

Holographic Construction of Generative Landscape Design Using Augmented Reality Technology

Yumi Lee¹, Soomeen Hahm², Jaeheon Jung³

¹Seoul National University, Seoul/Korea · yumil@snu.ac.kr

²Southern California Institute of Architecture, Los Angeles/USA

³KOH SX Studio, Seoul/Korea

Abstract: The Augmented Landscapes project is a workshop exploring the making of landscape solely with 3d models and AR devices without any processed drawings. The workshop promoted generative landscape design by inserting landscape elements by utilizing a multi-agent system based on the Boids algorithm. Microsoft HoloLens with the Fologram plugin allowed for a direct and real-time connection between Rhino and HoloLens. This paper documents the process, methods, and findings of the workshop with the holographic construction experience through AR technology.

Keywords: Augmented Reality, Mixed Reality, HoloLens, algorithmic design, smart construction technology

1 Introduction

In recent years, digital manufacturing technology has rapidly developed in the fields of architecture and engineering. Research is being actively conducted on automated construction using 3D printers and robots. However, digital manufacturing technology is often found to be limited when dealing with sophisticated and complex processes. It still relies on human labor owing to the complexity of operations and the fragility of materials (HAHM 2019).

The dependency on human labor is even stronger in the case of landscape architecture, which involves topographical features and planting materials as the main design elements. In the field of landscape architecture, construction technology automation has proceeded extremely gradually, owing to the fragility of the materials held by soil and plants. Automation has been applied mainly to design and documentation processes. It is thus essential to ensure efficient transition from design to construction phases. In this regard, introducing augmented reality (AR) technologies into design and construction processes will prove to be a vital breakthrough for landscape architectural practice.

Although AR is not a new concept, this technology has become mainstream only in the last three years, owing to the development of consumer AR devices (COPPENS 2017). The release of Microsoft HoloLens in 2016 made this technology more accessible to the general public. In particular, its development kit opened this technology up for amateur developers. Since then, architectural researchers and practitioners have increasingly started investigating AR. The examples of the use of AR in physical construction are projects such as Steampunk (Steampunk Pavilion 2019) and the projects from a research cluster – Augmented Craftsmanship – at the Bartlett (HAHM 2019).

2 Precedent Study

Designers and researchers have used AR construction methods. An exemplary project is the Steampunk pavilion in 2019, designed and built by a team of architectural designers and AR software developers. This project introduced a traditional crafting technique of the steam-bending process. This process has existed for thousands of years but is generally constrained by certain mold shapes, as the process requires timbers to be mounted during the drying process, which usually requires many hours. Conventionally, steam bending has always been performed on fixed molds, as it takes a lot of time to build one mold; however, Steampunk pavilion invented a customized molding system using simple custom-angled racks. These custom racks were placed and manually fixed by professionals wearing AR devices in order to create molds without any blueprints, robotics, or machines. This helped speed up the mold-making process, allowing each timber board to assume different shapes. This project allowed us to understand better how human intelligence and computational accuracy can perform collaboratively.

AR devices are especially useful for providing and guiding accurate spatial locations in large 3-dimensional (3D) spaces. If there exists a precise virtual 3D model, projecting it for human eyes would be easy. However, the physical world is distinctly different from the digital; hence, during the construction process, multiple errors and differences would be encountered when compared to the original digital model. Although AR devices can scan existing physical environments in real-time, the scan is still inaccurate. Accurate scans of the physical world require an additional process in order to feed to digital models for any interaction. In the Steampunk pavilion project, the design team custom scanned physically produced timber boards into a digital model using custom tools (i. e., by digitizing the physical model) only for some areas, as it requires additional customized joints. The project also utilized a design language that allows a high degree of tolerance in design accuracy.

3 Experiment: The Augmented Landscapes Workshop

This paper documents the process, methods, and results of the workshop with the holographic construction experience through AR technology. A workshop was conducted with 12 Masters students as a part of the Augmented Landscapes project. The workshop began by introducing smart construction technology via virtual reality (VR) and AR and sharing the convergent cases in architectural design later. Participants were grouped into three teams. Approximately 30% of the participants did not have prior experience with digital design tools, whereas the rest could perform basic computational techniques. The experiment was designed to test the holographic construction of complex design elements. A circular disc was set as the target site in the Rhino software. The Boids algorithm was used as a generative design tool in order to introduce complexity in the design (REYNOLDS 1987).

