International Digital Modeling Contest

IDMC 2024

Catalogue

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Contents

International Digital Modeling Contest 2024

The International Digital Modeling Contest 2024 (IDMC2024) aims to promote the use of fundamental technologies that inspire the creation of three-dimensional mechanisms and objects in a new and innovative environment centered on additive manufacturing (3D printers).

In this contest, we invited entries of works in which 3D data created by digital modeling from the original plan was output by a 3D printer, and the entire process was verified.

The Japan Society for Graphic Arts has held the “Digital Modeling Contest” for the past 17 years. Based on this experience, this year's contest was expanded to cover a wider range of fields, and entries were also invited from overseas.

Purpose of the contest

The Digital Modeling (Digital Content) Contest positions creation as an academic activity and will be held while maintaining the contest format. One of the goals of the contest is to explain in an easy-to-understand manner the process from the purpose of creating the work to the model production, with an emphasis on necessity and preservation of the process. To make effective use of 3D modeling machines, it is important to have content that can be used for 3D modeling, such as educational works and resource works.

Judging schedule

August 8, 2024 Short Presentation
August 9, 2024 Awards ceremony

Exhibition (Open to the public period)

August 6, 2024 - August 9, 2024

Venue

Kitakyushu International Conference Center
3-9-30 Asano, Kokurakita-ku, Kitakyushu-shi, Fukuoka 802-0001

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Finalist

Prosthetic Armor: Restoring the Human Body

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International Kansei Design
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Figure 1: Prosthetic armor mock-up, 3D modeled in 2023

Keywords: prosthetics, kansei design, 3D printing

Abstract

As prosthetic devices improve in function, the users' quality of life is improved, allowing independence and freedom in everyday activities. However, the amputee still experiences confidence and body image issues based on social stigmas. Current standard of care in the aesthetic aspect of prosthetic devices do not adequately address this issue. This is the reason behind this case of designing a personalized prosthetic cover using low-cost, rapid production pipeline with 3D printing for an adult subject who uses a prosthesis with a trans-femoral amputation.

1 Concept

Prosthetic lower limbs for trans-femoral amputees are comprised of a socket, adapters, a knee, a metal pylon, a foot, and an exterior cosmetic and protective piece called a prosthetic cover. The prosthetic covers that are widely available are manufactured to look realistic, using a simple skin tone color on a foam material in leg shape. During their process of recovery and learning to use their new limb, amputees experience self-esteem issues that affect their willingness to practice with the new limb in public [1]. Additionally, studies have revealed that most prosthetic users were dissatisfied with the aesthetics of their foam cover [2]. This feeling among prosthetic users has led to the design of a new type of cover that looks less like a medical device and more like a fashion accessory and a piece of emotional design, following the principles of Kansei engineering. This is something I will call prosthetic "armor", using this word to call on the human-based and aesthetic designs armor along with its protective qualities. A designer can assist the prosthetic technician and amputee, providing concept drawings, using 3D printing and post-processing to provide a beautiful, personalized and custom fit prosthetic armor.

2 Production process

The production process of a prosthetic armor begins with taking pictures of the subject in the anterior, posterior and lateral planes and measurements the subject's sound limb length from knee to ankle and circumferences at the largest and smallest parts of the calf. I administered a questionnaire to the subject to decide on details such as shape, color, texture, and surface design. Designing and 3D modeling took place from September to November 2023 with the subject's data taken at Hiroshima International University and production of the 3D printed prosthetic armor pieces began in March 2024 and printed in April 2024. A functional prosthetic armor with hinges and a clamp to connect to the prosthetic pylon is currently being developed as of May 2024.

2.1 Design

A series of concept designs were drawn by me using the patient's questionnaire. In this case we decided on a medieval "fluted" European-style greave, or leg armor aesthetic which features a basic symmetrical shape, sharp anterior edge and metallic texture and color. The basic structure of the cover is made up of anterior and posterior panels that can attach to each other with a hinge and a latch with a detachable clamp built into the posterior panel that fastens around the pylon.

2.2 3D Model

In Blender, I imported reference pictures of the subject and outlined his sound limb using vertex placements. Once the initial vertices are positioned, I connected them to make polygonal shapes and adjusted the shapes to match the subject's leg in 3D. The anterior and posterior panels of the armor are derived from this base shape and sculpted into the final design (Fig. 2). A mock-up image is made with texture maps with the 3D render of the prosthetic armor on the subject's prosthetic leg to share with the subject for approval to move forward with production (Fig. 1).

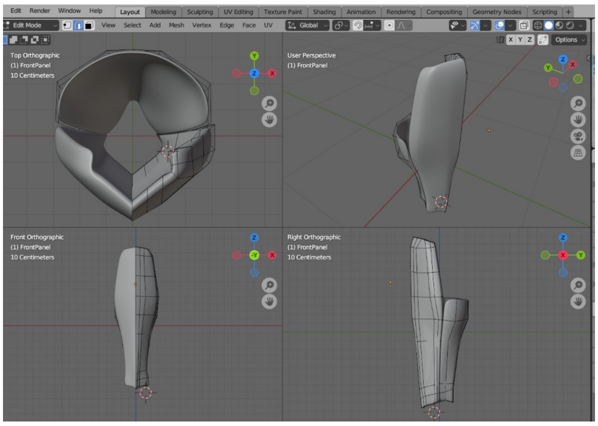

Figure 2: Final 3D model design

2.3 3D Print

The anterior and posterior panels of the prosthetic armor were then exported separately as .STL files and imported to PrusaSlicer and positioned on the print bed with supports. The G-Code data was exported onto an SD card and plugged into a Prusa i3 MK3 3D Printer and executed the print is executed using PLA filament. Please note: This 3D printer was chosen simply for its convenient availability. *I don't recommend this printer for adult-sized prosthetic armor due to its print volume of 250 x 210 x 210 mm. The anterior panel was printed in two pieces, so I used industrial strength glue to join them together and used silicone to fill in any gaps.

2.4 Post-processing

The panels were then sanded down with #60, #110 and #220 grit sandpaper in succession to smooth the surface and prepare it for priming and painting. Primer was sprayed onto the panels, followed by white gloss primer and paint spray, followed by another sanding with the same series of grit sandpaper as before to further refine the surface. Finally, a white gloss primer and paint was sprayed onto the panels and a wax metallic silver finish was rubbed onto the pieces with a sponge stick to achieve a reflective metal quality (Fig. 3).

Figure 3: Prosthetic armor, size 117 x 143 x 374 mm, PLA, 3D printed in 2024

3 Software & System

Blender ver. 3.4, PrusaSlicer ver 2.7.2, Prusa i3 MK3*, Windows 11.

References

[1] Holzer L. A., Sevelda F., Fraberger G., Bluder O., Kickinger W., Holzer G., *Body image and self-esteem in lower-limb amputees,* PLoS ONE 2014

[2] Sansoni, S., Speer, L., Wodehouse, A., Buis, A., *Aesthetic of Prosthetic Devices: From Medical Equipment to a Work of Design,* Emotional Engineering, Vol. 4, pp.73-92, Springer International Publishing Switzerland 2016

