Documentation research and digital semantic reproduction of archaeological achievements-
A Study of Six Steeds in the Zhaoling of the Tang Dynasty

Minnan Cang
Xi’an University of Technology

WEI ZHOU (✉ 1944692418@qq.com )
Xi’an University of Technology

HUI ZHANG
Xi’an University of Technology

Research Article

Keywords: archaeological achievements, immovable cultural relics, Zhaoling six horses, literature research, digital semantic reproduction

Posted Date: January 10th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2445742/v1

License: ☕️ This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.
Documentation research and digital semantic reproduction of archaeological achievements-A Study of Six Steeds in the Zhaoling of the Tang Dynasty

Minnan Cang1, Wei Zhou2, Hui Zhang3,

1.Xi'an University of Technology, School of Art and Design, Xi'an, Shanxi, China;
2.Xi'an University of Technology, School of Art and Design, Xi'an, Shanxi, China, (Corresponding author), E-mail: 1944692418@qq.com;
3.Xi'an University of Technology, School of Art and Design, Xi'an, Shanxi, China;

Abstract

There are many cultural relics in China, but many immovable cultural relics have been damaged due to social changes, time erosion, rogue destruction and archaeological development. Although the cultural relics can be repaired, the cultural, social, political and other semantic factors left behind the cultural relics cannot be deeply interpreted. Therefore, this study aims to take the stone carvings of Zhaoling in the tenth year of Tang Zhenguang as an example, carry out digital scanning measurement and digital reproduction based on semantics, and integrate cultural factors such as literature into digital means, so that users can deeply interpret the context behind cultural relics. Digital measurement applies the combination of technology of laser scanning and digital photogrammetry. After obtaining the 3D data, by searching the literature and extracting the contextual elements related to matching, their structures were systematically analyzed. Through splitting and extraction, many elements are analyzed and digitally reproduced, and finally integrated through digital modelling. Through these methods, all the data and information are recorded, stored, and managed. Research shows that damaged immovable cultural relics can be reconstructed through digital technological means and cultural context, and then recorded, preserved and studied through digital, information and systematic ways.
**Key words:** archaeological achievements; immovable cultural relics; Zhaoling six horses; literature research; digital semantic reproduction;

**I. Introduction**

China has produced countless cultural relics since ancient times. According to the results of the third Chinese cultural relics survey, there are more than 760,000 immovable cultural relics in China, due to historical changes, time erosion, rogue destruction and archaeological development. Among them, 26.2% are in poor condition, and about a quarter of the cultural relics are facing varying degrees of damage. The cultural relics have lost their original context, and the history, culture, society and other elements left behind the cultural relics cannot be deeply interpreted. Due to the complexity of cultural relics themselves and the limited carrier, even if imitation and digital cultural relics models are exhibited in museums or exhibitions, the audience cannot have a deep understanding of their historical background and cultural value.

At present, with the progress of digital technology, the digital modelling of archaeological achievements has been transformed, and the continuous updating and progress of technology make the digitalization of cultural heritage gradually mature. Some point-like research results have appeared at home and abroad, which involve many interdisciplinary fields such as archaeology, history, sociology and art.

**II. Analysis of existing results**

The number of immovable cultural relics researched in China in British and American academic journals is gradually increasing, but most of them focus on culture, aesthetics and craft. Chinese academic journals have their research on immovable cultural relics, most of which study their history and culture, aesthetics and craft. In China has been damaged immovable cultural relics, the use of handheld laser scanning (HLS) and unmanned aviation vehicle digital photography (UAVDP) such as digital measurement technology is less, in addition, digital measurement has damaged immovable cultural relics analysis make it as
components, and the use of literature on the extraction and matching research has not yet begun.

Since UNESCO launched the "Memory of the World" in 1992, a large number of domestic and foreign scholars have conducted theoretical research and practical path exploration on the content of cultural digital heritage. In the theoretical research, mainly with the theoretical framework as the leading digital, ASO Hajirasouli [1] put forward the theoretical framework of the digitization of endangered cultural relics sites based on virtual reality. The theoretical framework uses qualitative research methods to present the steps of collecting data, and finally, interactively present them. The framework is divided into three stages: documentation, data processing and modelling, implementation, and content presentation. The first step is documentation, using the longitudinal qualitative method to collect the required data. Step 2: Build a longitudinal data-driven model by processing the collected qualitative data. This step proposes that the data can be obtained using three-dimensional or two-dimensional scans. In the third step, the presented content mainly adopts non-interactive language narration such as narrative audio-visual language.

