3D modeling of stone statues based on stone carving of Ming Xiaoling Mausoleum and historical materials of Ming Dynasty armor

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Abstract: Based on the historical research on the shape of armor in Ming Dynasty, this paper explores the shape characteristics of general armor in Ming Dynasty in China through field research on the general stone statue of Ming Xiaoling Mausoleum in Nanjing. Through Ming Xiaoling Mausoleum general stone carving 3D animation technology restoration project, virtual material heritage practice is carried out. Through the modeling of the general stone statue in Ming Xiaoling Mausoleum by MAYA and Zbrush, UE4 realizes the construction of scenes and the output of interactive effects, so as to explore a mode of application engine animation that can preserve and propagate general stone carving in Ming Xiaoling Mausoleum.

Keywords: Armor in Ming Dynasty; Stone carving in Ming Xiaoling Mausoleum; 3D animation technology; MAYA; Zbrush; UE4

1. Introduction

In the course of history, Chinese armor has experienced the beginning of the pre-Qin period, the primary formation of the Qin and Han Dynasties, the innovation of the Southern and Northern Dynasties, the great achievement of the Sui and Tang Dynasties, and the peak of the Song Dynasty. The Ming Dynasty is already the mature stage of Chinese armor [1]. The types and shapes of Ming armor are in line with public perception. According to physical data, only a very small number of ancient armor objects have been preserved. In contrast, research on armor culture is largely derived from documentary sources, paintings, and sculptures. Among them, the armor in the general stone statue of Ming Dynasty is a reliable source of research on Ming armor culture. As the location of the tombs of the emperors and courtiers of the Ming Dynasty, many general stone statues have been preserved in Nanjing, which provide direct reference materials for the study of the armor shapes in the general stone statues of the Ming Dynasty [2]. The stone statue, also known as "Weng Zhong", is an image of a person or animal carved from stone and installed in front of the tomb. The stone statue is placed on both sides of the tomb, and its shape is lifelike. It is considered to be the symbol and epitome of the etiquette guard of the tomb owner. This practice began in the Qin and Han dynasties, and was later followed by emperors and ministers with different numbers and images

Cultural heritage displays focus on "authenticity" with the aim of giving viewers deep and direct understanding of material heritage. Among them, the traditional display methods are mainly museums and theme parks, such as the Terracotta Warriors Museum and Ming Xiaoling Mausoleum Park. This type of material heritage display not only protects the material heritage, but also allows viewers to have face-to-face contact with the cultural relics. However, due to the limitations of geographical location, traffic and audience number, the exhibition of cultural relics cannot be widely disseminated to let more people feel the historical significance of cultural relics. The emergence of 3D animation

technology breaks this time and space limitation and provides historical and cultural education functions and interactive experience, allowing viewers to experience the dynamic cultural relics display in an immersive form[3].

The main feature of 3D technology lies in the sense of immersion and interaction. The online stone statue display allows viewers in different places to experience these material cultural heritages and master relevant historical knowledge through the Internet platform. With the intervention of 3D engine animation, cultural relics can be spread to more people's field of vision in a new way.

2. Background

Clothing represents national aesthetics. Therefore, the restoration of ancient clothing is beneficial to the current film and television animation creation. The exquisite costumes in the costume drama "The Longest Day in Chang'an" are a sensation in that time. The reasonable and sophisticated expression of Tang suit culture meets the visual aesthetic needs of contemporary viewers. The design of clothing should not be single and fragmented, but needs to show the background and culture of the era[4]. Misunderstandings about armor culture are often seen in game animations, which shows how important it is. Many armor lovers show armor culture through restoration, exhibition, and new media dissemination. For example, armor restorer Jiang Feng spent two years restoring Tang kylin Mingguang armor. In addition, he also successfully restored China's first set of Shanwen armor. Armor restorer Li Hui held the Xuanliu Armor Cultural Solo Exhibition in Beijing in 2020, which exhibited a variety of armors from different dynasties in China. According to relevant statistics, the videos about armor on the video platform have been viewed more than millions of times, which shows that the armor has been loved by the public as a unique historical clothing culture and its intricate design details are also in line with the visual aesthetics of contemporary people.