3D Printed Origami Cellular Material Switching DOF and Poisson's Ratio

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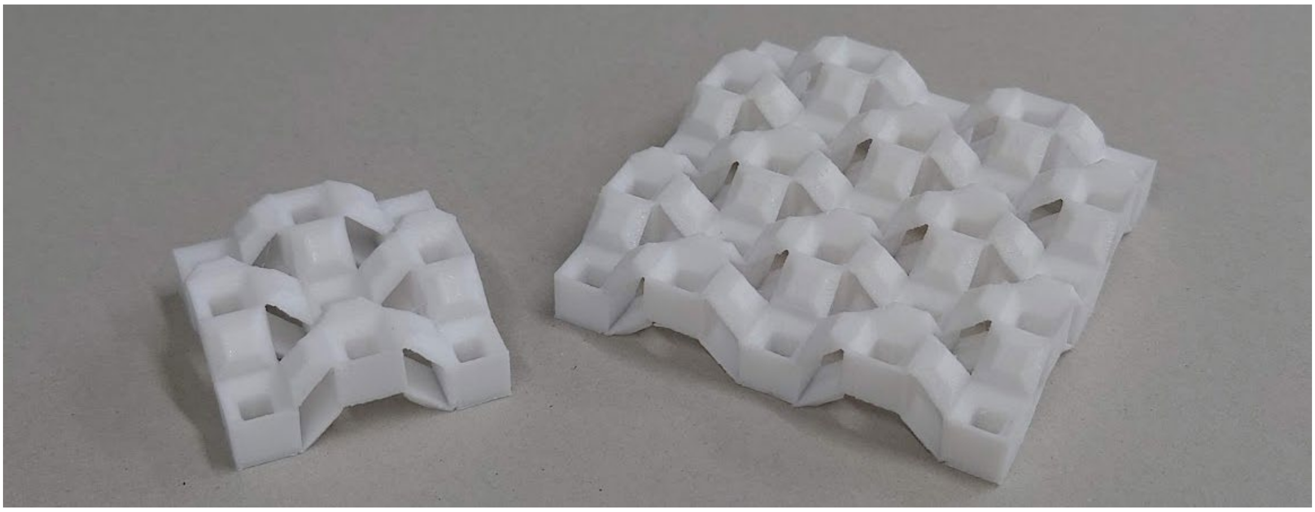

Keywords: origami cellular material, compliant mechanism, multi-stability, auxetics.

1 Background

Cellular structures constructed by the tessellation of origami cells have been gaining attention for their special mechanical properties such as flexibility and anisotropic stiffness. This type of structure was explored by artists: 'Snapology' by Strobl [1] and 'BuildVoid' by Tokolo (fifth author).

Our previous study [2] proposed an origami cellular structure inspired by BuildVoid. Figure 1 shows the composition of the structure. A *module* is constructed by connecting four cubic *solids* with four pairs of square *arms*. The module can be folded into two modes: parallel mode and skew mode, distinguished by the directions of opposite edges of the quadrangular hole. In parallel mode, the module has 2 DOFs: folding in x and y directions are independent. In skew mode, the module has 1 DOF: folding in x and y directions are synchronized. By arraying the modules in x and y directions, we can construct a *tessellation* of the structure. The choice of assignment of parallel/skew to each module can switch DOF and Poisson's ratio of the tessellation (Detailed kinematics is described in [2]).

2 Concept

In this work, we 3D-print the structure with a single material (TPU) as a compliant mechanism. This allows for easier fabrication. Moreover, the structure gets multi-stable, switching DOF and Poisson's ratio. This model can be an educational toy for learning mechanical principles through squeezing it.

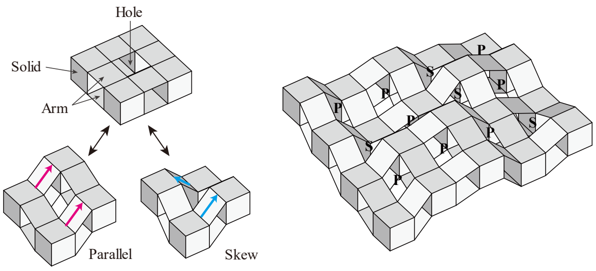

Figure 1: Composition of the mechanism proposed by [2]. Module (Left) and 4×3 tessellation (Right).

3 Modeling

Figure 2 shows a detailed view of a part of the 3D-printed model. The structure is printed so that all the modules are in skew mode folded by $\pi/4$. To utilize bending deformation of the material as hinges, the thickness of the hinge regions t must be sufficiently smaller than that of the other regions, making the ratio of bending stiffness $\propto t^3$ sufficiently large. We used $t = 0.75$mm. We added a thickness to the solids and the arms with a taper of 45°. This taper is for overhanging, reducing material (also printing time and weight of the structure), and avoiding collision while folding (Figure 3). The support material required at isolated boundary edges can be easily removed (Figure 4). We can construct tessellation by repetition.

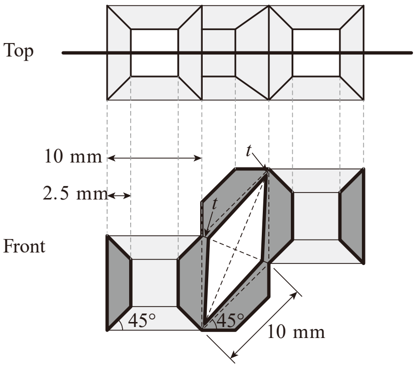

Figure 2: Top and front (section) views of a part of the model.

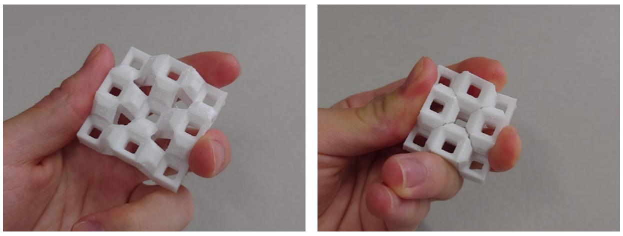

Figure 3: Tapered faces contact together when fully folded.

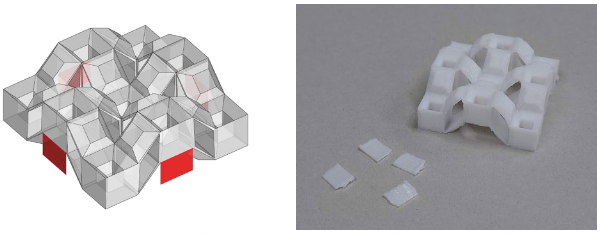

Figure 4: Locations where support material is required (Left).
Removal of support material (Right).

4 Multi-Stability

Due to the elasticity of the material and the half-folded printed state, the model gains multi-stability; inner arms can be flipped up and down (Figure 5). To analyze this behavior, we consider a simplified model where rigid solids and arms are connected by rotational springs that produce a moment proportional to the rotation angle: $M = k/4 \times \Delta\theta$, where $k/4$ is the spring constant (Figure 6 Left). Strain energy $U = k\,\Delta\theta^2/2$ is stored in four springs in the pair of arms. In the flipped state, flipped arms rotate more than the other arms. Due to the kinematic condition, the absolute angle θ between the arm and the horizontal plane must be equal in all the arms. By using $\Delta\theta = \theta - \pi/4$ and $\Delta\theta_f = \theta + \pi/4$, we find $\Delta\theta_f = \pi/2 + \Delta\theta$. In the case of 2×2 tessellation, there are 12 pairs of arms, and 4 of those can be flipped. Therefore, the potential energy of the two modes are

$$U_1 = 12 \times \frac{k\Delta\theta^2}{2} = 6k\left(\theta - \frac{\pi}{4}\right)^2,$$

$$U_2 = 8 \times \frac{k\Delta\theta^2}{2} + 4 \times \frac{k\Delta\theta_f{}^2}{2} = \frac{k(\pi - 12\theta)^2}{24} + \frac{\pi^2 k}{3}.$$

Figure 6 Right shows plots of these functions. U_1 takes the minimum of 0 when $\theta = \pi/4$, which corresponds to the printed state. U_2 takes the minimum of $\pi^2 k/3$ when $\theta = \pi/12$, which corresponds to the flipped state. The two plots intersect with $U = 3\pi^2 k/8$ when $\theta = 0$. Because this is larger than the minimum of U_2, the flipped state can be stable.

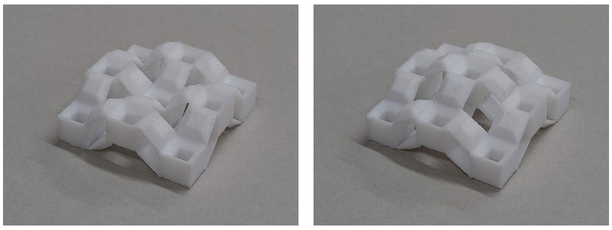

Figure 5: Two stable states of the 3D printed model.
Left: printed state, right: flipped state.

