

## Conservation Research and Design Application of Cultural Heritage Digitization

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### ABSTRACT

Cultural heritage is a valuable non-renewable resource containing human history, national culture and social progress, however, with the development of the times, some unpredictable natural and man-made factors have irreversibly damaged the cultural heritage. Therefore, it is imperative to develop and update more effective means of protection of cultural heritage. The digital activation technology with lower cost and higher dissemination efficiency has obvious advantages in the field of cultural heritage protection, bringing significant changes to the protection mode, dissemination channels, and inheritance and utilization of cultural heritage. The use of digital technology for cultural heritage conservation has developed by leaps and bounds in this century, and has become a popular trend worldwide, with a gradual trend towards interdisciplinary, cross-field and cross-organizational sharing and cooperation. With the continuous updating and iteration of digital technology, many high-tech means have been widely applied in the field of cultural heritage protection. With the increasing degree of digitization of cultural heritage, it is necessary to pay active attention to the new development and new application of digital technology in the field of cultural heritage protection, and to explore and practice the new forms and new paths of digital technology in the field of cultural heritage protection

**Keywords:** Cultural heritage, digital technology, design, protection, utilization.

### INTRODUCTION

Cultural heritage is the wealth left by history to human beings. It can be divided into material cultural heritage (tangible cultural heritage) and Non-material cultural heritage(intangible cultural heritage). Material cultural heritage is cultural relics with historical, artistic and scientific values; Non-material cultural heritage refers to various traditional cultures that exist in intangible forms, are closely related to people's lives and are inherited from generation to generation.

Cultural heritage carries rich historical information of different eras, such as cultural characteristics, social forms, political economy, living habits and religious beliefs, and is the crystallization of wisdom in the history of human civilization (Benton, 2010). Cultural heritage is a precious and non-renewable resource (Shan, 2009). With the change of time, human activities and natural factors, many cultural heritage sites around the world are facing unprecedented difficulties in survival, and are even in danger of disappearing or even on the verge of disappearing (Neil *et al.*, 2015). How to protect and inherit cultural heritage has become an important topic that cannot be ignored in today's society (Shan, 2007).

With the rapid development of digital technology, the field of cultural heritage protection is undergoing a profound change, and is developing towards multi angle, omni-directional and digital media recording in the fields of pictures, text, sound and image, which can well realise the storage, preservation and dissemination of information, and creates greater possibilities for the development and utilization of cultural heritage resources (Li, 2021).

### LITERATURE REVIEW

In 1992, UNESCO launched the "Memory of the World" project, which introduces digital technology into the protection of cultural heritage. It aims to promote the preservation, utilization and dissemination of cultural heritage on a global scale, and raise public awareness of the importance and necessity of preserving cultural heritage. In 2002, UNESCO released the "Guidelines for the Preservation of Digital Heritage" after consulting a wide range of countries on the protection of digital cultural heritage, which became the starting point for the establishment of digital protection of cultural heritage (UNESCO, 2015). In 2003, the Charter on the Preservation of Digital Heritage was promulgated, officially incorporating "digital" into a new form of cultural heritage, marking the beginning of digital protection of cultural heritage and providing standardized implementation guidelines and principled policy guidance for the practical work of digital protection of cultural heritage in various countries.

## Digital Preservation of Cultural Heritage

China is a country with rich cultural heritage resources. The digital preservation and utilization of cultural heritage follows the trend of the times, fully responds to the national strategic needs, and has received clear guidance and strong support from the national policy. In recent years, China has successively issued a series of guiding documents such as “the Guiding Opinions on Further Strengthening Cultural Relics Work”, “the Three-Year Project of “Internet + Chinese Civilization”, and “the 13th Five-Year Plan for the Development of the National Cultural Relics”, etc., which have strengthened the protection of traditional cultural heritage, while put forward clear requirements and guidelines on the application of digital technology. The National 14th Five Year Plan Outline released in 2021, which contains several chapters on the protection, utilization, and inheritance of cultural heritage, especially column 13 which includes key tasks of “Cultural Heritage Protection and Inheritance”. It highlights the importance of “focusing on digital empowerment” in the whole process of cultural heritage preservation, inheritance, and utilization, and continuously promotes the digital protection approach of cultural heritage.