The number of immovable cultural relics researched in China in British and American academic journals is gradually increasing, but most of them focus on culture, aesthetics and craft. Chinese academic journals have their research on immovable cultural relics, most of which study their history and culture, aesthetics and craft. In China has been damaged immovable cultural relics, the use of handheld laser scanning (HLS) and unmanned aviation vehicle digital photography (UAVDP) such as digital measurement technology is less, in addition, digital measurement has damaged immovable cultural relics analysis make it as components, and the use of literature on the extraction and matching research has not yet begun.
Since UNESCO launched the "Memory of the World" in 1992, a large number of domestic and foreign scholars have conducted theoretical research and practical path exploration on the content of cultural digital heritage. In the theoretical research, mainly with the theoretical framework as the leading digital, ASO Hajirasouli [1] put forward the theoretical framework of the digitization of endangered cultural relics sites based on virtual reality. The theoretical framework uses qualitative research methods to present the steps of collecting data, and finally, interactively present them. The framework is divided into three stages: documentation, data processing and modelling, implementation, and content presentation. The first step is documentation, using the longitudinal qualitative method to collect the required data. Step 2: Build a longitudinal data-driven model by processing the collected qualitative data. This step proposes that the data can be obtained using three-dimensional or two-dimensional scans. In the third step, the presented content mainly adopts non-interactive language narration such as narrative audio-visual language.

Gulec ozer [3] used the Multirama method to record the Parion Theater, an important ancient city located in Biga, Turkey. Based on the results of photogrammetry, the research reconstructed the digital model, printed the physical model based on the digital model reconstruction, and synthesized the background through AR and the website. Users can use the camera to view the combined physical model. The pathway is divided into three stages, first using photographic measurements of existing sites to establish data documentation. Secondly, data processing and modelling, with a focus on improving the images and background taken. Finally, it was presented using the AR program.

According to the analysis of the existing research results, the current digitization of cultural relics or its technology-oriented digital reconstruction, or culture and art are led by cultural demonstration or the overall digital restoration. In the current era, the purpose of digital cultural relics is to store, spread and record, so digital technology is essential, in
addition, the cultural attributes of cultural relics as its essential attribute is also very important, as a cultural relic, its own each element should be split, and eventually digital reconstruction. In this way, the restored digital model is realistic and worth examining.

The measurement method combines HLS and UAVDP to scan and measure the six horses in Zhaoling. Literature extraction and matching of its culture and other related semantic elements, which are based on 3-D reality modelling, component analysis, semantic modelling, processing and recording of 3-D data. The purpose is to establish a realistic model with cultural factors, use the three-dimensional real model to carry out literature analysis and digital semantic reproduction of Six Jun and manage and document the data and information of Zhaoling Six Jun based on the realistic model and semantic model.

In this study, Zhaoling Six Jun was taken as an example. The Zhaoling Mausoleum was built in the 10th year of Zhenguan (636 BC), and Li Shimin was buried here in the 23 year of Zhenguan. Li Shimin ordered the carving of six meritorious horses, standing in front of the mausoleum —— history called "Zhaoling six Jun". Respectively: Qinghai, fist, hair, red, special service, sar purple, white hoof. After thousands of years of wind and rain, in the early 20th century, the war, a large number of national treasures were lost. According to data taken by French writer Shawan and Japanese scholar Zu Lixi VI, Zhaoling Jun suffered an accident in 1907. Among them, two jun (as Lu purple, fist hair) was transported in China several times in 1913 and arrived in the United States in 1916. The Museum of Archaeology and Anthropology at the University of Pennsylvania in Philadelphia collected and exhibited it in 1918. Until now, sa Lu purple, fist hair is still lost overseas, the remaining four Jun collected in the Xi'an Forest of Steles Museum. From the current situation on display, six Jun has experienced wind and frost and serious damage. As a historical and cultural treasure of China's country, LiuJun has attracted widespread attention from all walks of life because of its particularity of identity and ill-crossed fate.
III. Digital scanning measurements and the literature study