Due to the lack of understanding of ancient Chinese armor culture, there are many wrong expressions of Chinese general armor in many game animations. For example, Ubisoft's DLC "For Honor • Winter Tommy" launched in 2018 has a character Tiandi designed based on the image of a Chinese military general. The character wears plate armor. Based on the current literature, the "plate armor" is rarely used in traditional Chinese armor. The game "Total War • Three Kingdoms" launched by Sega's Creative Assembly has a military commander image Lu Bu, whose shoulder armor design adopts the shoulder armor structure in the Japanese samurai armor. In more detail, the armor pieces of this armor are stacked horizontally, which is different from the shoulder armor in ancient Chinese armor. "Mulan", which released in the United States on June 19, 1998, is a computer-animated film produced by Disney and co-directed by Tony Bancroft and Barry Cook. The film is adapted from the Chinese folk poem Song of Mulan that tells the story of Mulan who joined the army in place of his father and defended against the enemy. One of the characters, General Li Xianghe, wears Ming armor. Broadcasted on TV Tokyo on April 3, 2010, "SD Brave Battle Warrioes" is an animation based on the Chinese classic Romance of the Three Kingdoms and combined with "Hero of the Storm" and "Heroic Assault" in the original work, which describes a series of stories that Gundam Liu Bei encounters in pursuit of justice in Sanlisha with friends Gundam Guan Yu and Gundam Zhang Fei. Among them, Gundam Liu Bei is an image of a general in armor. Ubisoft's DLC "For Honor • Winter Tommy" launched in October 2018 added city attack-defense mode and single-player battle mode, as well as 4 new characters. Among them, the character design of JiangJun and Tiandi refers to the image of Chinese generals. In more detail, JiangJun's image mainly refers to Guan Yu's shape with battle-hardened veteran temperament. Tiandi is set up as a loyal royal guard, and his image is a general in armor. (Table 1)

Digital Protection and Design of Southern Dynasty Stone Carving Art by Yang Xiangming of Nanjing University of Posts and Telecommunications mentioned the use of 123D Catch photo modeling technology to carry out 3D modeling and digital restoration of

Southern Dynasty stone carving [5]. In Study on 3D Digital Protection of Southern Dynasties Mausoleum Stone Carving, Ge Huaidong et al. mentioned the introduction of 3D reconstruction system and panoramic space measurement technology to digitally protect stone carving of Southern Dynasty mausoleums [6]. Hou Mole et al. proposed three methods for digitizing stone carving cultural relics in Retention and Application of 3D Information of Stone Relics, including traditional measurement method, close-range photogrammetry method, and 3D laser scanning method. Through the study of the above methods, primary digital modeling and secondary close-up photography are used to construct the digital model of general stone statue in Ming Xiaoling Mausoleum. During 2011-2013, the Etruscan EU project developed by Eva and Andrea from the CNR-IENI Institute in Italy carried out 3D virtual reconstruction of the stone carving of two important Etruscan tombs during the Orientalization period. The project focuses on communication needs, design, media composition, interface and presentation, and envisions 3D virtual reconstruction as a digital ecosystem that includes 3D reconstruction, content creation, and interactivity [7]. With ancient sculptures from the Mediterranean as research objects, the CRS4 Research Center has developed an interactive system for exploring 3D models in the museum. The combination of object-aware interactive camera controller and interactive user interface provides useful inspiration for the design of 3D detection user interface in future digital installations.

Table 1. Armor in animation movies and games.