3.1 Dealing with Absolute Position vs. Relative Position

From a few AR construction projects, including Steampunk, we learned that augmented methods work exceptionally well when dealing with processes that require digital models to guide to an absolute position (instead of relative position) in 3D spaces. Before explaining further, it is necessary to clarify the difference between absolute and relative positions of parts. For example, an actual world coordinate is an absolute position, but a relative position

is the position of a part relative to its adjacent parts. Naturally, in the physical world, and especially in 3D structures, when parts accumulate in the direction normal to the ground, the relative positions of the parts are more important indicators than the initially designated absolute position.

For example, if the construction material/components perform relatively precisely to the actual digital model (such as brick structure), then absolute position stays constant for the entire process. However, if the material is very flexible, the assembly process typically requires a clear understanding of part-to-part relationships instead of their absolute position or orientation. Steampunk pavilion worked out well, having the combination of fixed ground position with the accumulative assembly process between parts, which showed synergy between AR assistance and human intelligence. Furthermore, we also learned that this process has excellent benefits when dealing with groundwork, which usually requires an absolute position in spaces. AR technology has no limitations in scale, and it works better for projecting or scanning larger objects than smaller objects. Therefore, we see much potential of this system used in Landscape design.

Landscape construction typically requires delicate planting processes, which require manual labor; hence, there is considerable benefit in introducing this method to landscape construction. Compared to conventional methods, this method will prove to be more precise in communicating design ideas with creators. Moreover, it will eliminate any complex robotic processes that generally require highly skilled technicians and a long preparation time.

3.2 Generative Design with the Boids Algorithm and C# Library

As the AR construction process is beneficial for combining computer intelligence with human intuition, we have been extremely interested in building and constructing forms that cannot be conceived by the analogue methods. When used as a multi-agent system, computers can often generate geometries that are highly complex yet highly controllable, which usually is difficult or even impossible to be designed or sketched manually. As our proposed

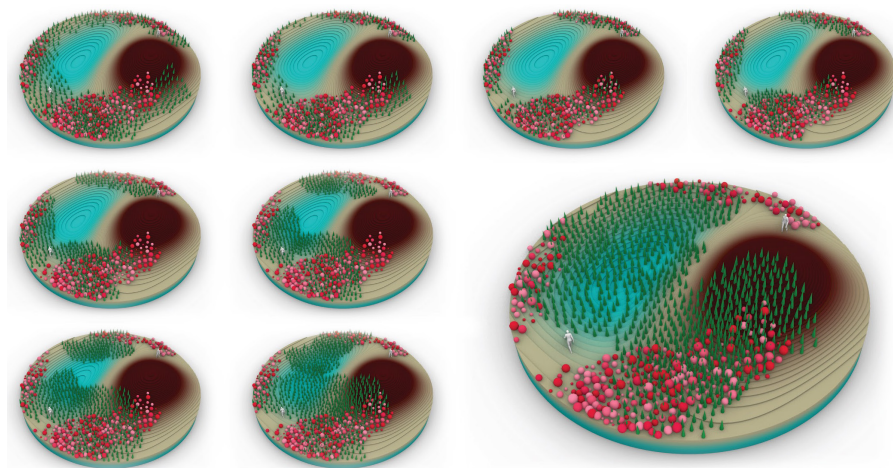


Fig. 1: Design alternatives using Boids algorithm

construction method is already manual, we consider that manual designing is not the best way of applying this method. This is because herein, the computer performs merely as a representative tool (i. e., as a projection tool).

We introduce the Boids algorithms in this workshop for educational purposes in order to elucidate generative modeling methods during the initial design process. This algorithm is widely used for design applications such as wayfinding for crowd simulation. Moreover, it is widely employed by designers who utilize a generative design method to create forms and shapes that cannot be manually designed in conventional practice. The algorithm is controlled by three simple principles: separation, alignment, and cohesion. Furthermore, it is set up such that the overall behavior can be intuitively controlled in real-time.

A grasshopper file with the Boids algorithm was provided as a generative design tool to perform computational design. The grasshopper file's parameter allowed for the generation of infinite design iterations that could be applied to the design of terrain and vegetation. The tools were developed specifically to design nonmanual/computer-generated patterns, shapes, and geometries. A device was used to insert a large number of landscape elements, which reduced the requirement for manual control and increased agent-based control. This is referred to as multi-agent modeling using object-oriented programming.