1. Data acquisition

1.1 3D Data acquisition and preprocessing

At present, close-view photogrammetry and laser scanning are widely used in digital measurement. Due to the limited scale of the Six Jun stone carvings, the apparent damage is more serious and some of them are located relatively far away (Pennsylvania Museum of Anthropology in the United States). Therefore, HLS and UAVDP are used to measure the six horses to obtain complete high-resolution 3D data. The handheld laser scanner uses the global
3 D laser scanner G7 to obtain the stone-carved 3D data and high-resolution images, and in the photogrammetric Angle, the Canon eos 5d mark ii camera and the SONY drone are used for photogrammetry. The images captured by the UAVDP are processed by the PhotoScan Pro software (version 1.2, Agisoft, St. Petersburg, Russia), which creates dense point clouds using workflows. The point clouds in the HLS were subsequently imported into the CYCLONE software for preprocessing. Finally, HLS is integrated with the point cloud of UAVDP, and the mean deviation of the point cloud is small. In the later stage, the fusion point cloud was further processed using Geomagic Studio software to conduct 3-D modelling through a series of operations, such as further cleaning, packaging into a polygon model, repairing the holes in the model, fitting the model contour curve, and texture processing according to the photos taken.

1.2. Literature collation

There are few historical records about the Six Steeds of Zhaoling, only a few historical documents recorded and depict the approximate details of their colours and names; one of the earliest documents about the Six Steeds of Zhaoling is the "Six Horses Picture Zan" written by Li Shimin, Emperor Taizong of Tang Dynasty (Figure 4), and the most valuable documents and images for this study are from the "Six Steeds of Zhaoling" inscribed by You Xionghsi of Song Dynasty (Figure 5) and "Six Steeds of Zhaoling" by Zhao Lin of Jin Dynasty (Figure 3). (Fig. 5) Moreover, Zhao Lin's "Six Steeds of the Zhaoling" (Fig. 3). The Six Steeds of Zhaoling is divided into two parts, the lower part of which describes the location, names, and praise of the six steeds of Zhaoling. The silk version of "The Six Steeds of Zhaoling" depicts the physique, appearance, colour, and accessories of the six steeds of Zhaoling one by one, which helps in the later digital representation.
1.3 Component analysis

After obtaining the high-definition three-dimensional data, the components are numbered and analyzed, and the historical documents are extracted based on the analysis number for study and matching.

2. Literature studies and element matching
2.1. Research and analysis of horse figurines of the Tang Dynasty

The war horses in the art of horse figurines of the Tang Dynasty often have both gods and forms. From the aspect of body shape, a smaller head, rounded hips, fat body, long legs, and even body shape are the portrayals of excellent horse body shape at that time. From the aspect of charm, the paintings and sculptures of Tang horses changed the smooth and clumsy style of the Qin and Han dynasties (Figure 6). They became famous for their vivid and high spirit, which was extremely in line with the majestic and confident style of the Tang dynasty. In the poem of Cen Shen of the Tang Dynasty, "The purple bearded bearded daughters with golden scissors cut out three manes high in the plain sky." Combining the "Lady of the State of Guo on a trip" (Figure 10) with the unearthed Tang three-color horse figurines (Figure 7) and horse-riding hunting figurines (Figure 6) from Prince Yi De's tomb, it is concluded that the excellent war horses of the Tang Dynasty were those with three hairs shaped like flowers on their heads and tied with horse tails.

2.2. Research and analysis of horse Harnesses in the Tang Dynasty
As a necessary item for war horses and all kinds of horses, the development of horse harness and horse decoration was very mature during the Tang Dynasty in China. The Six Stallions of Zhaoling, as a key work of horse art in the Tang Dynasty, the study of horse harnesses is naturally also extremely important. The basic modeling of the horse harnesses of the Tang Dynasty was shown in Sun Ji’s "Chinese Ancient Public Opinion and Clothing Series" (Figure 11).

The war horse of the Tang Dynasty mainly consisted of a Dang Lu, Luo Tou, Jiao Zhuanglian, Xing Ye, Pan Xiong, Yun Zhu, a stirrup, a saddle, Zhang Ni, Saddle cloth, and Hou Qiu. The war horses are omitted from the more decorative items composed only of reins, Luo Tou, Pan Xiong, Zhang Ni, Saddle, Hou Qiu, Piggyback rope and Jiao Zhuanglian.

(1)Luo Tou

Luo Tou is also known as Ji; its structure is a rope sleeve structure, and the material is leather. It is connected with the horn-like Lian and the reins to control the horse's head. The structure of the head of the lasso was finalized in the Qin Dynasty, consisting of the collar belt, pharyngeal belt, cheek belt, and forehead belt (Figure 12).