Type	Show time	Title	Dynasty	Representative role
2D animation	1956	The Conceited General	Imaginary	Leader crocodile
	1990	Gourd Small Diamond	Myth	General Li Xianghe
	1998	Mulan (USA)	Northern and Southern Dynasties	Er-Lang God
	1999	The Magic Lotus Lantern	Myth	Zhou Shenjiang
	2005	I-go Youngster (II)	During the reign of Emperor Tianqi in the Ming Dynasty	Wu Baisheng
	2008	Zheng He's expeditions	During the reign of Emperor Yongle in the Ming Dynasty	Gundam Liu Bei
	2010	SD Brave Battle Warries (Japan)	Imaginary	Zheng Chenggong
	2014	Zheng Chenggong	During the reign of Emperor Longwu in the Southern Ming Dynasty	Leader crocodile
3D animation	2014	Qi Jiguang	During the reign of Emperor Jiajing in the Ming Dynasty	Qi Jiguang
	2018	Whale Riding on Earth	Imaginary	Supporting soldier
	2018	For Honor WinterTommy (France)	Imaginary	Tiandi

3. Artistic style of Ming Xiaoling Mausoleum general stone carving

The general stone statue of Ming Xiaoling Mausoleum draws heavily on the characteristics of Tang Mausoleum. For the facial image processing of stone statues, the Tang Dynasty respected the philosophy of "studying nature outside and catching source inside". The detailed description of general clothing reflects the idea of "painting according to subjective feelings" proposed by Wang Lu of Ming Dynasty, namely the unity of objective image and inner image. The stone statue of Ming Xiaoling Mausoleum is as solemn as the stone carving of the previous imperial mausoleum, and its decorative style is prominent in the general's armor and clothing with complex structures and patterns[8]. The general in Ming Xiaoling Mausoleum wears armor and holds weapon. In more detail, these generals wear round bowl-shaped helmet with long tassel, armor and moire boots. Among them, there are tiger-shaped patterns on the shoulder helmet. This attire is similar to "armor, cape, hanging trousers and helmet" recorded in Wujing Zongyao [9]. This shows that the craftsman's carving respects objective facts. The orderly distribution of stone general and the corresponding dots, lines and surfaces create a sense of composition, coherence and rhythmic beauty [10].

Ming Xiaoling Mausoleum is the mausoleum of the founding emperor Zhu Yuanzhang and his empress. Under the national self-confidence of China's reunification in the early Ming Dynasty, the stone statue of Ming Xiaoling Mausoleum has a strong and enjoyable style. In the early Ming Dynasty, the society mainly followed a simple funeral style. Different from the finely carved stone statues in Thirteen Ming Tombs, the stone statues in Ming Xiaoling Mausoleum are generally carved with planes and line drawings, which look more concise and vivid. At the ideological level, Neo Confucianism in Song and Ming Dynasties advocates the harmony between man and nature, which is also one of the factors contributing to the elegant style of the stone statue. In terms of technology, the hard-textured dolomite directly affects the large-scale carving method used by the craftsmen, which will further affect the flat, freehand and other styles of the work. The details are mainly carved by flat carving, line carving and other methods, which affect the decorative style of the stone statue. In general, the general stone statue of Ming Xiaoling Mausoleum reflects the general's clothing characteristics, social atmosphere and mainstream thinking in the early Ming Dynasty[11].

Based on the analysis of the armor structure and characteristics of the general stone statue in Ming Xiaoling Mausoleum and Thirteen Ming Tombs, the characteristics of Ming armor in the general stone statue in Ming Dynasty are derived. The top-to-bottom structure of Ming armor is as follows. A round bowl-shaped helmet is worn on the head, with a long tassel at the top. There is full armor over shirt and petticoat. Among them, the upper body armor includes shoulder armor and arm armor, with animal head and other patterns. Armor jackets have cuffs turned up at the elbows, with hanging robe sleeves or jewelry adorning the robe tail. The armor on the forearm is embellished with a piece of armor. The torso armor protects the chest and back, and the breastplate is fixed to the chest. In addition, there are absolute armor, waist armor, leg armor, and combat boots. Considering the complex composition of the general stone statue armor in Ming Dynasty, this chapter studies the Ming Dynasty general stone statue from the two aspects of overall shape (including helmet, armor and foot protection) and detail patterns (divine beasts, shoulder armor, decorative patterns and detail patterns)[12].

