New Technologies + Algorithmic Plant Communities: Parametric / Agent-based Workflows to Support Planting Design Documentation and Representation of Living Systems

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Abstract: Planting design is a complex process: designers work with living, dynamic materials that change, evolve, compete, and thrive in ways that are difficult, if not impossible, to predict, and which evade simple modes of visual representation. This paper presents a set of agent-based parametric design tools, developed by OLIN, a landscape architecture, urban design, and planning firm based in Philadelphia, USA. These new digital tools have transformed our capacity to understand, create, and visualize planting design by managing and representing layers of complexity in real time, throughout the entire design process. Exploring such innovative digital workflows, tools, and methods in the realm of design with living systems is utterly important for the development of landscape architectural practice.

Keywords: Landscape visualization, agent-based, agent-based modeling, landscape architecture, digital representation

1 Introduction

As a practice, our firm solves representation and design challenges daily, often in the context of living systems. We are committed to addressing these challenges with a constantly evolving set of technical and representational tools and methods, developed specifically to support planting and ecological systems design. Olin Labs is a community of practice at Olin which, in addition to participating in original research, supports Olin's designers in discovering new processes, methods, and tools to improve our design and problem-solving capacity. Labs is organized into five interdependent research and development Labs: People, Tech, Build, Eco, and Design. Each Lab is responsible for working across design teams in order to identify larger trends in our project work and within the landscape architecture field to identify opportunities for innovation and positive impact. The research and development work that is described in this paper, explores agent-based planting design and is organized within both Eco and Tech Labs as a response to specific project work. This project work provided an opportunity for us to explore the relationship between new technologies, ecological design, documentation, and representation of plant communities.

The goal of this research was to explore and determine efficient workflows to support the design of living systems from early design stages all the way through sharing our vision with our clients, the general public, and our professional colleagues. By testing an exploratory, agent-based workflow between AutoCAD, Rhino, Grasshopper, Python, LandFX, and the Adobe Suite, we were able to better articulate design constraints, generate iterations, graphically represent our ideas, and present the work in a compelling way.

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This paper explains how these innovative workflows can be applied in the professional practice of landscape architecture and shows how project design strategies can evolve simultaneously with technology.

2 Purpose: Spatial Representation of Plant Communities for Design and Communication

First, it is important to understand the role of landscape visualization in relation to planting design. Often, while designing plant communities, designers are inspired by natural archetypes to direct plant selection and spatial arrangement of species. Claudia West describes the shortcomings of typical modes of representation in using nature as a reference for thriving plant communities in urban settings when she writes that "the essence of a plant community is the layering of different species [...] for designers accustomed to creating design in plain view, representing multiple layers of planting is often difficult. Drawings representing planting beds filled with circles or hatches may look full but in reality, there are often large areas of bare soil underneath shrubs and trees. In fact, the graphic techniques used by landscape architects often encourage the large masses of single species that typify their plantings" (WEST & REINER 2015). For example, when translating a complex ecosystem such as a Piedmont forest into an urban project, designers tend to simplify its representation, and by extension, to lose the plant diversity that makes the natural model most powerful. Typical two-dimensional representations may be successful in showing textures and species differentiation, but they often lose some of the qualities, complexity, and richness of ecosystems. They also fail to provide a full sense of space. Three-dimensional studies of planting communities can help to fill this gap in practice and furthermore they can help understand such aspects as the appearance of a garden, its functionality, and its spatial qualities.

Fig. 1: Ecosystem representation

Moreover, digital models are the most common tool used by designers to test, iterate, and speculate. CANTRELL (2019) mentions that by virtualizing the physical word it allows us to visualize more complex systems. The ultimate goal is to loop the data we are pulling from reality into ways to design, manage, maintain, and generate design proposals. But as mentioned before, these models are a simplified abstraction of reality. Most of the current 3D modeling software available for landscape architects provide a limited library of plant material. As a result, design iterations can portray generic, out of context, and dull representations of ecosystems. To avoid this problem, we explored Agent-Based Modeling (ABM). "ABM is an emerging approach to modeling complex processes and phenomena […] it is capable of depicting global consequences resulting from local constituent units, therefore is a potential tool to represent and analyze complex and dynamic processes in ecological and environmental applications" (CHENG 2012). BONABEAU (as quote) has captured the most essential characteristics of ABM saying that it "captures emergent phenomena; it provides a natural description of a system; and it is flexible". In a similar way, planting design and living systems deal with emergence, time, and change. The establishment of a plant community takes years and continues to evolve over time. By using ABM which "offers the possibility of constructing dynamic simulations at different time-scales," designers can speculate about the spatial qualities and appearance of a designed ecosystem based on real data and environmental factors across longer timelines (POPOV 2009). By exploring agent-based workflows under the lens of documentation and representation we are able to understand detailed ecological phenomena in space and time.