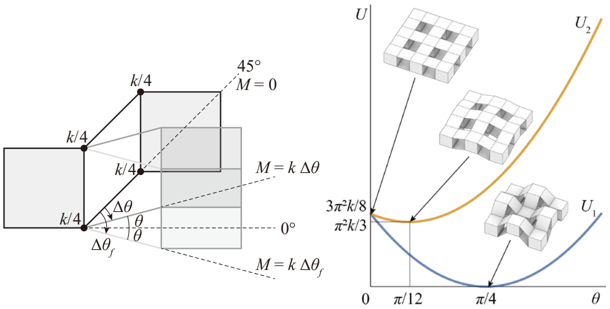

Figure 6: Rigid body and rotational spring model (Left).
Plots of potential energy (Right).

5 DOF and Poisson's Ratio

The two stable states of 2×2 tessellation have different DOFs and Poisson's ratios as follows:

(1) Printed state: All the modules are in skew mode, so all the rows and columns of the arms are synchronized. This results in 1 DOF and Poisson's ratio $\nu = -1$ (auxetic).

(2) Flipped state: All the modules are in parallel mode, so two rows and two columns of the arms are independent. This results in 4 DOFs and $\nu = 0$.

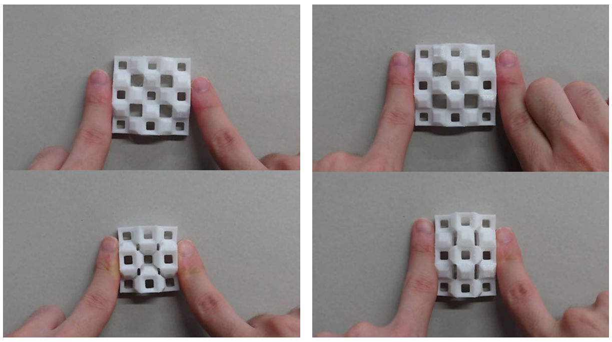

Figure 7: Model compressed in one direction.
Left: printed state ($\nu = -1$), right: flipped state ($\nu = 0$).

6 Software & System

Modeling software: Rhinoceros/Grasshopper
Printer: Qidi X-Pro
Filament: PolyFlex TPU95-HF

References

[1] Strobl, H.: Snapology, https://www.snapology.eu/, last accessed 2024/05/27.

[2] Adachi, A., Nishimoto, S., Totsuka, H., Warisaya, K., Tokolo, A., Tachi, T. (in press): Origami Cellular Material Switching Between Single and Multiple DOF Modes. 8OSME (2024).

Curved surface print without support material

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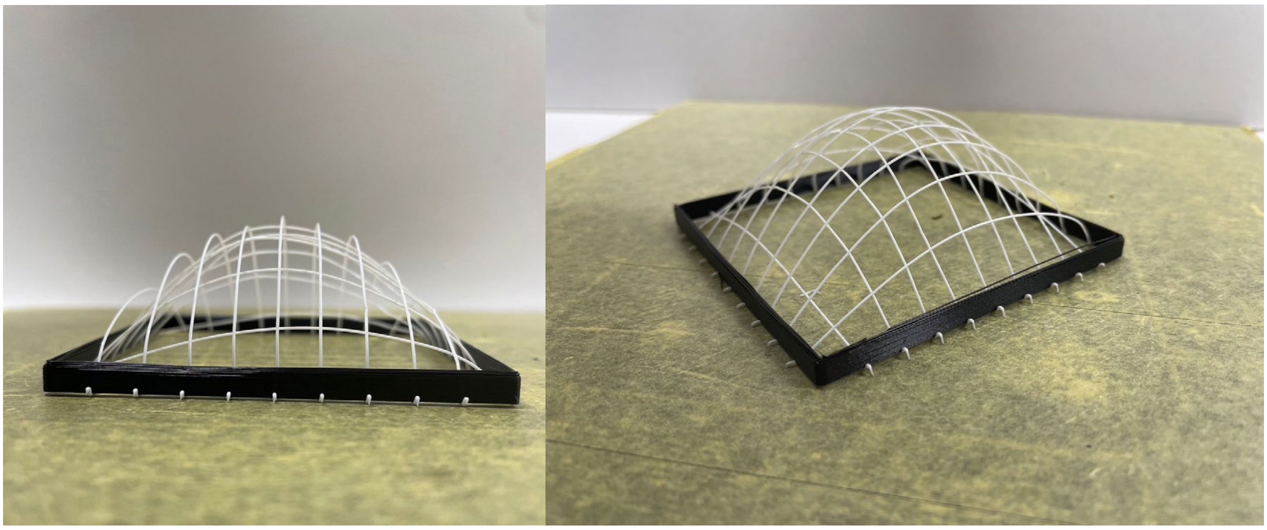


Keywords: Catenary 3D print, Supportless, Adaptive manufacturing

Abstract

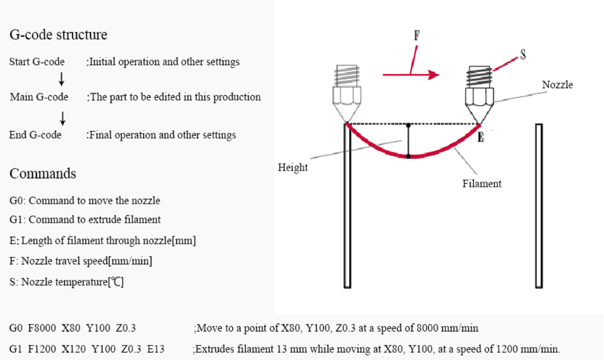
Using a rectangular frame shape, when the nozzle of a 3D printer is moved on a planar orbit, the ejected filament is suspended, creating a curve similar to a catenary curve. This work controls this curve by editing the G-code and applies it to a dome-shaped three-dimensional surface.

1 Concepts and Special Features

One of the challenges of 3D printing using the conventional MEX(Material Extrusion) method is that the amount of material used increases due to the need to print support members in the overhung areas.

On the other hand, when printing without a support member, sagging occurs, making it difficult to print the model accurately.

Therefore, we considered modeling using the suspending caused by gravity[1]. To print a suspending curve with the targeted height and shape (Figure 1), we edited the G-code and adjusted the nozzle speed and filament discharge volume.



G-code structure

Start G-code :Initial operation and other settings
↓
Main G-code :The part to be edited in this production
↓
End G-code :Final operation and other settings

Commands

G0: Command to move the nozzle
G1: Command to extrude filament
E: Length of filament through nozzle[mm]
F: Nozzle travel speed[mm/min]
S: Nozzle temperature[℃]

```
G0  F8000  X80  Y100  Z0.3             ;Move to a point of X80, Y100, Z0.3 at a speed of 8000 mm/min
G1  F1200  X120  Y100  Z0.3  E13       ;Extrudes filament 13 mm while moving at X80, Y100, at a speed of 1200 mm/min.
```

Figure 1: Catenary print method and G-code structure

2 Production Process and Method

In this work, the curve generated when a certain amount of filament ejected from a nozzle moving on a planar orbit hangs down due to its own weight is considered to be a catenary curve. PLA (Poly-Lactic-Acid), which is commonly used in small 3D printers, was used as the filament material. As shown in the figure, the curve length L and the amount of slack D of the suspension curve at constant line density can be expressed from the force balance equation as follows (Figure 2).

Definition formula for catenary curve

$$y = a \times \cosh\frac{x}{a} = a \times \frac{e^{\frac{x}{a}} + e^{-\frac{x}{a}}}{2}$$

$$a = \frac{T_0}{W} \quad \text{: catenary count}$$

$$L \fallingdotseq S + \frac{8D^2}{3S} \tag{1}$$

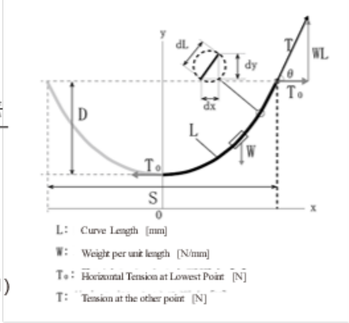


Figure 2: Definition Formula for Catenary Curves

The E value in the G-code represents the length (mm) of the filament ejected before it passes through the nozzle section. In this production, the PLA filament is 1.75 mm (=b) in diameter and the nozzle is 0.4 mm(=a) in diameter. Because the volume of the filament before passing through the nozzle is equal to the volume after passing through the nozzle,

$$E = \left(\frac{a}{b}\right)^2 \times L \tag{2}$$

Thus, theoretical values (E values) are obtained based on the curve length L of the catenary curve that we want to eject.