The development trend of relevant technologies is also increasingly distinct. “The China Internet Development Report 2020” points out that “traditional industries such as cultural heritage protection actively seek to transform to digitalization, network and intelligence”. The use of virtual reality technology to protect cultural heritage effectively alleviates the contradiction between the protection and value utilization of cultural heritage (Li, 2008); the use of a variety of digital technologies for the effective protection of cultural heritage not only perpetuates the cultural inheritance of the Chinese nation, but also maintains the cultural beliefs of the general public.

## THE CURRENT SITUATION AND PROBLEMS OF DIGITAL PROTECTION OF CULTURAL HERITAGE

### Inadequate Cultural Heritage Database and Low Openness of Resource Sharing

The construction of cultural heritage resource database is the foundation for the long-term development of digitalization of cultural heritage (Sun, 2012). Cultural heritage resources are abundant, widely distributed, and cultural heritage of different generations has its own distinctive characteristics, which makes it difficult to collect digital resources (Smith, 2012). The norms and technical standards for digital protection of cultural heritage are not yet perfect, so it is necessary to gradually improve the catalogue of cultural heritage items (Rao, 2010), unify data and information collection standards, and build a data system for cultural heritage resources. The development of open and shared cultural heritage resource data platforms, digital interaction platforms, and cultural heritage management service platforms is not comprehensive. It is necessary to gradually realize the dissemination, accessibility, searchability and updating, resource sharing and online supervision, and strengthen the protection of cultural heritage digital resources (Jiang *et al.*, 2023). Relying on the National Cultural Big Data Centre, a project to collect and record basic data on cultural heritage has been implemented, accelerating the construction of digital archives and databases of cultural heritage resources and optimizing various types of basic databases and relevant thematic databases. As cultural heritage data needs to be supplemented and updated with research results in a timely manner, a dynamic multidisciplinary cultural heritage database should be established.

### Insufficient Innovation in Digital Content of Cultural Heritage, Limited Application of Digital Technology, and Poor Interactivity in Dissemination

The digital age (Marta, 2013) has put forward higher requirements for the digital transformation and upgrading of cultural heritage. At every node of digital creativity, production, and dissemination of cultural heritage, creative transformation and innovative development can be achieved, avoiding homogenization and transformation, so as to more effectively display and vividly interpret cultural heritage, and preserve the soul of its connotation (Wang *et al.*, 2023).

The digital protection and inheritance of cultural heritage is in the initial stage, which makes the new mode of cultural heritage content products in the stage of barbaric growth. These digital products have played a certain role in promoting the protection and dissemination of cultural heritage, but they are also caught in the embarrassing situation of “insufficient innovation of content and lack of combination with digital technology” (Peng, 2021). The digital content of cultural heritage does not have obvious regional characteristics, the innovation path is not extensive, and there is a lack of organic combination with popular animation, film, e-sports, short videos and other digital media. The dissemination form of cultural heritage is not sufficiently integrated with the times, and the dissemination on new media platforms usually characterized by unidirectional output, which is difficult to arouse emotional resonance. It is necessary to transform cultural heritage into more vivid and lively dissemination contents and forms, to make cultural heritage “alive” and closer to the preferences of “young people on the Internet”, and at the same time, and to carry more flexible media and carrier platforms in the digital era, to enhance the interactivity of communication and to create a new type of cultural heritage dissemination mode. Integrating “cultural heritage + big data”, analyzing audience preferences through big data technology to achieve differentiated and precise content delivery, thereby enhancing the efficiency and relevance of cultural heritage dissemination. Actively build a digital publicity platform for cultural heritage, realize online and offline collaboration, carried out multi-dimensional publicity for cultural heritage, guided and encouraged the digital experience project of “cultural heritage + Internet”, and carried out inheritance of cultural heritage through the form of digital collections of cultural heritage, thus opening up a new channel of cultural heritage to the market.