3.1 Helmet

The general characteristics of the helmet of the general stone statue in the Ming Dynasty are the war helmet and the red tassels. Among them, there are mainly four kinds of helmets, namely phoenix winged helmet, watermill lock protective helmet, animal helmet and coronet. The phoenix winged helmet features a phoenix wing decoration. The shape of the phoenix wing on the helmet of the general stone statue varies in different periods and regions. The general stone statue in Ming Ancestors Mausoleum's phoenix wing shape with spread wings is similar to the phoenix winged helmet of the Song Dynasty. In contrast, the phoenix wing of the general stone statue in the Ming imperial mausoleum is more concise than that in the Ming Ancestors Mausoleum. In addition, the helmet shape

in the general stone statue of Ming Xianling Mausoleum is quite different from that in Ming Ancestors Mausoleum, in which the phoenix wing of the former is looser. For the shape of the phoenix wing, the phoenix wing on the helmet of the lost general stone statue in White Horse Park is in a cirrus state. The helmets of Ming Xiaoling Mausoleum and Ming Kaiping King Chang Yuchun are more inclined towards watermill lock protective helmet. Animal helmet also appears in Tomb of Li Jie and Tomb of Wu Zhen. The animal helmet began in the Tang Dynasty and was still used in the Song and Yuan Dynasties. By the Ming Dynasty, animal helmets are mainly used in religious art rather than practical applications. In the Shuilu painting of Eight Units of Heavenly Dragon in Baoning Temple during the Ming Dynasty, the general armor is decorated with animal heads, such as dragons and crocodiles. In the existing materials, the helmet of the general stone statue in Ming lost tomb in Jishan is more like a coronet. The coronet headdress mainly appears in Ming Dynasty Shuilu painting, such as the right general of the protective dragon gods. The crown is shaped like a Zhongjing crown or hair crown and decorated with precious stones. (Table 2)

Table 2. Types of helmets of stone statue of general in Ming Dynasty

Helmet type	Picture	Source of general stone statue	Picture	Source of general stone statue
Phoenix winged helmet		Ming Ancestors Mausoleum (the overall shape of the helmet in the early Ming Dynasty is similar to the phoenix winged helmet of the Song Dynasty stone statue of general)		Ming Xianling Mausoleum (the phoenix winged helmet in the mid-Ming Dynasty has been very different from the Song Dynasty)
Animal helmet		Tomb of Li Jie (animal head such as tiger)		Tomb of Wu Zhen
Watermill lock protective helmet		Ming Xiaoling Mausoleum (the overall shape is similar to the helmet recorded in the *Code of Great Ming Dynasty*)		Shuilu painting of Eight Units of Heavenly Dragon in Baoning Temple during the Ming Dynasty
Coronet		Stone carvings of Ming lost tomb in Jishan (only separate helmet similar to coronet, no phoenix wing and protective component)		

3.2 Armor

According to Code of Great Ming Dynasty, the vast majority of Ming Dynasty armors are made of steel, including waist armor, willow armor, long-body armor, scale armor, drag-scatter armor, and round-collar armor [13]. Based on the records of armor in Wujing Zongyao, most of the armor in the early Ming Dynasty adopted the styles of the Northern Song Dynasty, Tang Dynasty and Five Dynasties. Among them, the typical image is the general stone statue in Thirteen Ming Tombs. Except for the protective component, various shapes are consistent with the Song Dynasty armor, including bellyband, chest armor, and knotting. By the mid-Ming Dynasty, the image of the armor still maintained the basic style and style of the early Ming Dynasty. However, many aspects started to change. For example, the breastplate in the mid-Ming Dynasty was tied to the chest with a rope, which was significantly different from the general stone statue in the Thirteen Ming Tombs. The style of the bellyband is similar to that of the Southern Song Dynasty. Abdominal armor is decorated with animal heads, falcon tails hang under the abdomen, and the leg skirts on both sides are thick. Attached with belts and buckles, this is a device for hanging the leg skirt. Moreover, there is also this device on the shoulder that connects the arm armor and cloak. The armors in Ming Xianling Mausoleum general stone statue and the Shuilu painting of Eight Units of Heavenly Dragon in Baoning Temple are typical images of the mid-Ming Dynasty.