However, when printing with these theoretical values, it was difficult to print a catenary curve with the targeted height. The results are shown below (Figure 3).

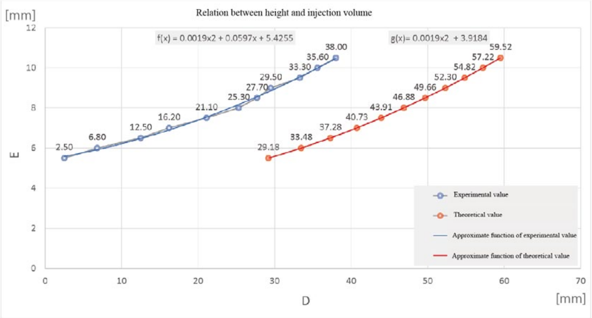


Figure 3: Catenary Printing Experimental Results

By comparing the experimental values with the theoretical values, we determined a function to derive the amount of filament ejection to print a catenary curve with the targeted height. (α=-15.711, β=1.0281)

$$f(x) = g(x + \alpha) + \beta \tag{3}$$

As the final modeling, we succeeded in printing a dome-shaped three-dimensional curved surface by weaving the catenary curve as shown (Figure4).

We believe that the error between this experiment and theoretical values and the accuracy of the injected curve shape can be more accurately controlled if a precise deformation analysis of the injection material, PLA, which has viscoelasticity, can be performed. As a future prospect, if it becomes possible to accurately form curved surfaces using this method of utilizing gravity-induced suspending for modeling, we can expect to use this method as a substitute for formwork and reinforcing bars at construction sites.

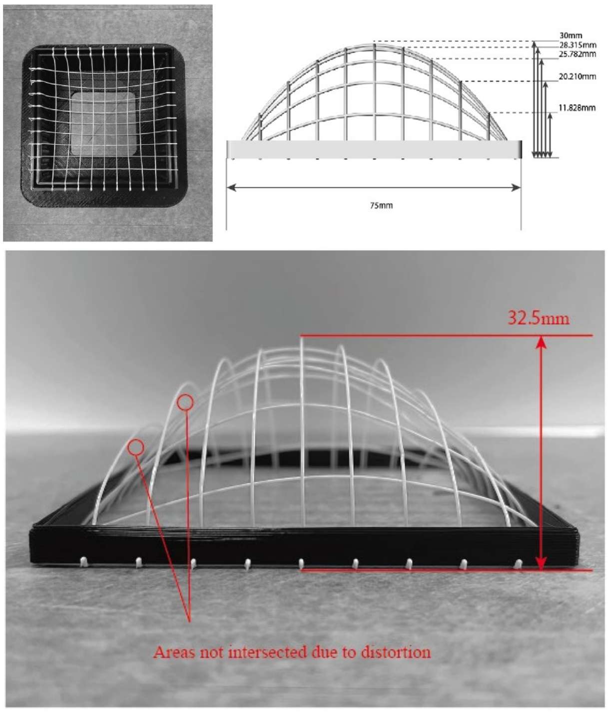


Figure 4: The catenary dome model

Software

Modeling soft: Rhinoceros, Grasshopper
Output device: snapmaker A250T
Filament: iBoss PLAwhite

References

[1] R. Kinoshita, H. Tanaka, Hanging Print: Plastic Extrusion for Catenary Weaving in Mid-Air, SIGGRAPH Asia 2022 Posters, No. 53, 2022.

A model of the Taj Mahal for tactile and visual recognition

触覚と視覚で鑑賞するタージマハル模型

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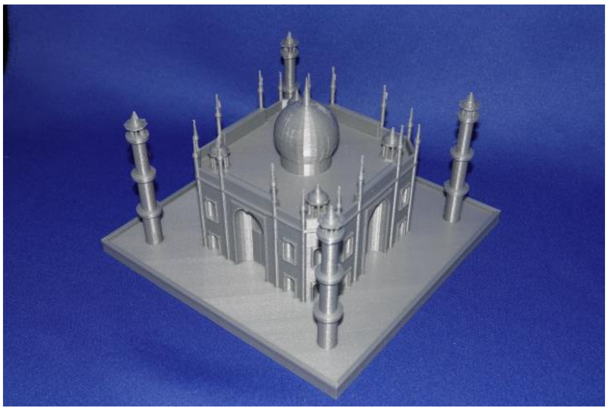
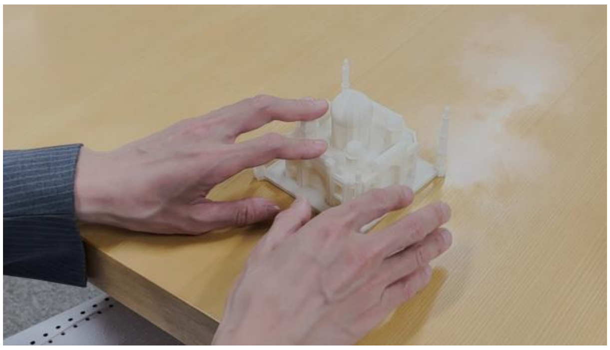


Keywords: The Taj Mahal, Visually impaired, Recognition by touch

1 Overview

A model of the Taj Mahal



Size of the work: 140mm * 140mm * 89mm

Material: PLA

Year of production of 3D data: 2024

Year of production of model output by 3D printer: 2024

The author, who is visually impaired, has been researching how visually impaired people can do 3D CAD and operate 3D printers. This time, he used observation by touch and creates a model of the Taj Mahal. In other words, he observed a model that had been created a sighted person then creates own model which can be understood by tactile observation. He did not duplicate the original model, but rather changes with his own creative arrangements. He expects that the Taj Mahal will be also recognizable by visual observation.

視覚障害者である作者は、これまで視覚障害者が 3D CAD を行う方法と 3D プリンタを操作する方法を研究してきた[1][2]。今回、作者は、触って観察した認識を用いてタージマハルの模型を造形した。つまり、晴眼者が視覚で観察して作った模型を触り、触って理解できる模型を造形した。製作に際しては、元の模型を複製するのではなく、作者なりの造形上の工夫やアレンジを行った。作者は視覚で観察してもタージマハルと認識されるものと期待している。

2 Production process

In addition, the modeling will be done in parametric CAD since the author cannot use common GUI CAD software. The modeling method to reduce obvious errors (simple calculation errors, typos, etc.) will be applied to a model of the Taj Mahal, which achieved a high degree of symmetry.