## EXPLORING METHODS FOR DIGITIZATION OF CULTURAL HERITAGE

There are two main ways for the use of cultural heritage (Poulios, 2014): improvement and optimization based on the material space; and dissemination and utilization based on the digital information (Guo, 2023). With the rapid development of hardware and software technologies such as big data, 5G technology, digital modelling, VR (virtual reality), and AR (augmented reality),

the protection of cultural heritage is gradually transitioning from the first traditional protection method to the second method of digital protection, development and utilization, which is not only a technological innovation, but also a perpetual continuation of the cultural heritage (Ming *et al.*, 2024).

The digital utilization of cultural heritage refers to the use of digital technology to collect, store, organize, and classify cultural heritage, and through digital technology, record, edit, manage, and reproduce it truthfully and completely, generating audio, video, and other databases to achieve three-dimensional digital archiving (Howard, 2006). At the same time, it also allows users to browse and search resource information, achieving visual retrieval of resources. Digital technology enriches the protection methods and approaches of the original cultural heritage, making the cultural heritage resources become a form of digital existence that can be used and shared for protection and restoration, archaeological research and cultural exchanges, and realizing the inheritance and dissemination of the values of cultural heritage resources in various aspects, such as history, art, science, society and culture (Tang, 2013). The use of digital technology to transform cultural heritage into digital form does not require direct surface contact with the heritage itself, thus showing various advantages such as strong reversibility and high security, which not only enables the sustainable development and safe protection of cultural heritage, but also realizes the restructuring, regeneration and utilization of cultural heritage to a certain extent.

At present, digital technology has gradually become an indispensable and important technical means in the field of protection, development and utilization of cultural heritage. Therefore, by constructing an effective interconnection between digital technology and cultural heritage, forming a set of strategies and methods of digital activation and utilization of cultural heritage with practical value, it can fully highlight and give full play to the advantageous and complementary relationship between the two, and further promote the digital interpretation, display and dissemination of cultural heritage, and enhance the protection and utilization of cultural heritage. It can fully highlight and give full play to the complementary relationship between the two, further promote the digital interpretation, display and dissemination of cultural heritage, and enhance the level of protection and utilization of cultural heritage, with a view to providing theoretical reference for the research and development of the field of digital protection of cultural heritage (Brodie *et al.*, 2006).

#### Digital Information Acquisition Technology for Cultural Heritage

In terms of information acquisition, RS (Remote Sensing) and GPS (Satellite Navigation System) are the main digital technologies currently used for cultural heritage data acquisition. RS technology is mainly used to acquire surface information of cultural heritage through indirect means, including 3D laser scanning (Table 1), satellite remote sensing, structured light scanning, photogrammetry (Table 1), close range photogrammetry, Synthetic Aperture Radar Interferometry (InSAR), etc.; GPS technology has the advantages of high precision, high efficiency and low cost, which makes it widely used in obtaining positioning information and deformation measurements of cultural heritage. Depending on the complexity of cultural heritage, multiple techniques can be integrated to improve the efficiency and accuracy of acquiring surface data and historical information of cultural heritage (Wen, 2022). The non-contact acquisition of cultural heritage data through digital technology can reduce the errors caused by manual acquisition of data, and at the same time reduce the unnecessary damage to cultural heritage caused by human factors. The acquired data and information can be directly stored in digital format to form high-precision audio and video information, which is convenient for edit, process and use in the later stage, and at the same time has the advantages of higher accuracy, lower cost and longer preservation time.

