Depicting a Landscape Architectural Installation Using Augmented Reality

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Abstract: The Augmented Depiction project is a workshop for fabricating a landscape architecture installation for the Seoul Biennale of Architecture and Urbanism 2021 using augmented reality (AR) technology. The fabrication process is divided into four steps to make it easier for students to understand the design and AR concepts. The workshop is focused on comparing the efficiency of the AR method from an educational perspective as well as time and cost. This project had allowed participants to understand the human-computer-machine interactions using AR technology and determine the value, potential, and efficiency of AR craftsmanship when a computational design was realized.

Keywords: AR fabrication, augmented craftsmanship, fabrication workshop, HoloLens, computational design

1 Introduction

We are living in an era of augmentation (KING 2016), and augmented reality (AR) is no longer a new concept, becoming a common technology in the development of AR devices (COPPENS 2017). The growth of AR technology markets has also increased the usage of AR and mixed reality in the manufacturing field beyond popular smartphone applications. With the development of automated construction and robotic production technology, wearable devices free up both hands of the workers, facilitating their workload. Therefore, rather than using a robot, it is possible to develop an efficient fabrication process that reduces the time and cost of human workers using their hands and eyes (JAHN et al. 2019). Some examples of this idea have been applied to various constructions, including Steampunk Pavilion in Tallinn, Estonia and Augmented Grounds in Quebec, Canada. Both projects were built entirely while wearing HoloLens, an AR device from Microsoft, without the use of blueprints or machines (LEE et al. 2019).

In particular, the Steampunk Pavilion is a handmade architectural project that applies the traditional steam-bending method for wood. It uses materials that are difficult to handle with machines, and complex shapes that are difficult to understand through drawings alone. This can be seen as an example of the advantages and efficiency of the AR production method (STEAMPUNK 2019). By contrast, Augmented Grounds, the original subject of this study, is a relatively less complex landscape project in an easy-to-read form. However, the reason this project was meaningful is that, during the early pandemic period when skilled workers were unable to visit the site, only two students who were unskilled in either AR or construction were able to quickly fabricate the same result as the pre-designed drawing (AUGMENTED GROUNDS 2020).

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Landscape architecture can be defined as "concerning with the relationship of man(kind) to his/her environment, dealing particularly with how the environment is perceived, valued and manipulated." (STILES 1994). The important values of landscape architecture are that, humans manipulate both outdoor and indoor environments at various scales and gain various experiences and perceptions through their relationship with the environment. In this study, we attempted to transform an outdoor landscape project into an indoor environment allowing people to experience an artificial landscape within an indoor environment.

First, we focused on two main areas: a) How deeply can students without experience in AR production build a landscape model for understanding and grasping the intentions of the designer after taking a class? b) How effectively can an AR construction be achieved when the same shape is produced through robotic fabrication? Although the AR production method is already being actively used in various fields in the educational area, allowing a student to implement his/her own design remains different from producing the work of other designers. In addition, it is assumed that a design of moderate difficulty would be suitable for comparison when applying various production methods with the same shape. We aimed to review the process and its results while producing a small installation.

2 Materials and Methods

2.1 Design Process

The main computational design concept was derived from the Metaball algorithm, which is a graphic form that shows a natural spherical connection by merging two other atoms. This algorithm matches a mixture of diversity and is one of the concepts of AUGMENTED GROUNDS (2020). Likewise, the installation of this study was designed using the same concept because it also meets the main theme of the Seoul Biennale of Architecture and Urbanism 2021, i.e., *Crossroads, the complexity of the relationships that shape our cities and to the key* (SBAU 2021), of which this project is a participant. Both projects aimed to achieve an artificial landscape where people could rest and play, and thus, the hill that appeared from

Fig. 1: AUGMENTED GROUNDS (2020) and Installation Design

the sphere of a Metaball could be said to be a form that satisfies such needs. In addition, by turning the shape of the hill on the floor and installing the hill shape in the air, visitors can see, touch, and feel the design more three-dimensionally. We attempted to create a new relationship between humans and the environment within the exhibition through the experiences of visitors. Although this installation was designed for an indoor exhibition, it was also an attempt to create another version of an artificial landscape in the future. In this sense, we wanted to use a human-driven process rather than the CNC method, which cannot be used in an outdoor environment. We chose the AR method, which allows nonprofessional construction personnel to easily participate in the construction.