作者は通常の GUI CAD ソフトウェアを利用できないので、パラメトリック CAD を用いて造形を行った。パラメトリック CAD のデータ製作では、自明のエラーが発生しがちである。こうしたエラーを抑制するため、作者は、今回、最低限要素造形手法を導入した。本手法は、高度の対称性を有するタージマハルに特に有効である。

The generation process from minimal piece to entire model

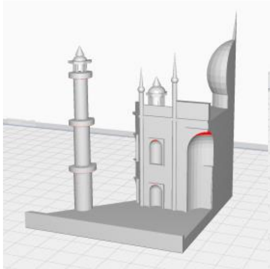


Figure 1 :Minimal piece

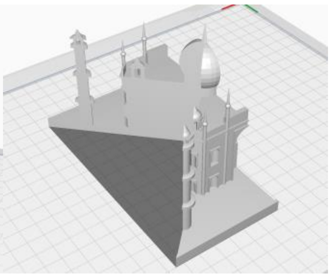


Figure 2: Mirroring by Y-axis

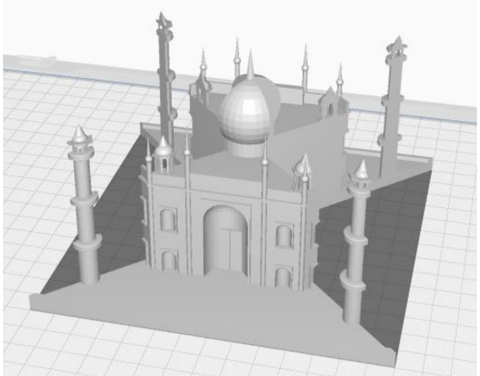
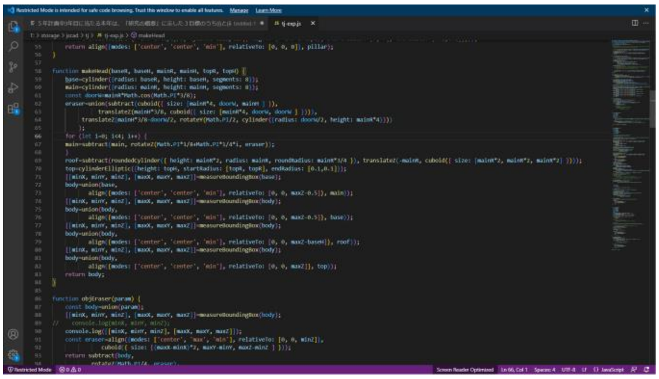


Figure 3: Mirroring by X-axis

3 Software & System

JScad was used as parametric CAD processor. Source code was written with Emacs and VS code. Original Prusa MINI was used for 3D printing in protyping stage then Ultimaker S5 was used in finalizing stage.

パラメトリック CAD の処理系として JScad を用いた。ソースコードは、Emacs と VS code を用いて記述した。試作の過程では Original Prusa MINI で印刷し、完成したデータは Ultimaker S5 で印刷した。



```
    return align({modes: ['center', 'center', 'min'], relativeTo: [0, 0, 0]}, pillar);
}

function makeHead(baseR, baseH, mainR, mainH, topR, topH) {
    base=cylinder({radius: baseR, height: baseH, segments: 8});
    main=cylinder({radius: mainR, height: mainH, segments: 8});
    const doorW=mainR*Math.cos(Math.PI*3/8);
    eraser=union(subtract(cuboid({ size: [mainR*4, doorW, mainH ] }),
              translateZ(mainH*3/8, cuboid({ size: [mainR*4, doorW, doorW ] }))),
          translateZ(mainH*3/8-doorW/2, rotateY(Math.PI/2, cylinder({radius: doorW/2, height: mainR*4})))
         );
    for (let i=0; i<4; i++) {
    main=subtract(main, rotateZ(Math.PI*1/8+Math.PI*1/4*i, eraser));
    }
    roof=subtract(roundedCylinder({ height: mainR*2, radius: mainR, roundRadius: mainR*3/4 }), translateZ(-mainR, cuboid({ size: [mainR*2, mainR*2, mainR*2] })));
    top=cylinderElliptic({height: topH, startRadius: [topR, topR], endRadius: [0.1,0.1]});
    [[minX, minY, minZ], [maxX, maxY, maxZ]]=measureBoundingBox(base);
    body=union(base,
          align({modes: ['center', 'center', 'min'], relativeTo: [0, 0, maxZ-0.5]}, main));
    [[minX, minY, minZ], [maxX, maxY, maxZ]]=measureBoundingBox(body);
    body=union(body,
          align({modes: ['center', 'center', 'min'], relativeTo: [0, 0, maxZ-0.5]}, base));
    [[minX, minY, minZ], [maxX, maxY, maxZ]]=measureBoundingBox(body);
    body=union(body,
          align({modes: ['center', 'center', 'min'], relativeTo: [0, 0, maxZ-baseH]}, roof));
    [[minX, minY, minZ], [maxX, maxY, maxZ]]=measureBoundingBox(body);
    body=union(body,
          align({modes: ['center', 'center', 'min'], relativeTo: [0, 0, maxZ]}, top));
    return body;
}

function objEraser(param) {
    const body=union(param);
    [[minX, minY, minZ], [maxX, maxY, maxZ]]=measureBoundingBox(body);
//    console.log(minX, minY, minZ);
    console.log([[minX, minY, minZ], [maxX, maxY, maxZ]]);
    const eraser=align({modes: ['center', 'max', 'min'], relativeTo: [0, 0, minZ]},
              cuboid({ size: [(maxX-minX)*2, maxY-minY, maxZ-minZ ] }));
    return subtract(body,
          rotateZ(Math.PI/4, eraser),
```

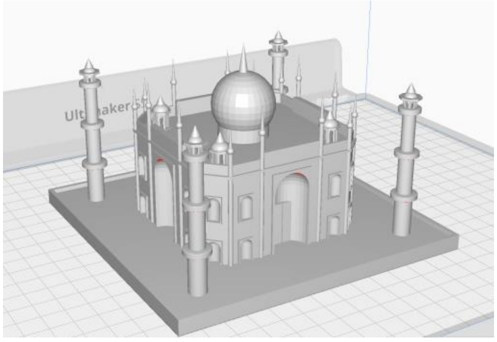


Figure 4: Rotating by PI/2

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I Interactive 3D zoetrope, with manual strobe lights

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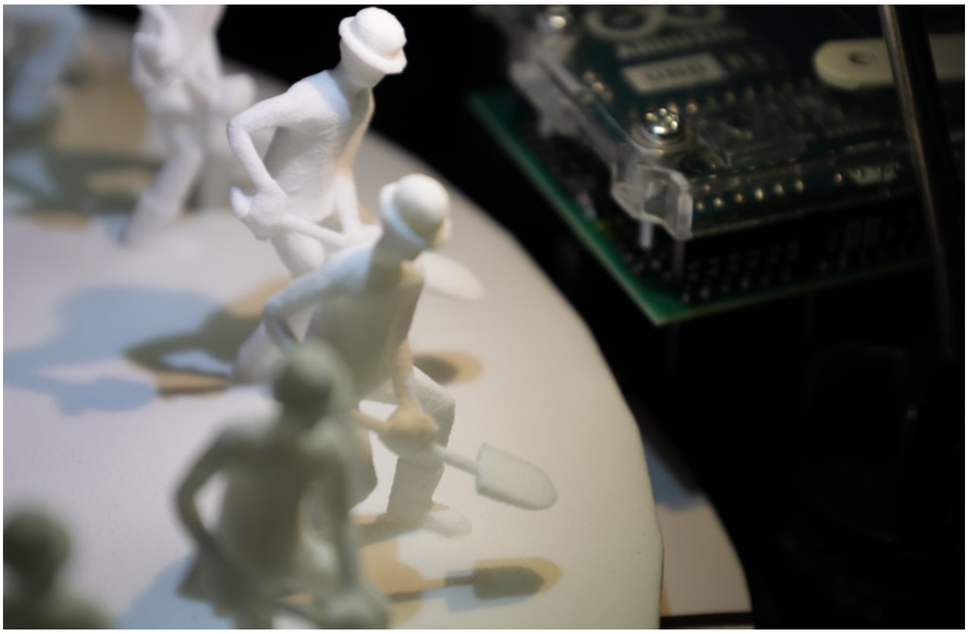

Keywords: 3D Zoetrope, Interactive strobe lights, Arduino

1. Seeing animation on 3D printed models

This work *Negative Homeostasis* is a 3D zoetrope made by 3D printer output. The work consists of 37 models arranged on a disk approximately 11 inches in diameter.

As with any existing zoetrope previously, the models can be rotated to animate. As the author has a background in filmmaking, she has previously produced 3D zoetrope animations that are viewed as stop-motion video, once filmed through a camera lens. However, in this work, due to a concept, the viewer spins the turntable by hand to create a stroboscopic, for the real time animated sequence under the strobe lights.