In different periods of the Ming Dynasty, there were different armor shapes and wearing methods, without obvious change in the overall characteristics. Ming armor absorbs many features of dynasties such as Song and Yuan. Ming armor adds breastplate to the chest or back, which was absorbed from the Liao Dynasty armor. In addition to this, Ming armor adds a completely independent absolute armor, which hangs around the neck like a "belly pocket" at one end and wraps around the waist at the other end or attaches to the breastplate. This "surrounding" abdominal protection survived and became a common form of Ming armor, also known as "belly protection". Ming armor's broad absolute armor was directly attached with inverted pointed armor. Over time, it developed into the large volume of Diaoyu in Peking Opera, also known as "Yutawei". There are many and complex types of Ming armor. Through data collection and induction, Ming armor in general stone statue can be roughly divided into body armor, arm armor, chest armor, Uighur tail, trouser armor, waist guard, leg skirt, and breastplate. With the armor structure of Ming Nanling King general stone statue as an example, the characteristics of the overall shape of the armor are analyzed in the form of three views. From the front view, the body armor is hidden under the chest armor. In the front view, the structure of the body armor is not obvious. Side and back views show the structure of the body armor[14].

3.3 Armor pattern

There are three main patterns of general stone statue armor in Ming Dynasty, namely scale pattern, hammer pattern and mountain character pattern. In more detail, the scale pattern is semicircular stacked fish scales. The scale pattern often appears in Yutawei, such as the general stone statue in Ming lost tomb in Jishan. The hammer pattern is a long bar with round hammer at the top, such as the horse leading soldier's body armor in Tomb of Li Jie. The shape of the mountain character pattern is like the Chinese character for "mountain", which is also called "lock" in Yingzao Fashi. According to the category of lock armor, there are humanoid pattern, chain pattern and dense-ring pattern. For example, the chest armor of the general stone statue in Thirteen Ming Tombs adopts the humanoid pattern. The general's chest armor in Protective general in Shuilu painting in Ming Baoning Temple uses a chain pattern. The leg armor of Ming Nanling King adopts a dense-ring pattern (Table 3). Mountain character armor has been widely used since it was introduced into China in the Tang Dynasty, and became a common armor pattern in the Song and Ming Dynasties. The armor of Ming general stone statue has patterns in protective component, chest armor, cloak, absolute armor, Yutawei and other parts. In addition, some armors use the same pattern all over the body. For example, the general stone statues in Ming Xiaoling Mausoleum all adopt the mountain character pattern. Some armors use

different patterns. For example, the trouser armor of Ming imperial mausoleum general stone statue adopts scale pattern, while other parts adopt mountain character pattern [15].

Pattern	Picture	Pattern	Picture
Scale pattern		Chain pattern	
Ming Ancestors Mausoleum		Protective general in Shuilu painting in Ming Baoning Temple	
Mountain character pattern		Humanoid pattern	
Thirteen Ming Tombs		Thirteen Ming Tombs	
Hammer pattern		Dense-ring pattern	
Tomb of Li Jie		Ming Nanling King	

4. Realization process of the VR animation display about the general stone statue in Ming Xiaoling Mausoleum

4.1 Research methods and technical route

Literature research method: Through the review of a large number of documents, information about the current status of the Ming general stone statue, the existing location and the artistic characteristics of the general stone statue, the development and evolution of the armor in different dynasties, the structural characteristics of the armor, and the shape of the Ming armor were collected. First of all, the structural characteristics of Ming general stone statue's armor in different periods are compared and analyzed, so as to summarize the modeling characteristics of Ming armor. Secondly, the structural features of 2D Ming armor and 3D Ming armor in animation works are compared and analyzed. Finally, the similarities and differences between the structural characteristics of traditional Ming Dynasty armor and the characteristics of Ming general armor in Chinese animation are explored, so as to obtain animation design elements about traditional general armor.

