3D Printed Materials Based On Model Structure Optimization in Environmental Art Design Applications

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Abstract. 3D printing materials are a rapidly evolving model intelligent manufacturing process that enables geometric modeling of any complex shape. In the practical application of environmental art design, we have begun to give full play to the technological advantages brought by 3D printing. Environmental art design is the subject of mainstream research in the current society. At the same time, it has a close relationship with social development and environmental construction. Applying 3D printing materials to the design of environmental art can not only further improve the level of environmental art design, but also effectively improve the overall quality of environmental design, while also saving production costs. The paper combines case studies to optimize consumables of environmental art crafts by using algorithms to reduce consumables and reduce the cost of 3D printing materials. At the same time, it points out the application prospects and directions of future 3D printing technologies and materials in environmental art design.

1. Introduction
The Environmental Art Design Department is a comprehensive multidisciplinary major that combines art, sculpture, home design, garden art, materials science, and model making. Modern environmental art design mainly includes two parts: indoor environment design and garden landscape design. With the development of technology, 3D printing technology is widely used, and environmental art designers are also making full use of this technology to continuously explore innovative design [1]. Among them, the diversity, environmental protection, and recyclability of 3D printed materials have provided great technical support for environmental art design. Through 3D printing models to complete their design works, no longer limit the innovative thinking of the sky, and high-quality, fine and accurate 3D models can help designers shorten the design period, and enable designers to communicate creative ideas directly with customers, avoiding wasting unnecessary time and effort. The current 3D technology is very mature under the influence of advanced science and technology. At the same time, the 3D materials produced by it have excellent environmental characteristics and good recyclability, and are also deeply loved by the environmental design field. However, in the process of environmental design, many stylings need to have good compressibility and strong resilience, and at the same time put forward higher requirements for model optimization of artworks. To this end, 3D material printing based on model structure optimization is an important part of environmental art design and development.
2. 3D material model structure optimization basic principles and techniques

2.1. Internal chiseling technology

Internal hollowing out is the most direct and simple way to reduce material usage [2]. Usually, the initial position of the hollow is first selected, and then the position and the hollow structure are gradually adjusted according to the constraint conditions and the optimization target, and finally a stable model wall thickness satisfying the condition is obtained. Figure 1 shows how to hollow out the model [3].

![Figure 1. Internal hollowing technology display](image)

2.2. Voronoi segmentation technology

The Voronoi diagram, also known as the Thiessen polygon or the Dirichlet diagram, consists of a set of continuous polygons that form a vertical bisector that connects the lines of two adjacent points, as shown in Figure 2 [4]. The Voronoi diagram is used to calculate the irregular honeycomb segmentation defined in the model and optimize it [5], which is one of the commonly used techniques for the internal structure optimization of the model. The Voronoi unit reflects the density and intensity ratios inside the model. A set of model internal units is given according to the pressure. The input boundary surface $S$ and the structural unit $\alpha = n_{sites} \{ S_i \}_{i=1}^{n}$ defined by $S$ are defined as the Voronoi unit $\{ \Omega_i \}_{i=1}^{n}$ set, then:

$$\Omega_i = \{ x \in S \| x - s_i \| \leq \| x - s_j \| , v_j \neq i \}$$  \hspace{1cm} (1)

The honeycomb structure shown in Figure 2 is determined by the input $\alpha$, which generates 50 cells and 100 cells, respectively. An optimal mosaic pattern is found based on the ratio of strength to weight, and the pressure within the cavity can be relieved.
2.3. Progressive structure optimization

The idea of the EOS method is very simple, that is, according to certain optimization criteria, the invalid or inefficient materials are gradually removed, so that the structure is gradually optimized. The design goal is to combine the Von Mises stress criteria to minimize the difference in stress levels and to make the stress distribution as uniform as possible. Xu et al. [6] used this method to optimize the grid model. In the optimization calculation cycle, the model volume is continuously reduced, the unit stress $\sigma_{\text{max}}$ is continuously increased, $\sigma_{\text{max}} / \sigma$ is calculated, and $\beta$ is called the stress ratio. When $\beta$ reaches a certain value, the optimization calculation goes to a finer level grid. In the optimization iteration, the method uses a fixed finite element mesh. For the existing material units, the material number is numbered as non-zero, and the number of material elements that do not exist is numbered zero. Structural topology optimization is achieved by this zero and non-zero mode and iteration.

3. 3D printing material selection in environmental art design

In the model making of environmental art design, the use of 3D printing to create physical models, such as sculpture, furniture, architecture, etc., is very conducive to the designer to grasp the overall design theme, providing the most intuitive performance for future engineering practice. In environmental art design, many shapes have certain requirements for deformability and compressibility, such as flowers, plants, and cables with certain tensile properties. In this study, prepolymers and reactive monomers were used as raw materials for 3D printing to study the viscosity and flexibility of specific printed objects. The raw materials of the 3D printing materials used in the experiment were divided into prepolymers and reactive monomers. The types are shown in Table 1.