Table 1: Commonly used technologies for acquisition digital information on cultural heritage.

technology	3D laser scanning technology	Photogrammetry technology
principle	Scanning of photos, drawings, texts, samples and other object information, and then converting them into digital signals using optoelectronic technology and digital processing technology.	Digital photogrammetry is to convert the acquired optical images of cultural heritage into digital signals through photoelectric sensors, and finally form digital images. In short, it is a modeling technology that uses 2D photos to record physical scenes and then converts them into digital 3D models.
process	Quickly obtain the three-dimensional shape, pattern color, surface albedo and other information of the target object in a short period of time, and then use the computer system to carry out three-dimensional reconstruction calculations, so as to create a three-dimensional digital model of the same as the target object.	<ol style="list-style-type: none"> <li>1. Take multi-angle photographs of cultural heritage in an evenly and softly light scene.</li> <li>2. Ensure that the photographing process is extremely detailed without any missing angles, and that the photographs are overlapped with each other more than 70%.</li> <li>3. Add various lighting environments in the later stage, and use a series of software to intelligently model.</li> </ol>

Typical example	"Digital Michelangelo" project launched by Stanford University, USA.	Dunhuang Cultural Heritage (Chen <i>et al.</i> , 2016) has launched a new model of "photogrammetry + automatic modeling". By uploading photos of cultural heritage from different angles, a 3D model can be generated.
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Source: This study.

In terms of information acquisition, the future trend is miniaturization, convenience and refinement. The application and integration level of various digital perception technologies will be significantly improved. Even with the further development of intelligent technology, it is possible to capture effective spatial information of cultural heritage through human optic nerve, and generate high-quality data of cultural heritage directly by using intelligent technology for image information processing, thus achieving the intelligent effect of "visual acquisition".

### Digital Restoration Technology for Cultural Heritage

Graphics and image processing software and modeling software are widely used digital technologies in the restoration of cultural heritage. With the acquisition of three-dimensional information data and the use of digital modelling techniques, staff can construct high-precision three-dimensional digital models of cultural heritage in a short period of time. The application of digital technologies in cultural heritage restoration work consists of two aspects: for damaged cultural heritage, digital technologies are used to carry out multi-angle and all-round observation and analysis, and to select the most effective means of restoration to repair the damaged parts; for cultural heritage on the verge of being damaged, virtual restoration can be carried out in advance by using digital technologies and predicting the state after restoration to assess the feasibility of restoration work. Pre-restoration can avoid unforeseen damages to cultural heritage and greatly improve the efficiency of cultural heritage protection by implementing protection plans and proposing feasible solutions in advance. A typical case is the restoration of Notre Dame de Paris.

In 2019, the nearly 900-year-old Notre Dame de Paris suffered the worst fires in its history, which almost destroyed the entire top of the building according to CNN. Faced with such a great loss of the treasures of cultural heritage, the local government proactively organized the post-disaster restoration work, the most important basis of which was the digital files of Notre Dame de Paris. The local government has the foresight to conduct all-round digital scanning of Notre Dame de Paris a few years ago, through Google Arts & Culture and with the help of digital reproduction technologies such as 3D scanning, VR (virtual reality), high-resolution photography and other digital technologies, completely preserved the building's details from all angles and stored this data for future reference. Since digital technology is a comprehensive record of historical building information, after the fire, a number of organizations used 3D digital technology to gradually restore and reconstruct the architectural heritage based on the comprehensive digital information of Notre Dame de Paris (Figure 1) that had previously been preserved.

The use of 3D technology to assist in the restoration of cultural heritage is relatively mature. 3D technology is mainly used to provide modelling support for the repair and restoration of cultural heritage. For cultural heritage that no longer has integrity or has disappeared, it can be repaired and restored through 3D technology. The preliminary use of high-definition images, LiDAR remote sensing and other technologies for 3D scanning of cultural heritage to obtain high-precision data information, and then combined with 3D technology for reverse modelling.

The future development trend of cultural heritage information restoration is to improve the splicing and fusion of multivariate data, the recognition and processing of complex images, and the fully automatic conversion of 2D and 3D information; to improve the operability and applicability of the software, which greatly facilitates the work of technicians. Ultimately, with the continuous improvement of Artificial Intelligence (AI), especially deep learning technology, human intervention will be reduced to achieve intelligent and efficient processing of cultural heritage information, and it is even possible to realize visual analysis, virtual restoration, deformation transformation and so on of architectural heritage with the assistance of AI technology.