3 Methodology

We developed a four-step strategy to test different agent-based workflows. Each step aimed to avoid linear processes in order to generate a rich design workflow. This helped to support decision making from diverse perspectives meeting the clients desire for a naturalistic planting and our design vision. We began with a clear planting strategy and a deep understanding of our planting selection. The plant palette of the case study drew its species from four landscape typologies that occur within the watershed of the Delaware River where the project sits: Piedmont Forest, New Jersey Hardwood Swamp, New Jersey Atlantic Cedar Swamp, and New Jersey Mixed Oak Forest. Until this point, we followed a rather traditional planting approach. We then generated and documented multiple planting design iterations with agent-based models first, and then using CAD and LandFX for documentation. This process helped us to very quickly quantify plants by species and communicate with other members of the team. We then used custom-built Grasshopper plugins custom-designed by Olin's Tech Lab leader Chris Landau, to visualize and study the proposal three-dimensionally in Rhino for its spatial and aesthetic qualities. Finally, we added a final layer of information to our process: time. We accomplished this by using an algorithm which animated the bloom sequence of each design iteration in order to understand changes in color and texture throughout the year. Each of these four steps is described in further detail below.

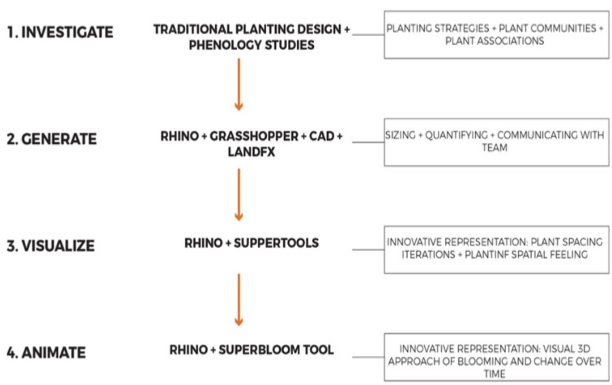

Fig. 2:
Goals and objectives at each of the four steps

4 Project Application

4.1 Investigate: 2D Studies – Understanding Plants as a Living Material

Software and media: Hand drawing, Photoshop, Illustrator

The success of the research relied on our thorough understanding of the plant palette. The first and most important step in the process is to have a rich selection of species, and to understand each species in terms of biological characteristics, phenology, and aesthetic qualities. Following plant research and selection, analog and mixed media graphics were used to capture the characteristics of each plant and to ensure correct location on the plan with regard to the different microclimates of the site. A schematic planting plan was generated and digitized in AutoCAD for further development. During this process plant characteristic were documented in a spreadsheet that included information such as ecosystem typology, habit, dimensions, light requirements / shade tolerance, salt tolerance, water requirements, leaf color, bloom color, and bloom time. This simple spreadsheet was an important component that allowed us to track our changes to the planting palette and the resultant evolution of the garden throughout the seasons. Portions of this spreadsheet were later utilized to generate different blooming simulations of selected plants within the designated vegetated areas.