(2)Sickle

The sickle used in the Tang Dynasty was mostly "S" shaped, called the horn-shaped sickle. The reins passed through the holes of the scythe and were mounted on both sides of the horse's mouth to control the horse's forward direction. This kind of harness was unearthed in the tomb of Li Feng of the Tang Dynasty in Lv Village, Fuping, Shaanxi Province.

(3)Saddle

During the Tang Dynasty, the "two-bridge vertical saddle" of the late Western Han Dynasty was changed to reduce the fatigue of soldiers who had to fight for a long time. The "two-bridge vertical saddle" of the late Western Han Dynasty was changed. After the upgrade, the rear bridge of the saddle was tilted back. The contact area between the saddle and the
body became more rounded and smooth so that the soldier would not feel tired after a long
time on the horse. Most of the saddles were cast on wooden bases. Leathers were wrapped
around the wooden base, and sheath wings were added to the underside of the saddle so that
the saddle could be placed on the horse's back. At the same time, the sheath fins were left in
place to allow for the perforation of the piggyback rope, the climbing chest and the rear swing
(Figure 13).

(4) Dan and Zhangni

The dan is located under the saddle, and one or two holes are sewn into the sides of the
harness to hold the saddle in place. Dan come in various shapes, the most widely used being
square and round; in order to show the owner's status and artistic vision, some beautiful
designs were sewn on the surface of the harness. The zhangni was placed underneath the
harness. It was used to block the mud that splashed under the horse's feet as it galloped (the
mud barrier was mostly made of brocade during the Tang Dynasty so that it would not rub the
horse's back when it came into contact with the horse due to the rough material).

(5) Stirrup

The stirrups are attached to the saddle on both sides of the harbor and the barricade and
are attached to the barricade when no one is riding. When riding, it is possible to accelerate
the horse by hitting the belly of the horse with both feet. This allowed the warrior to free his
hands when engaging the enemy and to keep the horse moving forward by striking the horse's
belly. Because of this, Tang warriors were very brave on the battlefield (Figure 13).

(6) Pan Xiong and Hou Qiu

The pan xiong and hou qiu are attached to the saddle, and the breast climbing goes from
the front hole of the saddle around the horse's front chest to the other side. The hou qiu
departs from the hole in the sheath wing at the rear of the saddle. It goes around the horse's
rump, passes under the horse's tail to the other side, and serves to hold the saddle in place so
that it does not sway when running fast. The climbing chest and the rear swing are made of leather, often decorated with pendants. There are three kinds of pendants: the first one is hung on the chest and the rear swing; the second one is hung with tassels on the chest, and the rear swing is decorated with a "rice" type grid, and the center of the grid is decorated with cloud beads; the third one is hung with tassels on the chest, and five piggyback ropes are hung on the left and right of the sheath wings of the saddle (Figure 14).

Fig. 11 Sun Ji of "Chinese Ancient Public Opinion and Clothing Series"

Fig. 12 The head of a horse in "Horse Harness and Horse Decoration of the Tang Dynasty"

Fig. 13 The saddle in "Horse Harness and Horse Decoration of the Tang Dynasty"

Fig. 14 Barrier mud in "Horse harnesses and horse decorations of the Tang Dynasty"

Fig. 15 Climbing chest and rear swing in "Horse harnesses and horse decorations of the stone warrior horses of the Qianling tomb of the Tang Dynasty - also talking about the imperial horses and warrior horses

2.4 Research and Analysis of Tang Dynasty Patterns

There are many kinds of decorative patterns in the Tang Dynasty, and the popular patterns in different periods also differ greatly. These patterns are very characteristic of the Tang Dynasty period. In the whole process of digital recovery, patterns are very important
historical and cultural symbols. By analyzing the patterns of the early Tang Dynasty, we can later integrate them into the 3D model to achieve a holistic and authentic digital representation.