### DESIGN PRACTICES FOR DIGITIZATION OF CULTURAL HERITAGE

At present, the digital protection of cultural heritage is mostly focused on the application of digital technologies such as digital information preservation, restoration modelling, virtual simulation, etc., emphasizing the ways and methods of digital restoration of cultural heritage, and focusing on case studies and empirical research, while the deep digital development and display and dissemination of cultural heritage's associated historical background and humanistic connotations are still relatively weak (An *et al.*, 2013; Xu, 2014)). Recognizing the current situation (Holtorf, 2011) of digital protection of cultural heritage, understanding its essence, applying cutting-edge digital technology, relying on multidisciplinary cooperation, and exploring with foresight to carry the rich historical information behind cultural heritage through content innovation, and bringing people closer to cultural heritage (Ma *et al.*, 2019), which is the directions and challenges for future research, so as to achieve a longer and more effective protection and inheritance of cultural heritage in China.

China has a rich cultural heritage (Lu, 2015), including traditional architecture, art works and unique cuisine. With the development of technology, 3D printing technology has gradually matured and been widely used in the field of cultural

heritage preservation. This design combines Chinese cultural heritage and 3D printing technology, using 3D food printer to present traditional cuisines with the morphological characteristics of cultural heritage, to achieve customized production of traditional cuisine and innovative inheritance of cultural heritage, aiming to provide new ideas and technologies for the protection and inheritance of cultural heritage, which is of important research value and practical significance (Holtorf, *et al.*, 2013; Byrne, 2014)).

3D food printing is a new high-tech application technology formed by integrating 3D modelling, electromechanical control, food science and other interdisciplinary knowledge (Koh *et al.*, 2021). For different individuals or groups, food 3D printing technology can not only achieve precise control of nutrition, but also personalized nutritional meals (He *et al.*, 2020). At present, many types of food have been successfully produced by 3D printing technology, such as chocolate, cake, candy and artificial meat, etc.. The food materials commonly used in 3D food printing are mainly include protein, starch, fat and hydrogel, etc.. With chocolate as a typical printable ingredient, industrialized production has been achieved both at home and abroad (Wilms *et al.*, 2021).

### **Design Concept**

Taking the innovative utilization of cultural heritage as the source of inspiration, the design scheme selects some characteristic cultural heritage elements as 3D printing materials, aiming at integrating cultural heritage and advanced 3D printing technology, combining traditional culture with modern technology (Kou *et al.*, 2020). Through the integration of cultural heritage elements, a unique 3D food printer is designed, which not only demonstrates the unique charm of cultural heritage, but also provides users with a personalized experience of close contact with cultural heritage, showing the beauty of the intermingling of science and culture heritage, and injecting new vitality into the inheritance and innovative development of cultural heritage (Sun *et al.*, 2017).

### **Functional Requirements**

#### ***Cultural Integration***

Adopting the symbolic elements of cultural heritage as the design theme and integrating them into food modelling and patterns.

#### ***Customized Service***

Focusing on users' personalized needs and experience, users can customize the shape, taste and nutritional content of food according to their personal preferences to achieve personalization, thus creating food that meets their personal tastes and health needs.

#### ***Intelligent Control System***

Provides a simple and intuitive user interface that enables users to print food products easily; supports wireless connection, which makes it convenient for users to control the printer through mobile phones or computers, and remotely control and monitor the printing process; troubleshooting function, which automatically detects and solves common problems and reduces users' operational barriers.

#### ***Environmental Protection and Sustainability***

Select biodegradable food materials to reduce the negative impact on the environment and advocate green production.

### **Technology Requirements**

#### ***Material Selection***

Select materials suitable for food printing, such as edible starch, chocolate and other food-grade materials; the materials should have good plasticity and safety to ensure food safety and taste (Van, 2016).

#### ***Intelligent Recognition***

Through image recognition technology, achieve intelligent recognition and optimization of food forms.

#### ***3D Printing Technology***

Adopt advanced 3D printing technology such as light curing and fused deposition to ensure printing precision and speed to provide high food quality (Liu *et al.*, 2017) (Figure 1).