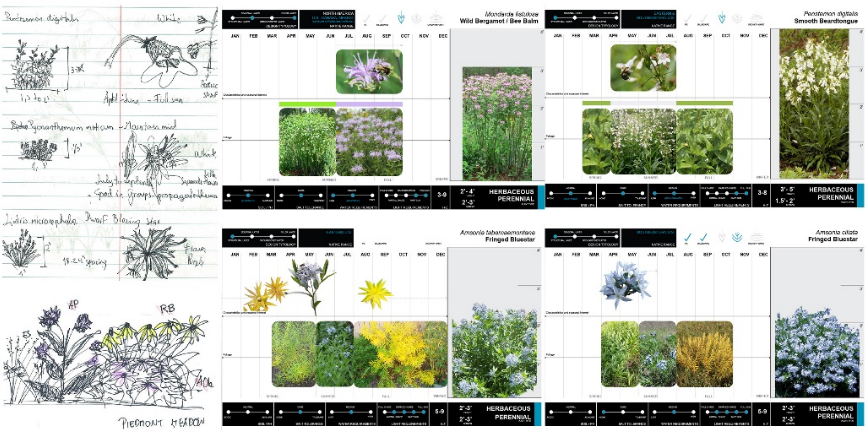

Fig. 3: Phenology studies

4.2 Generate: 2D Studies – Speculating but not yet Documenting

Software and media: AutoCAD, Rhino, Python+Grasshopper, LandFX

In traditional planting design representation, mixes of species are represented by hatches. We used agent-based design tools to interpret plant mixes in a more realistic way as plants do not follow a rigid grid but organically find their place. Our design team established the design criteria that set the parameters for the automation. Each species was represented with a specific, individual block that was sized to accurately represent its form and dimensions at maturity. Static elements such as existing tree root balls and manholes were located, then each vegetated area was populated with points with a given spacing using one of the custom-build tools in Rhino according to our team's pre-established parameters. These points were replaced with generic circle blocks, which then were distributed automatically according to specific plant characteristics and spacing documented on the master planting spread sheet. Blocks were automatically selected to respond to mix percentages. As an example, Mix A was comprised of three grass species: 50 % of Bouteloua curtipendula, 25 % of Andropogon virginicus, and 25 % of Sorghastrum nutans. By selecting 50 % of the generic blocks and defining those as Bouteloua curtipendula an accurate number of individual species and plant counts were established through a randomized selection within the overall mix. This workflow allowed for a naturalistic placing of plants.

While this mix generation process had great results in terms of design quality, documentation was still needed. A traditional set of drawings was required for coordination with other professionals. To tackle this task, the agent-based model was imported into AutoCAD. Rhino blocks were replaced with LandFX blocks. During this step species counts were tested and documented, and a standard planting schedule was generated.

The first set of drawings showed the rich complexity of the planting mixes instead of generic hatches. While sharing this work many good questions were raised. When technology allows designers to go beyond the imaginable, how can documentation follow these advances? Can we use complex digitally generated models to share the naturalistic planting designs with contractors? Is it possible to move away from traditional documentation for a better result on site when constructing naturalistic plant communities? Can ABM link phenological plant data from other disciplines such as horticulture, botany, or ecology with landscape architects and designers? For the final submission we took a step back and developed a more traditional set of planting drawings with hatches representing different plant mixes and symbols for trees, shrubs, bulbs, and ephemerals. Nevertheless, we used our agent-based drawings for the planting mixes' details.