2.2 Pre-setup for Fabrication of Augmented Reality

Digital modelling that can be efficiently applied in AR was prepared. We prepared the shape as a line segment using a contour, which allowed the worker to easily understand the detailed shape. Meanwhile, it is difficult for ropes to perfectly match the thickness or length through digital modelling; thus, the actual winding direction of the rope was not modelled individually. Moreover, because the designers worked together during the production stage, it was possible to make an immediate judgment of the design location, which clearly shows the ability of AR craftsmanship to make design decisions according to changing circumstances (HAHM 2019).

2.3 Fabrication Workshop

Twelve graduate students majoring in landscape architecture conducted a fabrication workshop to produce the installation. The fabrication process consisted of four steps: crafting, shape maintenance, rope winding, and reinforcement.

The first step, crafting, involves creating upper hanging objects and the curved shape of the lower part. We used balloons to produce the shape of the upper-hanging object. We implemented this shape by continuously checking the holographic model using HoloLens. Balloons can quickly form a curved shape and can be easily removed. However, balloons are weak, making it difficult to control and maintain their shape. For the lower part, the main material was changed to Styrofoam to divide the shape into four pieces, considering the ease of later movement and the construction stage. After setting up and stacking the Styrofoam, we projected the AR model onto the floor through HoloLens, allowing the creator to interact

Fig. 2: Shaping with balloons and cutting Styrofoam (view with AR holographic model)

with the AR model in real time and efficiently shape it with a heated wire. The fabrication itself was similar to that of CNC because we cut out the foam, although only by human hands. As the advantage of this method, the material itself is relatively more stable than a balloon, making it easy to maintain its form. Implementing a computer-aided curved 3D model using AR is more accurate (Figure 2).

The second step is to maintain the shape. We used a metal mesh wire and plaster bandage to keep the shape of the base more rigid. To maintain the shape of the upper base, we covered the balloon with an air cap and applied a wet plaster bandage. As the plaster dried, the balloon firmly held its shape. By covering the mesh wire on top of it, it was possible to keep the form even tighter and easily attach the rope. The lower base shape maintained a solid structure, and only the metal mesh wire was covered and fixed (Figure 3).

Fig. 3: Covering the object with plaster bandage and metal mesh wire

The third step involves winding the rope. We implemented the rope design pattern by attaching ropes of various colors to the base form and the metal mesh wire using a glue gun. Owing to the material properties of the rope, it was impossible to completely match the 3D modelling, and errors inevitably occurred. To implement a rope pattern as similar to the design as possible, the person winding the rope used their judgment while checking the AR model in real time. The creator had to attach the rope based on certain judgments, such as which direction to wind the rope, how many lines to wind, and how to twist it while checking in real time through a combination of the AR model and reality (Figure 4).

Fig. 4: Positioning rope with AR devices and winding with a glue gun

The fourth step is reinforcement. To enable people to touch, climb, sit, and run around the installation for an extended period, we needed to reinforce the rope. In addition, reinforcement was essential for maintaining the shape of the upper hanging rope installation. The resin was used to strengthen the rope in a solid form resistant to contamination. It was applied to the rope, and after the resin dried, the rope became harder and retained its shape. In addition, we changed the material to one that was resistant to contamination. We completed the landscape architectural installation through the AR fabrication workshop (Figure 5).

Fig. 5: Applying resin to the rope and letting the resin dry

2.4 Evaluation

In this study, we measured the time and cost of evaluating the work efficiency when using the AR method to produce this installation. We surveyed the students participating in this project to evaluate the strengths and weaknesses of the AR method.