### **Application Scenarios**

#### ***Family Use***

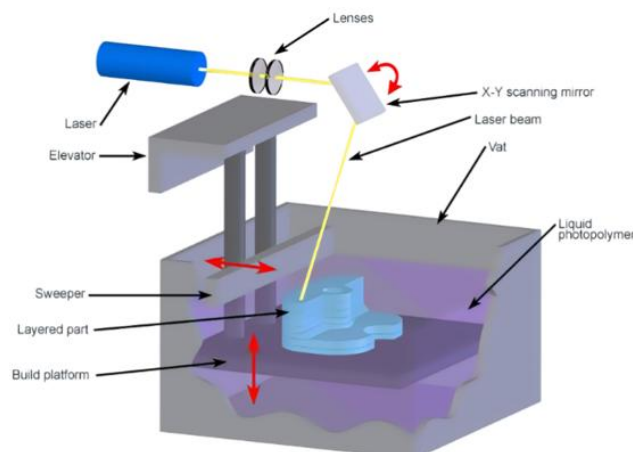
Provide families with a healthy and interesting food production experience, and enhance the interaction of family members and awareness of cultural heritage.

#### ***Commercial Promotion***

It can be used for commercial and tourism promotion (Park *et al.*, 2019) related to cultural heritage, customizing food with cultural heritage characteristics to attract customers and enhance brand image.

### Cultural Inheritance

Through the form and pattern of the food, it conveys cultural heritage and historical stories, and promotes cultural inheritance and communication.



Source: Baidu pictures.

Figure 1: Schematic of 3D Printing Light Curing.

### Design Implementation Process

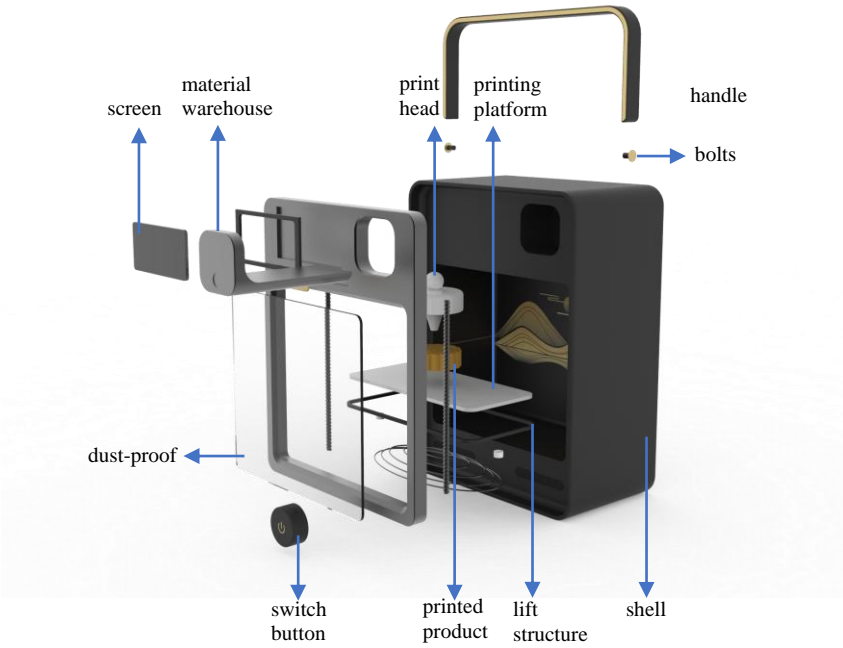
Firstly, import cultural heritage related pictures as reference in Rhino5.0, including traditional architecture, handicrafts, food, etc.. Then carry out basic geometric modelling using the basic geometric tools of Rhino5.0, such as lines, curves, circles, etc.. Based on the reference images to construct basic modeling and build the outline of the overall structure. Secondly use the editing tools of Rhino5.0 to adjust and modify the basic geometry, so as to make it closer to the design requirements and the characteristics of cultural heritage, such as adding traditional patterns, carving details and so on. Thirdly, according to the design requirements of the 3D food printer, build the mechanical structure in Rhino5.0, including the print head, transmission device, printing platform, etc., to ensure the function and stability of the mechanical parts. Design and add control system components, such as buttons, displays, screens, etc., in order to control and monitor the printer. Select appropriate materials and set its appearance texture in Rhino 5.0, the overall black and gold colour scheme is used to make the design more luxurious connotation and cultural characteristics. Fourthly, assemble the various components to ensure that they are well connected and fit together, and also arrange the layout to make the overall design more reasonable and beautiful. Finally, refine the design details, including adding details of decoration, adjusting the proportion of components, etc., in order to enhance the quality and expressiveness of the overall design (Figure2-5).