Although we used the Boids algorithm to mimic crowd behavior and populate a large number of elements, we noted the more significant potential of extending this tool, as there are various ways of translating this algorithm to manifest different types of geometries. It is also possible to translate the resulting data sets into a collection of useful information for the future design process.

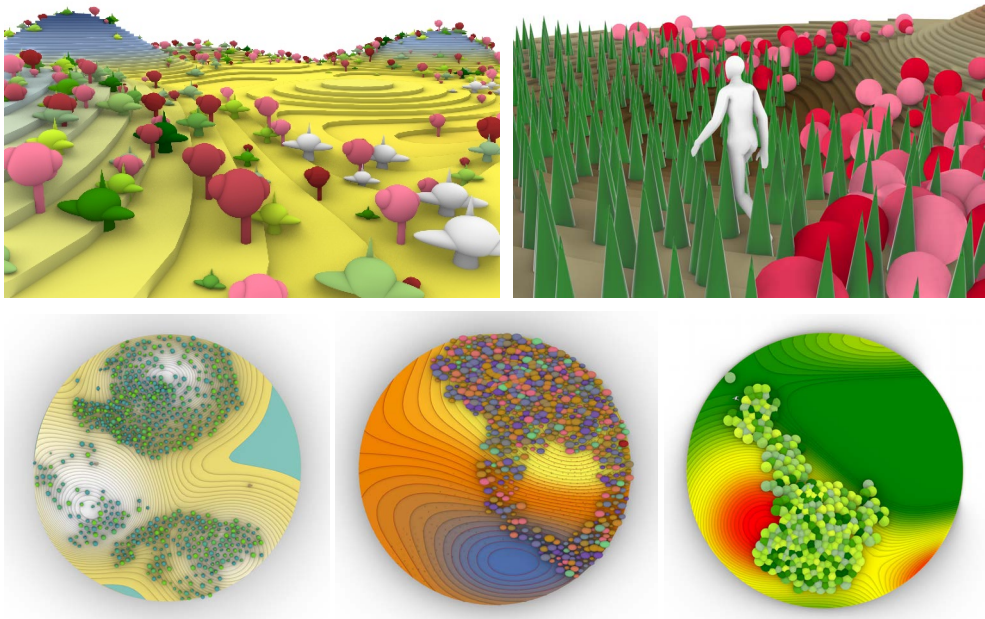


Fig. 2: Perspective views and plans of 3D model

C# was used as the primary coding language. It was compiled with the RhinoCommon and Grasshopper APIs and organized as a Rhino Grasshopper library to enable complex text-based coding that can be easily accessed and used by nonexperts. Even though C# is programmed in a text-based coding platform, it can be used within the Rhino Grasshopper platform because it is compiled as a library. The entire process from designing to fabrication could be performed within the same software environment as generative design, and AR communications were controlled within the Rhino software. This process provided a designer-friendly interface and a fluid design for production workflow.

3.3 Microsoft HoloLens and Fologram

We used Microsoft HoloLens as the primary hardware device and Fologram as the leading software to project a holographic template to be experienced in the real world at a 1:1 scale. Fologram is a plugin that was mainly developed to simplify the link between HoloLens and 3D modeling software, as most of the AR operating software are game engines such as Unity3D or Unreal. This game-making software is often potent in dealing with interaction, interface, and simulation. However, they usually are not very good at dealing with modeling. Fologram enables designers to rapidly and efficiently deploy virtual models to Microsoft HoloLens. Users can make real-time changes; this allows for quick review. This experimental setup, involving Microsoft HoloLens with Fologram plugin in the Rhino Grasshopper environment, has the same tools as those used in the Steampunk Pavilion.

Introducing Fologram allows us to manipulate geometries in our typical design environment while being able to add AR functionality simply. Fologram currently only operates in Rhinoceros; therefore, it became our chosen software platform for our design exercise. Also, this platform has great potential in developing custom tools using scripting. It became a perfect environment to start exploring our research agenda.