What this animation represents is a negative loop which always not too easy to break, such as unhealthy habits, addiction, or relationships that we are chained to in our everyday lives.

This model is a part of VR/MR art installation therefore was output physically to synchronize with the 3DCG in the VR space. The strobe light required for the animation was designed to be triggered by the interaction with the viewer, as it was intended to be used as an interface between the virtual 3D landscape and the real space.

2. Model Making

The Model was modeled and animated with 3D CG program Autodesk Maya. Once the animation was tested and revised in the program, the model was exported as a .stl file to 3D print. The scale was decided by the of the diameter of the turn table which made for LP records size of 12 inch. Each model turned out as short as an inch of its height due to the limitation of the final output size.

3. Output Data

Table 1: Example of Table

Dimensions	280 x 280 x 65(mm)
Printer	HP Multi Jet Fusion 積層ピッチ：0.08mm
Material	PA12（ナイロン 12）

Figure 1: Sample of a wide figure. Caption (serif font, 9pt, numbered, e.g)

4 Interactive Strobe Lights

The speed of rotation of the turn table would not constant when the turntable on which the model is placed is rotated manually by an audience. White and black markers corresponding to the arrangement of the model were used (specifically, a 12-inch disk with 20 radiation lines printed on it protruding from an 11-inch model), and an Arduino infrared sensor was used to recognize the linear markers as a pattern, causing the LED lights to blink in sync.

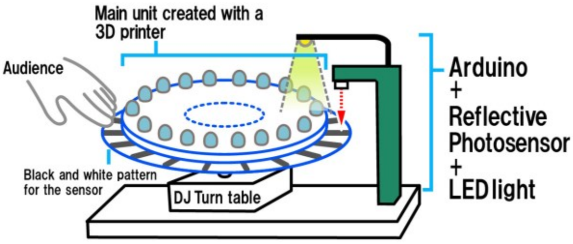

Figure 3: The strobe system

References

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[2] Autodesk Maya, https://www.autodesk.com/
[3] Arduino https://www.arduino.cc/

3D printed Splinter prosthesis socket for forearm amputees

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Keywords: forearm amputees, splinter, crouching start

1 Background

This prosthesis user has a congenital forearm deficiency. She had been interested in short distance running since childhood and was a member of a local athletics club. Her performance in athletics began to decline in her senior year of primary school. This is because she has no left forearm and is not able to do the crouching start with both hands. The lack of a left forearm made her consider changing sports. Her mother decided to have a splinter prosthesis made, which is not covered by insurance in Japan. The cost of a splinter prosthesis using the traditional manufacturing method would be 300,000 yen. The problem is that she is growing and needs to change sockets as often as she needs new shoes. The crouching start is important for short distance running. A good crouching start requires a proper socket fit. This project was initiated in order to reduce the financial burden and to ensure that the athletes are in the best possible condition to compete.

2 Points of consideration

The advantages and disadvantages of sockets produced by traditional methods were first examined. The advantages are that the sockets are made in a way that has been used for a long time, so they are safe. The disadvantages are the high cost of materials, the fact that expensive parts are coated with resin and cannot be reused, and the fact that they are not immediately resizable and manufactured. To overcome these problems, a 3D scanner and CAD were used to manufacture the sockets (Fig1). The strength setting was a problem for the 3D printer fabrication. This was because the strength of sockets for forearm prostheses produced by traditional manufacturing methods had not been reported. First of all, sockets were fabricated (Finite Difference Method: FDM) with various 3D printer filaments and tensile tests were carried out to determine which filaments had the highest strength (Fig.2). Filaments made of expensive composite materials did not show stable and strong strength due to delamination on the lamination surface of the filaments. Conversely, filaments of a single material showed stable strength, although weaker than those of composite materials (Table.1,2). Secondly, the strength of the sockets made by traditional manufacturing methods was subsequently verified by tensile tests. Three tensile tests were carried out, with an average value of 1170 N. Then, the stacking planes are a problem in FDM manufacturing using a single material, and the strength is not competitive with traditional manufacturing. For this reason, the Sockets were manufactured using Selective Laser Sintering (SLS) with Nylon12, which is less likely to separate on the laminate surface. In clinical practice, the most frequent breakage is at the anterior edge of the socket. Therefore, sockets with a thicker anterior edge of the socket were also included in the tensile tests (Fig.2). However, as a result, the Nylon 12 sockets were almost as strong as the traditional sockets, but the sockets with thickened edges were not as strong as the sockets with thickened edges. Following these various examinations, it was decided that we would offer a socket made of ABS, which prints stably and does not cause discomfort to the user, as both wings of the socket have some deflection, like a traditional socket. The slight deflection of the socket also accommodated the circumferential changes caused by the daytime swelling of forearm amputees. The ABS socket are not as strong as traditional sockets. However, the user was able to wear the 3D printed prosthetic hand and participate in competitions without problems. This may indicate that the current strength of prosthetic hands may be overstrength. Finally, a small change in the volume of the stump could be corrected in CAD and the socket could be remade. The cost of this 3D printed socket was approximately 900 yen (cost of 3D printer filament). Furthermore, the expensive parts were not coated with resin, so the expensive parts could be reused for the next socket. This manufacturing process could be of great help to growing amputees.

Table1: Tensile test results of sockets (N)

	PC	ABS	PC-ABS	PC-FR	PA6-CF	Socket
30%	534	350	333	612	290	
60%	549	300	365	626	323	
90%	633	455	330	583	433	
100%						1170

In this table, socket is made by traditional way. This value is the average of three times.

Table2: Average of tensile test results of NYLON12 sockets (N)

	Normal	2mm thinker	4mm thinker
1st	1034	1255	845
2nd	1079	1055	645
Average	1056.5	1155	745

Each NYLON 12 socket produced by SLS was tested twice. Comparing the normal and 4 mm thickness, the normal is stronger. The results of the tests were not stable for the 2 mm and 4 mm thicknesses.

Fig.1 Right: traditional plaster moulding. Left: digital mould with a 3D scanner. It is digital, corrections can be made on the CAD.

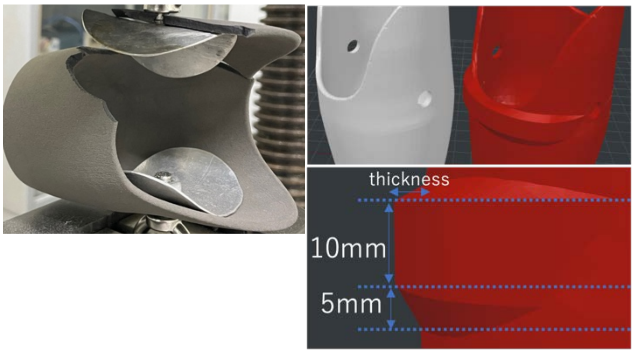

Fig.2 Left: Values recorded during a large crack in the socket. Right: Detail of increasing the thickness of the socket edge.

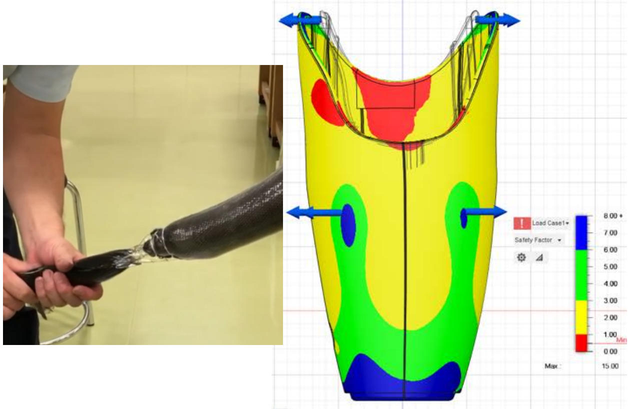

Fig.3 Right: Socket is manufactured by, annually soaking the resin into the fabric. This method is labour-intensive and costly. Left: A finite element method was used on a PC to simulate the stress concentration in the socket.