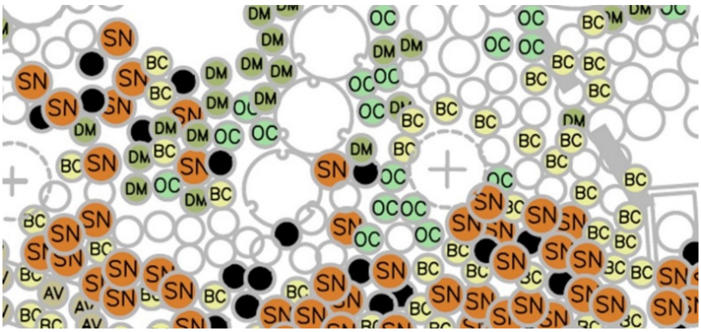

Fig. 4: Initial planting set sample

4.3 Visualize: 3D Studies – Spatial and Aesthetic Analysis

Software and media: Photoshop, Rhino, Phyton

As the process continued, more challenging questions came up. Testing the design in 3D models was fundamental to ensure that the desired quality of space was being realized. In order to test our design iterations in 3D we used Rhino billboards, 3D representations of vegetation that use simple raster surfaces in a 3D environment. We created our own billboards, usually one or two per species, in order to allow for a more complex and varied representation of textures and seasons. More commonly used 3D software, such as Lumion or Sketch Up, only allow for the representation of planting material with their built-in, default vegetation library. So, even though a model can be easily populated in those programs, the resultant images can be generic and nonspecific, inaccurate, and often repetitive. The intention behind using customized billboards in Rhino is to avoid nonspecific representation of vegetation and to more accurately represent the ecological function and aesthetic outcome of the designed landscape. The images we generated with the Rhino billboards were curated and targeted to represent not only particular species, but selected cultivars as well, and this allowed us to represent sizes, seasons, and unique qualities as accurately as possible. These representations of the evolving design provided insight into how plants relate to each other and to their surroundings and gave us the ability to more quickly and accurately develop design solutions for the project and to answer critical design questions: Is the allée of trees giving the feeling we are looking for? Should Mix A have taller plants along a path? Is the plant spacing leaving too much room for weeds? Additional design decisions were made after understanding the physical and spatial qualities of each plant community iteration. Perspective renderings from various angles were quick to generate, allowing us to see the site holistically, and rapidly.

Fig. 5: Rhino Billboards

4.4 Animate: 3D Studies – Seasons and Time

Software and media: Rhino, Python+Grasshopper+Photoshop+Illustrator+AfterEffects

"Plants in the landscape present one of the most daunting challenges to modeling and visualization because they encompass such a range of levels of detail" (ERVIN & HASBROUCK 2001). This statement mirrors our thoughts after 3D testing our case study design. We made many discoveries and yet so many elements of the plant community remained outside of our representational abilities. Specifically, the sequencing of bloom times for flowering plants and seasonal foliage change needed to be studied further. After several weeks working in collaboration Tech Lab built the Superbloom tool, designed to allow designers to animate the seasonal sequences of bloom times and foliage change by inputting flower size, time, and color. A similar approach was used in previous project work in order to animate rendered plans that illustrate bloom color and duration throughout the year. This technique for creating a 2D drawing was developed further to create our 3D representations and utilized ABM to generate point clouds in each billboard determined by parameters based on quantified aesthetic qualities. Our agent-based model comprised four subsystems: (1) fixed elements such as proposed trees, shrubs, and manholes, (2) flexible groundcover layer of perennials, grasses and bulbs represented with billboards (3) environmental elements including terrain, and (4) point cloud layers (one for each flowering species.) For this process, selected species were analyzed individually with a nuanced perspective which led to fascinating results. The next step in the process was to take advantage of the nature of ABM, which deals with complex systems that consist of "many basic but interacting units (COVENEY & HIGHFIELD 1995, as cited in KOCH 2006). We overlaid all the species' bloom data, revealed how these evolve over time, and tested the overall visual outcome of the planting design. This agent-based technology helped us to simulate this dynamic, non-linear phenomenon. Each simulation allowed us to understand the evolution of each species during every month of the year and, as a result, we were able to represent and understand how the design would perform over time.

As a final step, and to summarize this complex design process, we made a video of the bloom sequence over the course of spring and summer. We started with exported images from the Superbloom tool and from the Rhino model. We created a framework for the animation in Adobe AfterEffects by connecting plant images, species names, and bloom time, duration, and color. AfterEffects provided us with the ability to represent additional design factors and existing conditions of the site such as sun and shade, water availability and hydrogeology, and underground infrastructure, in addition to our proposed design. This final video was a useful tool for sharing and describing our design, as well as our design process, to our client, our peers, and to a broader audience outside of the landscape architecture field.

Fig. 6: SuperBloom render

5 Conclusion

After a process that entailed several months of work, extensive trial and error, and many designs iterations – a few conclusions about the importance of the relationship between new technologies, ecological design, documentation, and representation of plant communities were identified.

First, the tested workflows helped to develop a rich and innovative approach to planting design, while also raising questions regarding how we communicate our work to other professionals and with a general audience. Second, designing plant communities three-dimensionally assists in understanding the spatial qualities and aesthetics of plant selections, while developing a deeper, and more efficient design process. Additionally, experimenting with various media to create final deliverables should be an ongoing challenge for landscape architects.

Finally, it is undeniable that ABM is suitable to generate and represent the dynamic evolution of plants, as these newly emergent processes and tools assist designers in understanding the inherent complexity and detail required for successful planting strategies. ABM also affords designers a means to utilize environmental data in our work, and for it to be managed and accounted for throughout all phases of the design process. It is utterly important to mention that the ABM software development collaboration between the project designers and the in-house tool developer was the key to the success of the research. It is important for designers at landscape architecture firms to keep testing and pushing technology to advance our abilities in landscape representation.

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