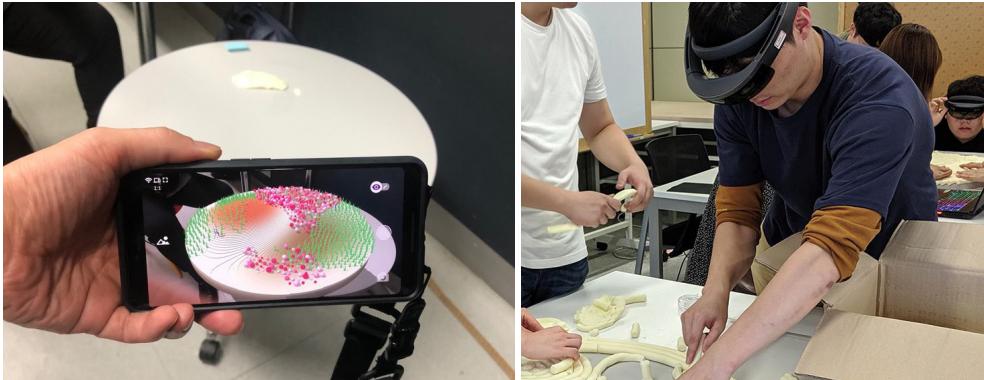


Fig. 3: Augmented reality by Fologram and model making with Microsoft HoloLens

Holographic lenses were used as the primary design communication tool for creating physical models. Using Microsoft HoloLens, the result of the generative design was virtually floated over a wooden disc with a diameter of 70 cm to create a stereoscopic model. A set of HoloLens was provided to each team. The holographic leader of the team reviewed the design as an augmented instruction for the on-site construction of a physical model. A topography

was created using ivory-colored modeling clay by adjusting the height to match the holographic model.

3.4 Results

The results of the workshop were evaluated via exhibitions and reviews. Participants indicated positive responses to intuitive instructions and immediate communication. The most acknowledged advantage was that the process of creating stereoscopic models using HoloLens did not require a large amount of processed data and that it printed base drawings, or sketches.

Program tutorials with algorithm design and model creation using AR technology required five hours, which was perceived as a reasonably short duration compared to the conventional design and model-creation processes using drawings and sketches. The limitation was that the narrow viewing range of HoloLens reduced the impact of immersive experiences, and the requirement for efficient communication methods between holographic leaders and general users was discussed.

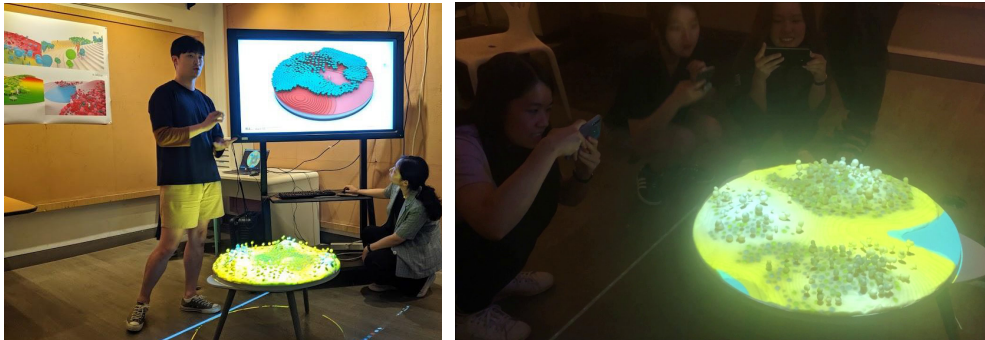


Fig. 4: Final presentation and 3D projection

4 Conclusion and Discussion

This research contributes as one of the first experiments that use mixed reality in landscape architectural design and construction processes. The workshop promoted generative landscape design by inserting landscape elements by utilizing a multi-agent system based on the Boids algorithm. Microsoft HoloLens with the Fologram plugin allowed for a direct and real-time connection between Rhino and HoloLens. Therefore, we could execute real-time generative design elements by constructing virtual models in physical materials directly from designs without any printed drawings.

AR/VR technology is being mainly developed and used in the entertainment industry. Most hardware/software is developed for gaming purposes. In the architecture and landscape fields, AR is still mainly utilized as a representative tool. However, we consider that this technology has potential beyond being a virtual experience provider or representational tool. We consider that this technology can help us shape our physical reality instead of remaining in the virtual world. For this reason, Fologram is an excellent example for AR/VR developers to consider

the out-of-the-box application of this technology and actively develop more creative and insightful methods of applying this technology in different fields (JAHN et al. 2019).

There are still numerous technical limitations, mainly owing to the amateur use of the hardware device, the limitations of viewport size, the resolution of projected images, the weight of headsets, and the sensitivity of the device in a bright environment. The second generation of Microsoft HoloLens appeared to overcome the majority of current limitations. We believe that advanced development in this technology will flourish.

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