3 Software & System

Please write your used software and system.
-CAD Software: Autodesk Fusion (Autodesk, Inc.)
-FDM: Raise3D Pro2 (Raise3D Technologies, Inc.)
-SLS: FUSE1+ (Formlabs, Inc.)

Prosthetic Forearm Socket Design

New Possibilities Fusion of 3DCAD and Leather

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Keywords: Boxel, leather, socket

1 Reversed thinking

Current prosthetic arms and legs face the challenge that they are difficult to design freely. This is because restrictions in the insurance system and manufacturing process limit the degree of freedom of design. In this study, we attempted to produce a socket for a prosthetic hand, making use of our knowledge of spatial configuration and form design developed in the Department of Architecture.

The sockets produced were designed from new perspectives, such as the use of 3D CAD to enable low costs despite their complex shape, and to allow the prosthetic hand to experience the warmth of the texture and the change over time of the leather. The aim is to add new perspectives to the conventional prosthetic hand to create a fashonable prosthetic hand.

Conventional prosthetic hand sockets have many constraints in their production. When leather is incorporated into conventional prosthetic hand sockets, it is not possible to design freely and the inherent appeal of leather cannot be utilised. However, the incorporation of 3D printing creates a degree of freedom in socket design.The flexibility, plasticity and ageing properties of leather allow the complex shapes of 3D printers to be adapted and new possibilities to be pursued.

A voxel-shaped prosthetic hand socket, which cannot be produced with conventional prosthetic sockets, was produced. Voxel shapes and leather were chosen to express the fusion of digital and analogue.

BOXEL

When blending with leather, a streamlined 3D model (general 3D model), the leather's original the natural characteristics of leather could not be utilized to the fullest. Flexibility, plasticity and ageing. Voxel is used to take advantage of flexibility, plasticity and ageing. Fusion with leather Fixed concept of 3D printers and lead to a rethinking of the stereotypes of 3D printing. Reverse thinking to find the essence of things. To invite the viewer's questions and evoke a range of emotions and feelings.

Making use of the plasticity of leather Making the most of its greatest strength voxel Perfect adhesion between leather and resin, Complete adhesion between leather and resin Express voxels from expression to feel. Aiming at the fusion of resin (3D model) and leather Adopts the quilt of leather shoes

Means to keep out mud and dust. Use as design Exaggerate the design with holes and threads Low center of gravity Wrapped around a metal plate Accelerates the swing of the arms and aids running.

Photo 1.

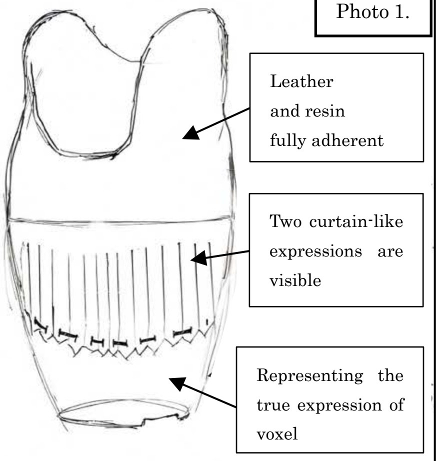
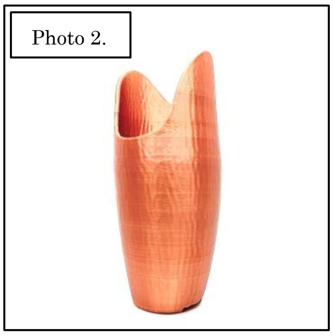
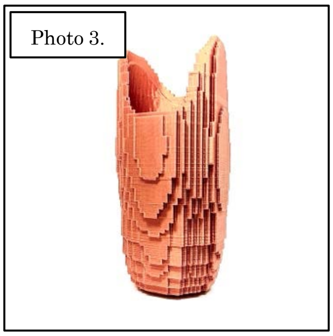


Photo 2.



normal socket

Photo 3.

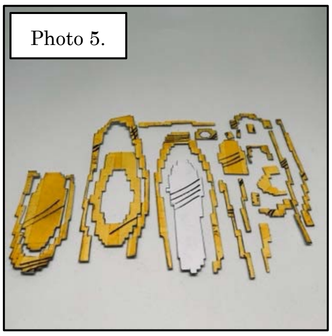


voxel socket

Photo 4.

Boxel socket with leather attached.

Photo 5.



Re-made stencils.

2 The process of integrating leather and 3D. models

The voxel shape from the conventional prosthetic hand socket shape has increased the number of variations of leather and socket combinations.

Therefore, leather was applied to the voxel-shaped socket to check the texture of the leather (Photo 4). As shown in Photo 4, the 3D model with leather attached lacked a sense of massiveness and stylishness.

In addition, the voxels in the upper half of the model were hidden from view by the leather. In this work, the leather parts were separated one by one in order to give the feeling that the leather blends in with the voxel-shaped socket. This allows the leather and socket to become one piece, giving a more natural look and feel. It also improves the close fit between the leather and the 3D model, giving it a more three-dimensional and stylish appearance.

3 Software & System

Fusion（Autodesk)
Anker Make (Anker)

4 Size of work

73 x 74 x 154 (mm)

5 Material

Pla resin

6 Years of creation of 3D data

2024

7 Production of 3D printed models

2024

Objects	**Design of prosthetic forearm sockets New possibilities by combining 3D CAD and leather**
Photo 1.	Voxel socket idea sketches
Photo 2.	normal socket
Photo 3.	voxel socket
Photo 4.	Boxel socket with leather attached.
Photo 5.	Re-made stencils.

A study for tessellation with motif of Escher

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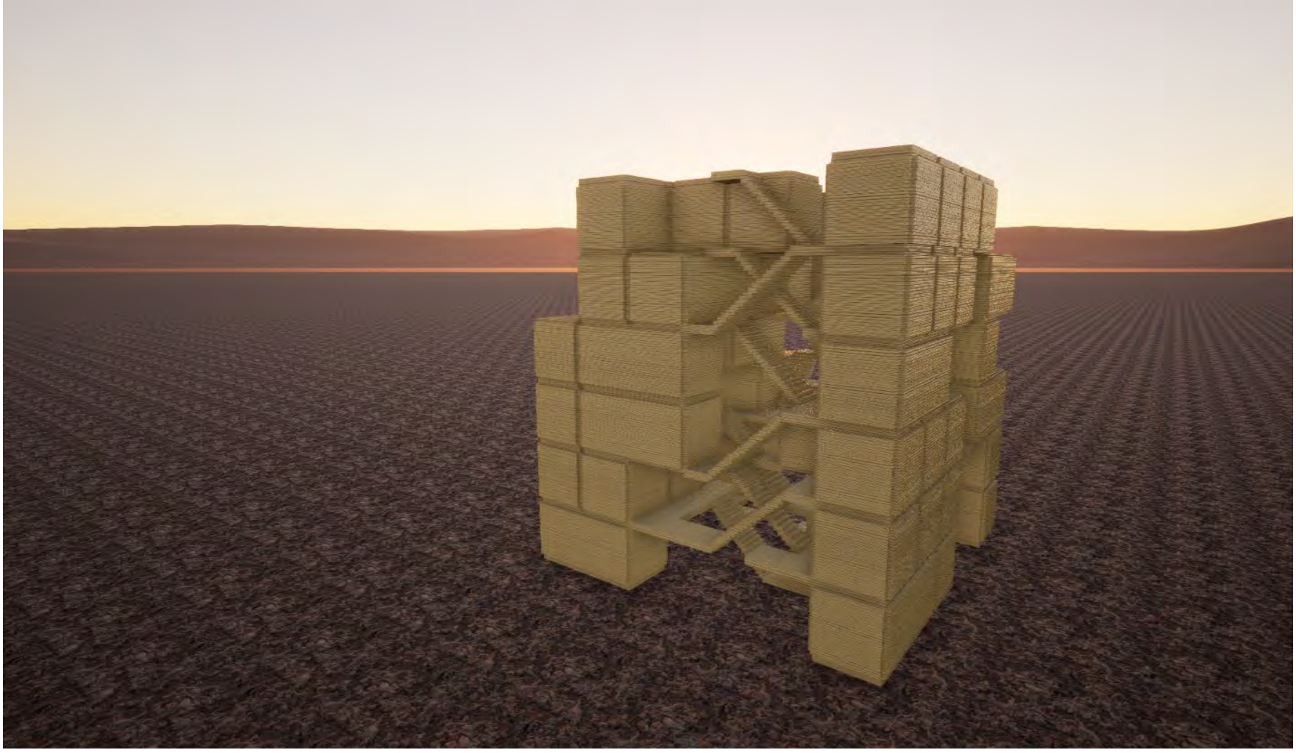

Keywords: 3D tessellation, M.C. Escher, Box Stacking

1 Introduction

M.C. Escher (1898-1972) depicted many pictures in which unique geometric patterns to tessellate 2D surfaces and express illusions. Many of Escher's paintings are so mysterious that they cannot be formed as 3D objects, even though they can be depicted as 2D figures. However, there are some paintings in which he seems to have attempted to tessellate a 3D space. In addition, these paintings have a common feature in that they do not define the direction of gravity, so it is making this form possible within the painting.