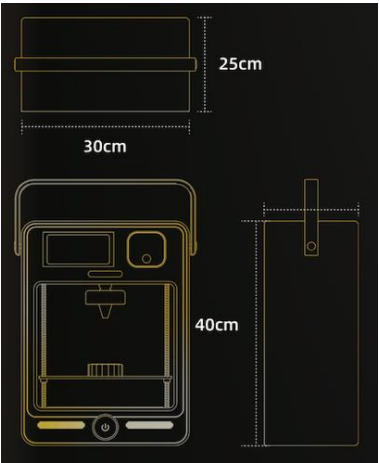
Source: Author's drawing.

Figure 2: Product model and rendering.

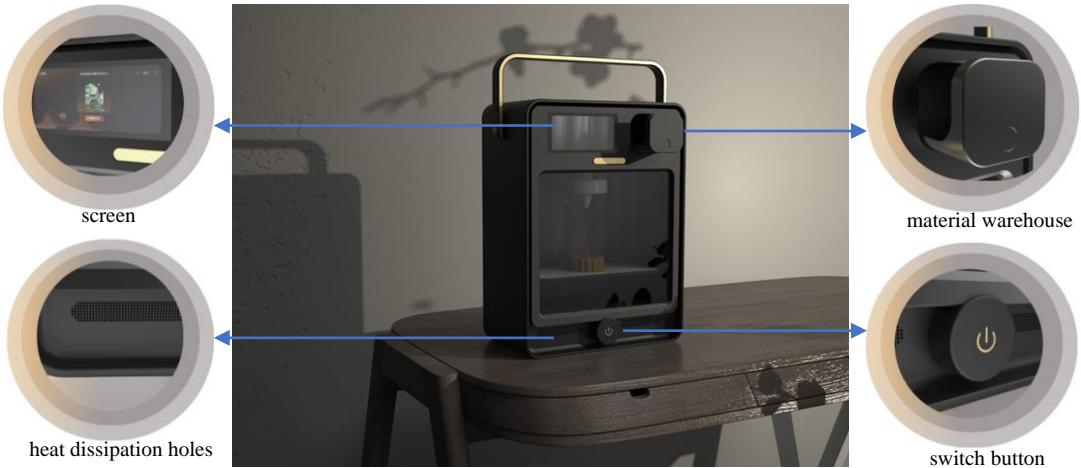
The 3D food printer consists (Lille *et al.*, 2018) of dust-proof, material warehouse, screen, switch button, printed product, lift structure, shell, bolts, handle, and other components (Figure 3).



Source: Author's drawing.  
Figure 3: Component diagram.



Source: Author's drawing.  
Figure 4: Dimension drawing.