Field investigation method: Through the literature, the artistic features of the general stone statues of the Ming Dynasty are studied. In addition, the sites of the general stone statue of Ming Dynasty in Nanjing are, and the overall image and detailed patterns of the general stone statue are recorded.

3D modeling: Digital technology is used to digitize the general stone statue in Ming Xiaoling Mausoleum. Based on multidisciplinary theories, methods and results, the 3D animation display of Ming Xiaoling Mausoleum general stone statue is comprehensively studied. Through several field visits to Ming Xiaoling Mausoleum, relevant data were collected to ensure authenticity and accuracy. The technical route of this subject is shown in the figure below.

4.2 Preliminary preparation

With great overall preservation, the size of Ming Xiaoling Mausoleum's general stone statue is 0.9m *1.2m *3.2m. However, some of the detailed engravings are blurred due to factors such as weather. In order to understand the detailed composition of the general in detail, this paper consults about the Ming imperial mausoleum general stone statue, the Thirteen Ming Tombs general stone statue and the description of the armor in Wujing Zongyao. Finally, the overall costume structure of Ming Xiaoling Mausoleum general stone statue was understood (Figure 1).

Figure 1. Ming Xiaoling Mausoleum's general stone statue.

4.3 Mid-term production

After understanding the detailed composition of Ming Xiaoling Mausoleum general stone statue, a data model based on MAYA and Zbrush is constructed. Zbrush is used to sculpt the main frame. MAYA is used to model decorations for helmets and swords. After obtaining the low poly, the obj format is exported hierarchically. In the detailed sculpting based on Zbrush, the brushes used are ClayBuildup, Standard, DamStandard, Move and TrimAdaptive, with Z intensity and Rgb intensity of about 25. Due to the same mountain character armor as the stone statue, PS is used to make a similar mountain character texture with Material of dolomite (Figure 2). Combined with the alpha functionality in Zbrush, new texture brushes are made for armor texture sculpting. After sculpting the stone statue, Zbrush is used to deface the model. Low poly with few faces is exported to MAYA for adjustment. Taking into account the texture of the stone statue dolomite, PS is used to make the base texture. Finally, the digital model of Ming Xiaoling Mausoleum general stone statue is constructed (Figure 3).

(**a**)   (**b**)

Figure 2. (**a**) mountain character armor; (**b**) Material of dolomite.

4.4 Post rendering output

After completing the overall setup of model and scene, the next step is to edit the VR animation footage(Figure 4). It is necessary to arrange some storylines and events to guide the viewing of physical heritage, so as to achieve the purpose of interactivity and immersion unique to the display of VR animation digital cultural relics [16]. For this, the Add Level Sequence Animation tool in Unreal Engine 4 is used for the shot production. A total of two shots are designed in the animation display of the general stone statue, that is, the overall advancement of the overall scene and the display of a single stone statue. After adjusting the shots, the movie is rendered.

Figure 3. The digital model of Ming Xiaoling Mausoleum general stone statue is constructed.

Figure 4. Edit the VR animation   Unreal Engine 4(UE4).

5. Cultural analysis of Ming armor

In history, there were many wars in Ming Dynasty, which led to its huge military machine and elaborate military system. After the establishment of the Ming Dynasty, Zhu Yuanzhang set up garrison towns in key areas of the country, which are considered to be a major creation of the military system. It should be noted that the Ming Dynasty was at a turning point in which hot weapons gradually replaced cold weapons as the main weapons of war. In order to win the war, the Ming government invested a lot of manpower and funds in the research and development, introduction and imitation of weapons. The emergence of new weapons led to the corresponding adjustment requirements for strategic tactics and protective equipment, which made the development of armor in the Ming Dynasty also show new signs. As military clothing, Ming armor has three functions, namely, protection, indication and deterrence[17].