Considering this point, we created this work as a container-shaped box that can infinitely tessellate 3D space. Although it has an architectural form in which the boxes are physically stacked, by adding stairways inside that connects all the boxes, we created a model that would work as an architecture even if it was flipped upside down if there was no gravity. As a result, this model expresses the visual confusion that Escher depicted. In addition, since it can be used in low gravity or zero gravity, it can also be used as an architectural proposal for human habitation plans in space development which has been actively carried out in recent years.

2 Production Process

This work is a 3D model output at a scale of 1:300 of a structure within a volume of 30000x30000x30000 mm. Five boxes with dimensions of 5000x5000x10000 mm were placed randomly on the ground floor. Additional boxes with the same dimensions were stacked on the upper floors, and stairways were added to

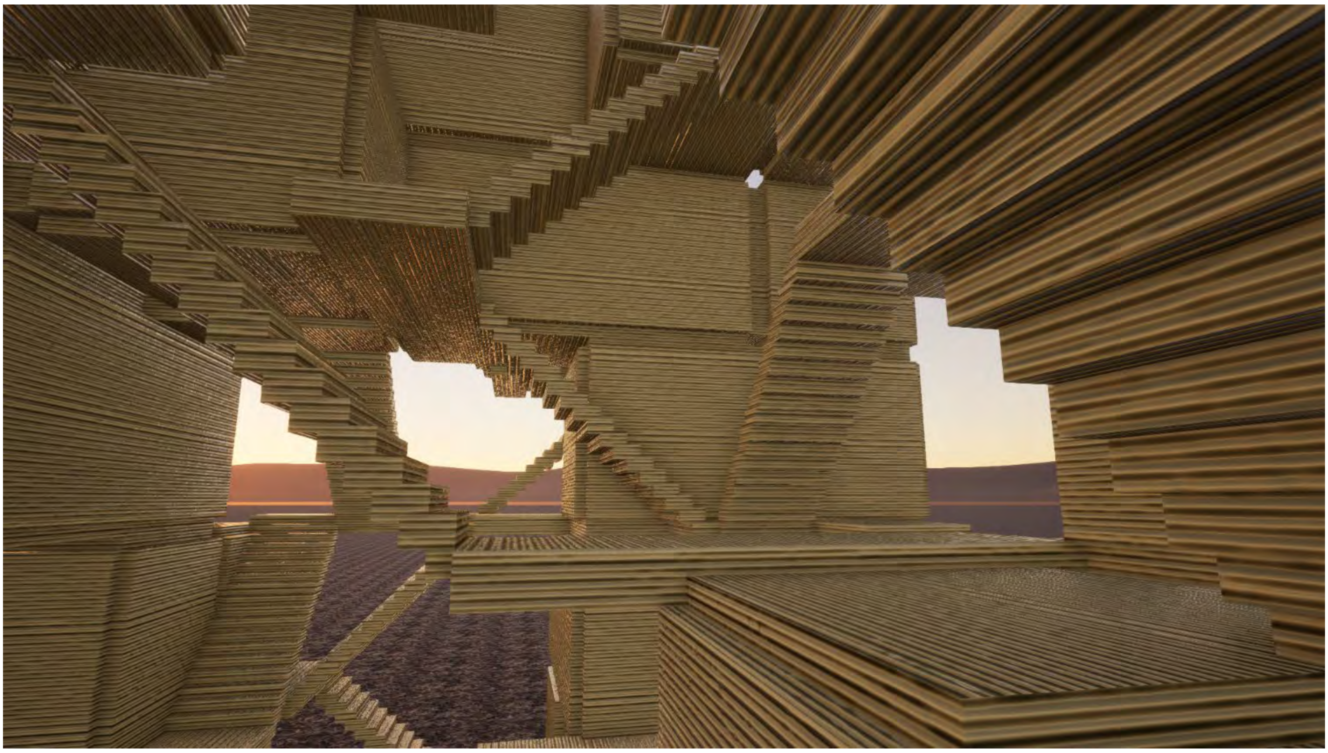

Figure 1: Internal Space
In this 1/300 scale model, the stair steps are modeled 1 mm in depth, 1 mm in height, about 10 mm width.

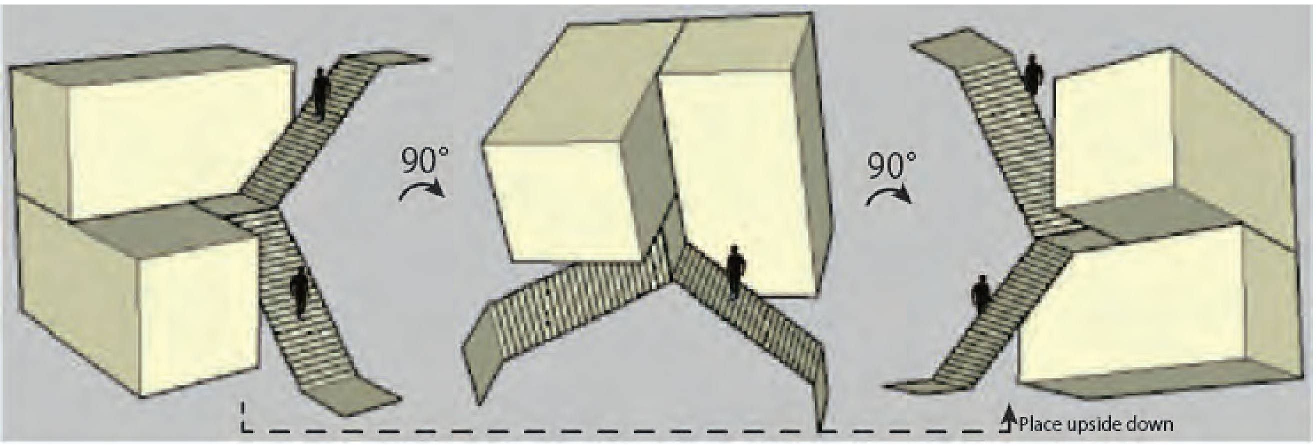

Figure 2: Rotation of Structure
Since the front and back side of stairways are accessible, they work at all angle as a building.
They do not only define the direction of gravity, but also represent tessellation of 3D space of Escher.

connect the boxes (Figure 1). The sloping angles of the stairways were set to 45 degrees, allowing the stairways to be used even if the structure is rotated 90 degrees or placed upside down (Figure 2).

Regarding the printout of this model, we requested an external output service company and selected acrylic material which is toughness and rigidity, named AR-M2, which was output by AGILISTA.

3 Software & System

We used Rhinoceros, a 3D modeling software, along with Grasshopper, a programming plug-in tool for Rhinoceros. The structure was modeled by randomly stacking container-shaped boxes. A Python script was utilized to place a designated number of boxes on the ground level and to stack additional boxes. Subsequently, we used SketchUp, another 3D modeling software, to add stairways connecting the boxes. Our model was completed in a month conclusively.

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