2.4.1 Time and Cost Measurements

To compare the overall efficiency, we calculated the time and cost of the AR+Human and CNC methods during the crafting step. The total working time for the AR+Human method was approximately 24 hours and four students participated in the study. We can calculate the cost of the AR+Human method using Eq. (1).

$$\text{AR} + \text{Human cost} = \text{minimum wage} \times \text{number of people} \times \text{total hours worked} \quad (1)$$

The time and cost of the CNC method were measured using two methods. First, we contacted local companies to estimate the time and cost required to craft the design. Second, we directly calculated the time and cost of operating the CNC machine. In general, the formula for calculating the CNC machine working hours is as follows (STEPCRAFT 2021):

$$\text{T} = \text{L}/\text{f} \times \text{N} \quad (2)$$

N [rpm: revolution of the job per minute] = (vc [m/min] *1000) / 3.14 * ø d1 [mm])
T = Machining Time
L = Length of cut in mm
f = feed in millimeters per revolution
Vc = cutting speed in meters per minute
D = Diameter of the rod in mm

2.4.2 Survey

We attempted to evaluate the strengths and weaknesses of the AR method by comparing it with the drawing method used in a general landscape construction process. We reconstructed the survey items by referring to LEE and KIM's (2019) user experience survey items for AR applications. The survey items were divided into six categories: usefulness, usability, desirability, findability, accessibility, and credibility. The participants were asked to evaluate their user experience of the drawing and AR methods (Table 1). We used a 9-point Likert scale for evaluation. The survey subjects were 10 graduate students with direct experience with the AR method through this project, all landscape- and architecture-related majors with more than 5 years of study, and who were familiar with the drawing method.

Table 1: Survey items and questions

Component	Questions
Usefulness	Were you able to easily understand the shape of the design using this method?
	Were you able to easily understand the designer's intentions using this method?
	Did you find the creation process convenient by using this method?
	Do you think using this method helped in many ways throughout the whole process?
Usability	Were you able to easily learn how to use this method?
	Did you use this method to avoid making mistakes in the manufacturing process?
	Were you comfortable with the process you went through to use this method?
	Was this method sufficiently intuitive without needing further explanation?
Desirability	Was it interesting to use this method in your working process?
	Is the visualization of the design model using this method concise?
Findability	Is it easy to find various information on design modelling in this method?
	Is it easy to find the view of design modelling you want in this method?
Accessibility	Can this method be conveniently accessed anywhere, anytime?
	Is the equipment used for this method readily available?
Credibility	Is the visualization of modelling in this method sufficiently reliable?
	Is it the same as the actual modelling measured value when using this method?

3 Results

3.1 Landscape architectural installation production results

We demonstrated the landscape architectural installation completed in this study at the Seoul Biennale of Architecture and Urbanism 2021. To reassemble the installation, we first resolved the slope of the floor of the exhibition site and installed a circular structure below it. The bottom part was then fixed to locate the correct positions of the desk and column. A steel structure was installed to allow the upper installation to be suspended. Finally, the installation process was completed by lighting the upper structure. During the on-site installation process, we were able to use AR to check the exact location of the separate installation pieces and install them at the same location and with the same shape as the design.

Fig. 6: On-site installation supported by HoloLens and exhibition with web AR model

3.2 Evaluation Results

3.2.1 Time and Cost Measurement

Using the above time and cost calculation methods, we calculated the measurement results for both the AR+Human and CNC methods (Figure 7). Local companies have stated that using the CNC method costs approximately 2.7–2.8 million won and requires approximately 2 days to customize the shape. When we directly calculated based on the above CNC working-time calculation formula, assuming a milling of 10 mm, the total working time was approximately 40 h. Local CNC milling companies offered an estimate of approximately 70,000 won per CNC operating hour, ultimately requiring approximately 2.8 million won. However,

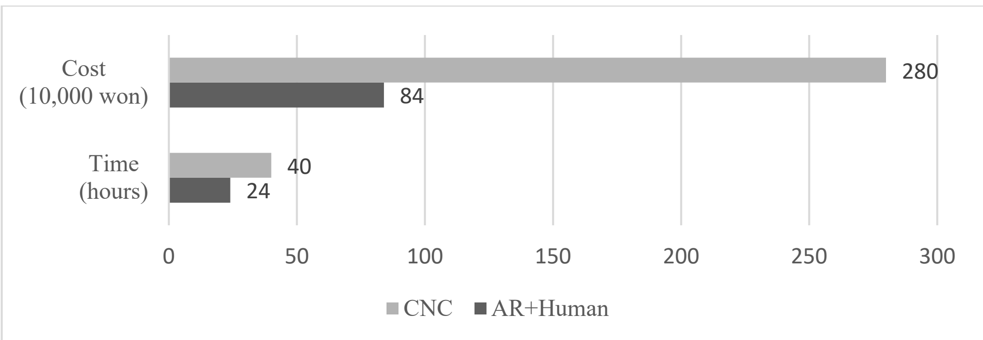

Fig. 7: Comparison of time and cost of AR+Human and CNC methods

the AR+Human method took approximately 24 h with four people, and the cost was approximately 840,000 won based on minimum wage.