5.1 Protection

The main role of armor design is to reduce the damage to the body during combat. The pursuit of functionality is a rational and moderate realistic attitude in the functional aesthetics of clothing. "Functionality" means that the stronger the defensive function of war clothing, the more it can protect the wearer from injury, and the more favorable it is to the outcome of the battle. According to Art of War by Sima • Fourth Strict Position, "As long as the chariot is strong and the armor is well-armed, even a small unit will have great combat effectiveness". Wu Zi • Third Soldier Governance mentioned that "as long as there are sharp weapons and solid armor, all soldiers can fight bravely", which emphasizes the great significance of strong armor to protect life and improve combat effectiveness. The point of view of "functionality" is actually the emergence of thick armor. In History of Ancient Chinese Weapons, Zhou Wei proposed that "armor is divided into shoulder armor, chest armor and leg armor, as well as head armor (helmet)". That is, the protection of the armor was further developed. According to the records of Wujing Zongyao, the overall shape of armor in Song Dynasty mainly includes helmet, body armor and cloak. The spirit of advocating force has a long history in China. According to the pre-Qin classic book Book of Lord Shang, "Agriculture and war can make a country prosper." According to Commentary of Zuo • Thirteen Years of Chenggong, "The great event of the

country lies in worship and war." The above description affirms the positive effect of armed war on the prosperity of the country. The heroic general has been regarded as a hero since ancient times. In Book of songs • Tuzhi, "a majestic samurai is a good guardian of the prince", which praises the general. After the establishment of the country, Ming Taizu set up dusi and garrison considering that literati were not good at fighting and commanding the army. In addition, important locations were set up with garrison general. In the early Ming Dynasty, the idea of emphasizing martial arts and despising literature was reflected in the design of Ming armor, which focused on protection [18].

5.2 Indication

Due to the increasing complexity of the war, the organizational structure of the army is correspondingly large, and the level is also subdivided. In order to avoid confusion, a strong need for the marking function of military clothing was born. Art of War by Sima • Second Emperor's Righteousness summarizes the simple clothing marking methods used in the Xia, Shang, and Zhou dynasties: "The Xia Dynasty used the sun and the moon to represent light; the Yin Dynasty used tigers to represent might; the Zhou Dynasty used dragons to represent literary grace." In the Warring States Period, the specific form of war became more and more complex, and the scale became larger and larger. At that time, simple signage was out of date. Weiliaozi raised the need for effective management of increasingly large army of soldiers. Furthermore, Seventeenth Jingzuling mentioned the important role of clothing in marking. On this basis, the Chinese professional military uniform system was finally produced, which is considered to be the highest achievement of the marking function of eastern military clothing. After ascending the throne, Zhu Yuanzhang adopted a variety of means to strengthen the centralized rule, including a careful control system and a complex ceremonial dress system. According to Ming History • Records of Vehicle and Clothing, the armor in Ming Dynasty is mainly gold, silver and black. As for the official uniforms and daily clothes of military attachés, the clothes of military attaches from 1st to 4th ranks are crimson, the clothes of military attaches from 5th to 7th ranks are cyan, and the clothes of military attaches from 8th to 9th ranks are green. Generals generally wear helmets decorated with red tassels and wear boots or greaves. Lower-level soldiers generally only wear shoes with cloth strips instead of boots[19].