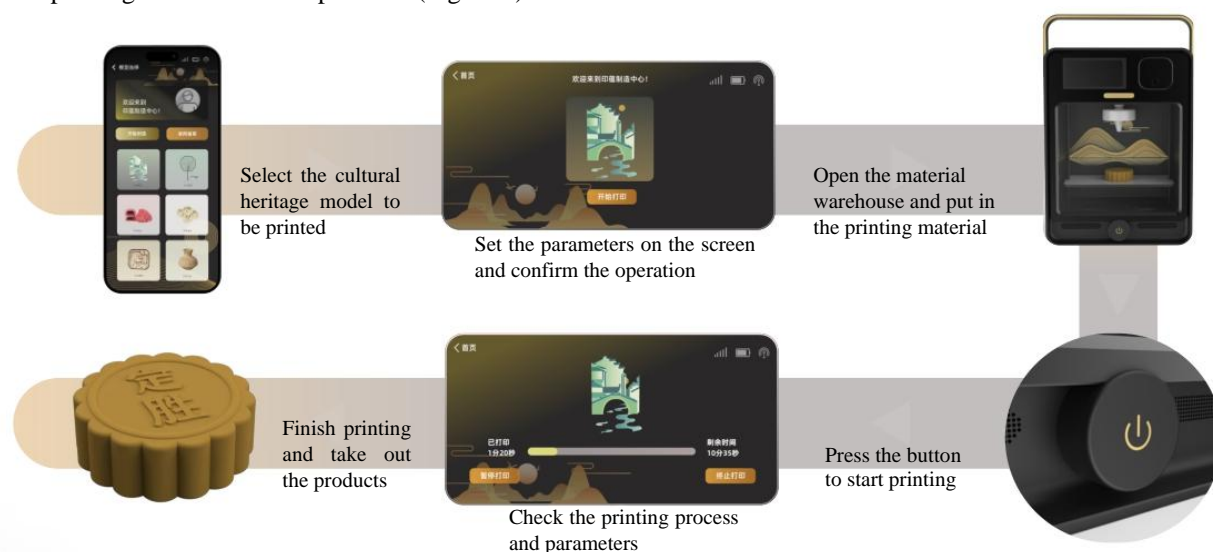


Source: Author's drawing.  
Figure 5: Product Rendering & Product Details.



### The Procedure of the 3D Food Printer

1. Select the cultural heritage model to be printed
2. Set the parameters on the screen and confirm the operation
3. Open the material warehouse and put in the printing material
4. Press the button to start printing
5. Check the printing process and parameters
6. Finish printing and take out the products (Figure 6)



Source: Author's drawing.

Figure 6: The Procedure of the 3D Food Printer.

### The Significance of The Design

#### *Inherit and Promote Culture Heritage*

Through the combination of 3D food printing technology (Godoi *et al.*, 2016) and the characteristics of cultural heritage, cultural heritage can be inherited and promoted in a new form, conveying cultural heritage and the historical stories behind it (Smith, 2006). This helps to attract the attention of the younger generation to cultural heritage, promote the protection and inheritance of cultural heritage, and realize the perpetuation of culture.

#### *Promote the Integration of Science and Technology with Culture Heritage*

The 3D food printer (Pallottino *et al.*, 2016) not only meets people's catering needs, but also carries cultural memories and emotional values. By integrating cultural heritage elements into modern technology products, it promotes the combination of. The design combines cultural heritage with science and technology, tradition with modernity, providing an empirical case for the integration between the two.

#### *Enhance the Cultural Power*

Successful design and promotion of 3D food printers based on cultural heritage will help to enhance the dissemination of cultural heritage, which will have a positive effect on the protection and utilization of cultural heritage, as well as enhance the visibility and attractiveness of cultural heritage.

### SUMMARY

With the innovation of digital technology, the protection of cultural heritage is gradually upgraded from the traditional passive protection to the active preventive protection mainly based on digital science and technology. The application of digital technology in the field of cultural heritage protection is an inevitable product of the digital era, which is not only a remedy for the traditional protection methods, but also broadens the scope of cultural heritage protection and utilization as well as the depth of the dissemination influence. The application of digital technology provides a brand-new technical way for the protection of cultural heritage, provides a more accurate way of information acquisition and storage, makes the permanent preservation of cultural heritage and its historical information possible, and promotes the integrity, safety and integrated utilization of cultural heritage related resources (Willems, 2014). It provides cutting-edge restoration technologies, which are widely adaptable to the widely distributed and diverse forms of cultural heritage around the world, enabling the restoration of architectural heritage to be completed with high quality and efficiency. It provides innovative and diversified display methods and convenient and efficient dissemination paths, which can achieve the sharing of cultural heritage in the global context across time and regions, promote the exchange, dissemination and inheritance of outstanding cultural heritage in the international context. It also facilitates research and use by scholars, enhances cultural influence, achieves cultural continuity and transmission of national memory, and is conducive to improving national identity and self-confidence.



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