3.2.2 Survey Results

Table 3 shows the evaluation results of the user experience regarding the drawing and AR methods used in this survey. The AR method was evaluated more positively in 12 out of 16 evaluation items than the drawing method. In terms of "usefulness," "desirability," and "findability," the AR method is more positive. For "usability," both methods showed the same value in terms of the difficulty of learning how to use them, and for the other three questions, all rated the AR method more positively. For "accessibility," the drawing method was more positive. For "credibility," the AR method received more positive results for the "reliability of modelling visualization" question, whereas the drawing method received more positive results for the "Is the measured value the same as the actual modelling" question.

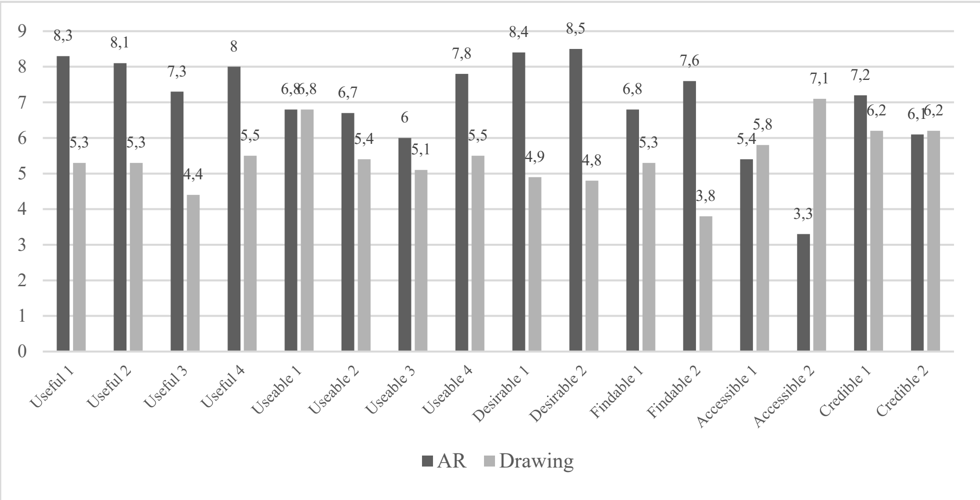

Fig. 8: Results of user experience evaluation survey for AR and drawing methods

4 Discussion and Conclusion

Using the AR+Human method, we verified the efficiency by implementing a modelling form at a lower cost than with the CNC method. Although the CNC method is superior in terms of sophistication, the AR method can accommodate a project with a flexible design and allow a relatively large error range, as in the present project. In addition, we cannot ignore the interest and experiential value obtained from the process of realizing a design with one's own hands through human–computer–machine interaction. This will be the same not only for the use of Styrofoam, but also in the process of cutting and filling the ground outside.

One of the greatest AR values found in this study was the educational aspect. The survey results showed that many students quickly understood the intention of the design through an intuitive visualization experienced through AR and were interested in the production method used to implement the design. Based on these experiences and training courses, both the main designers and other experienced designers were able to actively discuss and develop a design, serving as a catalyst for greater production efficiency.

However, the popularity, convenience, and accuracy of the AR equipment will continue to improve. AR devices such as HoloLens are weak in terms of popularity, being aimed at professionals and businesses rather than general users. In addition, students were presented with questions regarding the accuracy and error of the modelling, as well as the discomfort of HoloLens, such as the resolution, viewing angle, and resulting eye fatigue. As such, several limitations in terms of accessibility, convenience, and accuracy of the AR equipment remain.

Rapidly developing AR hardware and software fields will provide more accurate and accessible information, allowing AR to quickly become established in the public arena, providing additional value instead of replacing the legacy drawing method. With landscape architecture, in particular, which places importance on the various experiences in the relationship between humans and the environment, it is possible to provide diverse experiences to people (including users and producers) through a human-driven process with AR rather than through a machine-driven process. These experiences create additional value, such as education and productivity. In line with this trend, AR technology will be applied in a wider and more sophisticated manner in the field of landscape architecture.

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