5.3 Deterrence

Although the eastern peoples are mainly based on agricultural production methods, the struggle for territory and dominance always runs through the eastern wars. Due to the nature of the major wars, traditional military thought values deterrence, that is, "subduing the enemy without war" as proposed by Sun Tzu. The reason for adding beasts to battle costumes is to deter opponents. In the early stages, the costumes would take the form of animal head decorations or beasts. With the development of the times, it is more advanced than partial imitation to symbolize the image of beasts, such as the decoration of fierce animals such as tigers and lions in helmets, shoulder armor, and absolute armor. Tigers are creatures that are deterrent to most ethnic groups. This not only uses the visual image of the beast to achieve a deterrent effect, but also ensures the structural integrity and rationality of the armor itself to the greatest extent. Force is considered a way of pursuing a peaceful society. The meaning of "force (Wu)" in the Analytical Dictionary of Characters is "consisting of 'stop(Zhi)' and 'weapon(Ge)'". A common belief is that people marching with arms means war is imminent. There is also a view that it means to stop the war, that is, the ultimate purpose of "Wu" is to stop the war. In Commentary of Zuo • Twelve years of Xuangong, King Zhuang of Chu said: "The seven virtues of martial arts include preventing violence, pacifying disasters, protecting honor, establishing merit, appeasing the masses, uniting the people, and enriching wealth." [20] The embodiment of this "martial arts" spirit in armor culture is the emphasis on "peace". With the development, the overall social dynamics of the Ming Dynasty tended to be stable. Therefore, Ming armor in this period focused more on visual deterrence and expressiveness in design, rather than practical protection.

6. Conclusions

Chinese armor has experienced the beginning of the pre-Qin period, the primary formation of the Qin and Han Dynasties, the innovation of the Southern and Northern Dynasties, the great achievement of the Sui and Tang Dynasties, and the peak of the Song Dynasty. The Ming Dynasty is already the mature stage of Chinese armor. In the hundreds of years of stability, a set of mature armor with strong national characteristics is presented to the public. The research on armor modeling includes the modeling characteristics of this type of clothing, as well as the cultural and spiritual connotations. In various dynasties, emperors and politicians have attached great importance to the construction of the army, including the military uniform system that is conducive to the military's combat effectiveness and easy command. Therefore, the ancient Chinese military clothing is a systematic and standardized clothing, which can reflect the development and evolution of the war, army construction and military attaches system in the past dynasties. Because of its history and uniqueness, armor has gradually become a symbol of cultural symbols that is integrated into traditional culture, such as general stone statue armor in imperial mausoleums, general armor in Menshen pictures, and general armor in operas. As for the production method of armor, it integrates various techniques such as metal smelting, clothing making, weaving, and carving in ancient China, which can fully reflect the craftsman spirit of the ancients.

Through 3D modeling, the Ming stone statue is restored. Coupled with appropriate camera movements and spoken text introductions, the viewer's sense of immersion in viewing material heritage is greatly increased. The construction methods of digital cultural relics are mainly 3D modeling and digital scanning, which can repair the incomplete and damaged cultural relics while restoring the cultural relics. The restoration of digital artefacts requires a study of the cultural context. 3D modeling is not a static display of artifacts. By creating animations that are more historically relevant, the ways in which digital artifacts are displayed and disseminated are broadened. The significance of digitizing cultural relics is not only to preserve cultural relics, but also to give full play to their cultural and educational functions, so that future generations can know these crystals of human wisdom.

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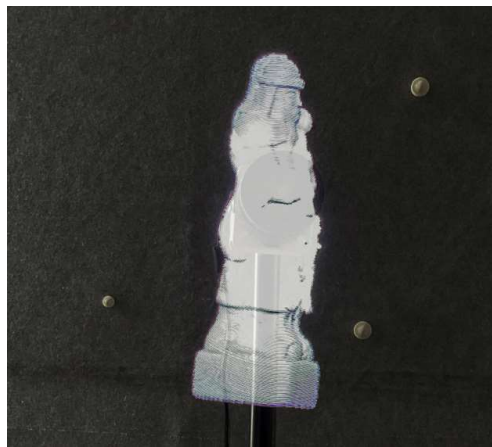
Appendix A

(**a**)	(**b**)

3D model of Ming Xiaoling Mausoleum general stone statue is displayed on the LED holographic fan.: (**a**) side view; (**b**) back view.

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