(1) Lianzhu pattern

It is also known as a ribbon pattern. It is one of the traditional Chinese ornaments, a combination of similar round beads arranged in a zigzag or circular shape. Commonly, they are lined up in a single line or striped, with round beads as the base to form a diamond-shaped skeleton filled with decorative patterns inside. The beads are often solid and hollow circles, some of which are nested together in concentric circles. The Lianzhu pattern is one of the representative decorative patterns of the late Sui and early Tang dynasties. (Figure 16)

(2) Baoxiang pattern

The pattern is composed of several natural elements, such as flowers, roots, leaves, and buds in full bloom, which are rearranged and combined according to the law of radial symmetry. The basic structure of the pattern is based on three symmetries: the cross, the meter, and the circle. Lotus flowers and peonies played an important role in the evolution of the pattern. (Figure 17)

(3) Group flower pattern

The group flower pattern is a very characteristic pattern of the Tang Dynasty, based on foreign culture and combined with traditional Chinese culture. The patterns of the Tang dynasty are divided into the dumpling pattern, floral dumpling pattern, treasure-phase dumpling pattern, and animal dumpling pattern. The overall pattern of the group pattern is centrally symmetrical and radiating, followed by a cross structure or a hexagonal structure to form its skeletal vein. (Figure 18)
The Tang Dynasty curly grass pattern originated from the Lonicera pattern, which evolved from the Lonicera pattern and cloud air. The basic pattern of the curly grass pattern includes flowers, birds and animals, and grasses. After the subjective artistic processing by Tang artists, the pattern was arranged and combined with "S"-type wave-like curves to form a two-sided continuous pattern. Later, decorative patterns were made by exaggeration and other techniques and were also called Tang grass patterns because they were popular during the Tang Dynasty. It was mostly used in architectural decoration and ceramic decoration. (Figure 19)

2.5. Qiu Xinggong and Sa Luzi

"Sa Luzi" was the war horse that Li Shimin rode when he defeated Wang Shichong. Li Shimin once rode Sa Luzi to investigate the enemy and was met by Wang Shichong's troops. At that time, he was surrounded by only a few dozen cavities, and instead of retreating, Li Shimin rode Sa Luzi to disperse the enemy's formation. During this time, Sa Luzi was hit by
an arrow in his left front chest, and general Qiu Xing Gong, who was accompanying him, exchanged his war horse with Li Shimin to ensure Li Shimin's safe retreat and led the wounded Sa Luzi himself out of the siege and back to the camp safely. After Qiu Xinggong Sa Luzi plucked arrows, Sa Luzi's stone carving is expressed in this scene; after the arrow was plucked, Sa Luzi immediately fell and lost his life.

1. Analysis of Qiu Xinggong's facial portrayal

There are few historical records about Qiu Xinggong. The Liu Yan, Old Book of Tang, records that Qiu Xinggong was "good at riding and shooting, brave and excellent. His personality was so harsh that all his colleagues were afraid of him". Ouyang Xiu and others in 《New Book of Tang》: "Xinggong was brave and good at riding and shooting. Xinggong was so strict that the bureaucrats were afraid of him." According to the combination of records and stone descriptions, Qiu Xinggong was a brave and stern military general. Therefore, the face is dominated by a serious expression, and the thick eyebrows further portray Qiu Xinggong's coldness. The stone carving shows that Qiu Xinggong's decree lines and cheekbones are deeply carved, which is presumed to show his brave and stern side. The overall reference of Qiu Xinggong's restored model figure is based on stone carving, and the subjective widening of the shoulders shows sturdiness. Combined with the above study, the overall image of Qiu Xinggong gradually becomes three-dimensional.

2. Research on the dress form of Qiu Xinggong

During the late Sui and early Tang dynasties, the interaction between the Tang dynasty, frontier minority groups, and other countries increased. Influenced by the minority groups in the northwest and the foreign customs and cultures of Tianzhu and Persia, the culture of "Shang Hu" was formed from the court to the people. The Hu people were good at riding and shooting, so this culture influenced the military costumes and gradually formed military costumes with the style of the Tang Dynasty. For example, the representative crotchless robe
and the big-mouth pants. The poet Cen Shen of the Tang Dynasty has a poem: "Scattered into the pearl curtain wet Luo curtain, fox fur is not warm brocade coverlet thin", where the fox fur and brocade coverlet are the cold military clothing influenced by the nomadic people in the north. In addition, through the comparative study of the wall paintings and excavated artifacts in the tomb room of the Tang Dynasty, together with the Six Stallions of Zhaoling, the shape of Qiu Xinggong's costume is deduced. From the analysis of the decoration of the head, it is a soft-wrapped, soft-legged turban (Figure 20); the clothes are divided into two layers: the outer layer is a brocade hu suit (Figure 21), the inner layer is a round-necked robe (Figure 22), the waist is tied with a mincing belt (Figure 23), the pants are medium, and the shoes under the feet are Wu Pi hexagonal boots (Figure 24).