| Prepolymer type | Reactive monomer |
|-----------------|------------------|
| Aliphatic urethane acrylate | Ethoxyethoxyethyl acrylate |
| Hyperbranched polyester acrylate | 1,6 hexanediol diacrylate |
| Epoxy acrylate | Tripropylene glycol diacrylate |
| Aliphatic urethane acrylate | Neopentyl glycol diacrylate |
| Polyester acrylate | Dipropylene glycol diacrylate |
| Bisphenol An epoxy resin E44 | Trimethylolpropane triacrylate |
| Bisphenol an Epoxy Resin E51 | 3,4 epoxy cycloethylyl methyl |
| Monofunctional oxetane | Cyclohexane 1,2 dihydroxy acid diglycidyl ether |
| Difunctional oxetane | 3,4 epoxy cyclohexylformate |
| Polyfunctional oxetane | 3,4 epoxy cyclohexylformate |
| Epoxy polybutadiene |
Through research, it can be found that the viscosity of the material is affected to some extent by different kinds of prepolymer. In addition, the same kind of prepolymer will still have a certain influence on the viscosity of 3D materials when the internal content changes. Fix the type and content of the photoinitiator, coagent, and active monomer of the 3D printing photocurable material to ensure that the content of the V400 prepolymer does not change, and the content of the V400 prepolymer is adjusted. Polymer content. The experimental samples of the 3D printed materials were fabricated by 3D printing technology, and then the viscosity of the materials was measured. The relevant results are shown in Fig. 3.

**Figure 3.** Effect of the prepolymer and the type of reactive monomer on the flexibility of the material

### 4. Case study of environmental art design case analysis of optimized structure

#### 4.1. Case study background analysis

Ethnic and local cultural and artistic works are the material wealth that highlights the cultural characteristics and religious beliefs of the region. In order to inherit and carry forward the national cultural treasures, 3D printing technology can restore local ethnic art works for future generations to pay tribute. The case is based on the Miao nationality whistle. On the basis of 3D scanning and reverse modeling, the 3D digital model is improved and finally the rapid prototyping technology is used to manufacture the sample. The example process and results show that applying CAD/CAM and 3D printing technology to the complex handicraft protection and development can effectively shorten the cycle and improve efficiency, and provide a new way for the digital protection and development of ethnic handicrafts [7]. Guizhou mud whistle pays more attention to the characteristics of the head, exaggerated form, complex shape and outstanding features; the body shape is simple and succinct, but the surface has decorative carving patterns or patterns, and the features are small and complicated. There is a return hole at the bottom of the mud whistle and a cavity inside. These characteristics require comprehensive analysis and comparison of various rapid prototyping methods to select the optimal solution when selecting the mud prototype construction scheme.
4.2. **Voronoi diagram and progressive method to achieve entity model optimization transformation**

The paper uses the Voronoi diagram and the progressive method to reconstruct the surface to obtain a smooth spliced muddy NURBS surface. At the same time, the surface model is converted into a three-dimensional solid model. The specific conversion steps are as follows: 1 Import the muddy model into UG8.0 in. igs format, and use the “Insert-Combination-Sew” command to convert the muddy surface model into a 3D solid model. 2 Get the 3D solid model of the mud whistle and export the file in. STL format. Prepare for the next model build. Convert the muddy solid model obtained in the previous step to the STL file output. Finally imported into the object studio system, using the ‘Objet30 Smart’ 3D printer for prototyping. It is made of rigid clear transparent material, high temperature resistant material and polypropylene-like material. The process technology has the advantages of high speed, high elasticity, low cost, convenient carrying, strong compatibility, high resolution and accuracy (±0.1mm), and can make almost any shape.

4.3. **Mud formation process**

Start the software, import the model file in STL format, and adjust the position of the model in the print box to print the sample. During the printing process, the software transmits the data to the printer for printing while making the slice file of the model. The specific steps are as follows: 1 Open the object studio software interface and import the well-organized 3D solid model in. STL format. 2 Use the command to set the size ratio of the print model. The ratio between the solid model and the original model set in the experiment is 0.5, as shown in Figure 3a. 3 Use the placement command to adjust the optimal position for the muddy model print, as shown in Figure 3b. 4 After the validate command is detected, there is no problem with the unclosed surface, and the model is qualified. Press the build command to create a print request. 5 Turn off the printing system. The muddy three-dimensional print model is shown in Figure 5.

![Figure 4. Miao nationality muddy surface model](image)

**Figure 4.** Miao nationality muddy surface model

![Figure 5. Mud whistle 3D printed products](image)

**Figure 5.** Mud whistle 3D printed products
5. Conclusion
The application of 3D printing technology has a significant effect in the 3D model, so 3D printing technology is widely used. The development of 3D printing has shortened the time period from model design to production, so that the printing-related factors can be fully considered and processed during the design process, so the designed model will be more practical. On the other hand, for printing the research work for further optimization of the process has also contributed to the rapid development of 3D printing technology. However, although 3D printing technology has reduced the labor intensity of designers, it is of course worrying. In the future development of the environmental art design industry, will this personalized creative labor be replaced, and there will be many people who are engaged in design unemployed? In today's information and digital era, many professions and professions will disappear with the development of science and technology, and of course promote the development of some new professions and industries. However, as a technology designer who creates a comfortable, environmentally friendly and safe environment for human beings, environmental art designers should develop in a timely manner, accept new technologies, accumulate new knowledge, and constantly improve their artistic literacy. The tacit knowledge and creative abilities that we accumulate in the design process can guarantee our unbeaten advantage. Among them, the individual's creative ability can't be quantified, and it can't be turned into software to mass-produce. This is the source of our future transformation into great spiritual and material wealth.

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