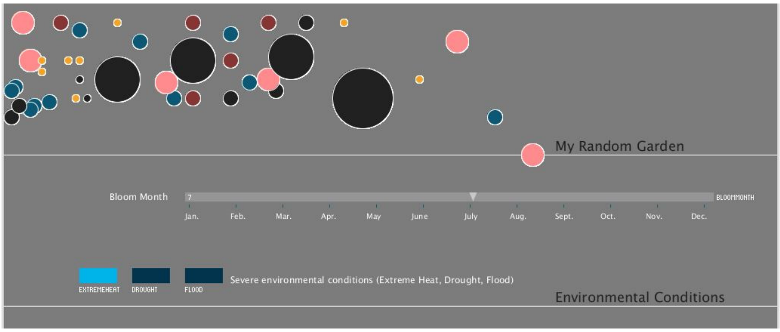

Fig. 3: Three buttons designed for severe environmental conditions. Here, the black circles show the species that will fail under an extreme heat event.

4 Discussion

The newer revision on the application also provides the number of species in bloom for each month and shows if there is both flood tolerant and drought tolerant species in bloom in each single point during pollinators' season. Although there are some limitations in using the application, it provides a dynamic platform for early design decisions. The main two important contributions of the application are in:

1) Providing an example of linking rule-based ecological design strategies to existing data for small-scale landscapes.
2) Incorporating the idea of resiliency to the early stages of design instead of seeing it as an ad-hoc strategy.

The limitation of this application is on linking the designed planting schemes with the data. Although exporting a CSV file for each planting design layer can easily be done in the existing CAD platforms such as AutoCAD and Rhino, for each change a new CSV file should be produced and be imported to the application code. While Processing provides a helpful platform for data visualization, the newer instances of this application can be designed as a plug-in for an existing CAD software such as Rhino. In doing so, the application can be integrated to the place where many possible users (landscape architects and students) design. The algorithm also can be turned into an online platform developed with HTML5 with the options for the real-time interactive design. In doing so, the application targets its user not only from design experts but also it provides insights for lay-users on how to design resilient small urban gardens. In this regard, the app can be considered as an expert system for facilitating public participation in resilient landscape design. The next step in the development of this application is to prototype different aforementioned platforms (software plug-in or web application) and try it with actual users for further evaluation on its function and user experience design.

Another challenge is that the USDA database does not provide all the necessary information. Although it is easy to add some of the needed factors to the database for small designs, it is important to find a long-term solution for gradual development of a plant database with all the necessary information for design/analysis. A more detailed database that has, for example, the annual average growth for each species also helps to simulate other time-related factors such as growth pattern in time. The growth pattern can consider other spatial factors such as plant initial size and plant spacing. Here, a more detailed database allows for analysing direct relationships between the planting scheme's spatial configuration (including plant volume and spacing) and its resiliency under different environmental stressors.

5 Conclusion and Outlook

Time has been always an important factor for landscape design in any scale and is an indispensable part of landscape resilience analysis. However, the lack of approaches and tools for incorporating the dynamics of resilient landscapes in small-scale design, in many cases, results in designs that are the static renderings of fixed scenes. In the context of ever-increasing attention to resilient landscapes and access to big databases, this paper argues that the border between data visualization and design should be blurred. Data visualization as one approach to parametric design can fill the gap between the rule-based approaches to ecological landscape design and specific design decisions at site scale. Although the quality of visualization outcomes is always dependent on the quality and quantity of data and the extent to which our resiliency rules are comprehensive, they provide a base for exploring the dynamicity of landscape through time.

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