![Fig 21 The tomb of Prince Zhang Huai in the mural painting that appears brocade Hu clothing](image1)

![Fig 22 Round-necked robe in the tomb of Prince Zhang Huai](image2)

![Fig 24 Chinese pants and hexagonal boots appearing in Li Shou's tomb](image3)

![Figure 23 Mincing belt](image4)

### 3. Research on the color of Qiu Xinggong's military costume

The Tang Dynasty had very strict regulations on the color of military dress. In the Tang Dynasty, black was the main color for soldiers, and people were forbidden to wear black. The color of armour in the Tang Dynasty was mainly gold, silver and black, which was quite majestic and played the role of strengthening military prestige and reviving military spirit. The costumes of military generals had different shapes, decorations and colors, and the Tang Dynasty was when the system of military officials was fully established in China. Hence, the costume system of military officials was more complete than in previous generations. The
Tang dynasty was a period in which China's official military system was fully completed, so its official clothing system was more complete than in past generations. 《The six Tang dynasties》, volume 16 of the military treasury order: "The military treasury order to hide the world's weapons and equipment.....The robe system has five: one said cyan robe, two said crimson robe, three said yellow robe, four said white robe, five said black robe." According to the rank of officials in order down the row, the "New Book of Tang - Qiu He biography" recorded Qiu Xinggong: "repeatedly from the war and expedition, labor very thick, more work, promoted to General hussar". The General hussar belonged to the first rank of generals in the Tang Dynasty, second only to Li Shimin of Emperor Taizong of the Tang Dynasty (The general sealed by heaven). According to historical records, extrapolation, and analysis, Qiu Xinggong's battle robe was cyan.

4. Research on Qiu Xinggong's armor

In the cold weapon era, armour was a necessary piece of equipment for the army and played an important role in the stage of the war. According to the Tang Dynasty armour, the material varies; according to 《Tang six classics》 volume 16 of the military treasury order: "the system of armor ten have three: one said bright light armor, two said light to armor, three said fine scale armor, four said mountain armor, five said hammer armor, six said white cloth armor, seven said Fu silk armor, eight said cloth back armor, nine said infantry armor, ten said leather armor, ten have one said wooden armor, ten have two said lock armor, ten have three said horse armor. " Additionally, contains: " bright light, light to be, fine scale, mountain man, Wu hammer, locking son are iron armor also." The texture of the Tang Dynasty armour is iron, copper, copper and iron alloy or with gold and silver coating but also with the addition of colorful lacquer. Iron armour is most commonly used “The Old Book of Tang. Taizong's Chronicle (above)" : "In June of the fourth year of Wu De, the triumph. Taizong himself clad in gold armor, Chen iron horse 10,000 horses, armorers 30,000 front and rear drums, captured
two false lords and Sui Sui’s artifacts carriage offered in the Imperial Temple.” Golden armor is gold-coated iron or copper armor. After the historical analysis combined with the Dunhuang mural in the "Zhang Yichao unified army travel map" (Figure 25), Qiu Xinggong wore Mingguang armour and painted silver to help the grandeur

![Fig. 25 “Zhang Xuanchao's Travels”](image1)
![Fig. 26 “The Five Stars and Twenty-eight Stars of the Gods”](image2)
![Fig. 27 “The Drawing of the Deer”](image3)

5. Study of Qiu Xinggong's weapon accessories

The structure of Qiu Xinggong's accessories is relatively simple, and the combination of the relief carving and the "Six Stallions of Zhaoling" makes it clear that Qiu Xinggong is wearing an arrow quiver and a bow, while on the other side is a sword. However, the stone carving is damaged, and the form is not visible, so it needs to be analyzed with historical sources. “The Tang Six Classics”, Volume 16 of the military treasury order records: "The military treasury order to collect the world's weapons and instruments, to identify their names and numbers, in order to prepare for national use; bow system there are four: one said long bow, two said angle bow, three said little bow, four said ge bow." Combined with the 《five stars twenty-eight divine shape chart》 (Figure 26) in the shape of the corner bow size comparison and the 《Tang six classics》 volume 16 of the military treasury order record: "the horn bow is made of bull tendons and horns, cavalry using it." It can be concluded that the corner bow was worn by Qiu Xinggong.
On the other side can see Qiu Xinggong's waist hanging a knife, 《Tang six classics》 volume 16 of the military treasury order records: "knife system has four: one said the instrument knife, two said obstacle knife, three said the horizontal knife, four said the stranger knife... This instrument knife cover ancient class sword and so on, Jin, Song has come to be called the imperial knife, after the Wei said long knife, is applied to the dragon and phoenix ring; to Sui called the instrument knife, installed with gold and silver feather instrument by the executive, place knife cover with place body to defend the enemy. Crossed knife, knife, soldier wear, the name also started in Sui. Stranger knife, long knife also, infantry held, cover the ancient broken horse sword." Combined with the "get deer map" (Figure 27) and the Tang knife (Figure 28) excavated from the tomb of Li merit of Tang Zhaoling, we can conclude that the knife worn by Qiu Xinggong is the Tang horizontal knife.

From the "Six Steeds of Zhaoling" (Figure 29) and the stone inscriptions, it is clear that Qiu Xinggong was wearing a Hu Lu. According to "The New Book of the Tang Dynasty", "(the military) was equipped with a bow, 30 yards, arrow quiver, crossed swords.... In addition, his armour, military equipment hidden in the warehouse.

" Hu Lu is the arrow quiver, with leather for it, because empty Hu Lu lying on the ground can hear the sound of human and horse action; southeast and northwest can be seen in Hu Lu, also known as the ground to hear. There is a completely unearthed Hu Lu in the Tang tomb complex in Astana (Figure 30), which was digitally restored in combination with the unearthed Hu Lu and the partial restoration of the Six Stallions of Zhaoling.

![Fig 28 Tang knife excavated from the tomb of Li Merit in Zhaoling, Tang Dynasty](image1)

![Fig 29 Partial view of the Six Stallions in Zhaoling](image2)

![Fig 30 Hu Lu excavated from the Tang tomb complex in Astana](image3)
2.6 HuLao Pass and Zhaoling Six Steeds

Li Shimin has professional military ability, and the Battle of Hujuan is the best work of Li Shimin. In this battle, Li Shimin surrounded Wang Shichong and then surrounded the point to defeat Dou Jiande's 100,000-strong army with only 3,000 people, defeating the two camps of Wang Shichong and Dou Jiande in one fell swoop. Among the six steeds, the "Sa Luzi" was Li Shimin's mount while trying to eliminate Wang Shichong's forces. Among the six steeds, "Qing Zhui" and "Shifa Chi" were the mounts of Li Shimin in the battle with Dou Jiande. The poet Huang Ying has a poem: "The moon is as frost on the Tiger Prison Pass, the river outside the tree is brown and yellow. The bottom is even the regulator horse is frighteningly heavy, and the separation is a million drains into the sorrowful intestines."

1. HuLao Pass building form

In terms of architectural form, the civil and wooden structure system before the Han Dynasty was based on the core of the earth structure. Moreover, after the Eastern Han Dynasty, it gradually changed into the earth and wood structure system with wood structure as the main framework. The building structure continued to be used and developed in the Sui and Tang Dynasties. In addition to Chang'an city, the architectural achievements of the Tang Dynasty were also scattered among the people. The most representative temples were the monasteries and Taoist temples of the Tang Dynasty, which reached a very high level. The most famous ones are the Nan Chan Temple and Foguang Temple, which are famous for their wooden structures. There is a record about Bright Hall in “Qualifications. Tang Ji 20” "Two hundred and ninety-four feet high and three hundred feet wide, there are ten enclosures of huge wood, the upper and lower pass-through......", so it can also be analyzed that the more important buildings in Tang Dynasty were still based on wood structure.

2. The overall structure of HuLao Pass
Ancient Chinese architecture comprises three parts: roof, frame and foundation. The roof accounted for the largest proportion of the three parts, and its height usually reached half the overall height. The roofs of the Tang Dynasty were usually double-roofed, and the high eaves were shaped with bucket arches, such as the Golden Hall of the Tang Zhaoti Temple in Japan (Figure 30) and the Nansen Temple in Shanxi (Figure 31). Similar to a bird's wing, the roof's natural flow has changed the square frame's monotonous and straight architectural style. During the Han dynasty, it was called scops owl, and most of them were shaped like a tail curl, and this form continued until the Song dynasty.

The bucket arch is an ancient Chinese building wooden frame structure, and the inevitable product of the earthen wall bucket arch has a very strong load-bearing role. The eaves arch has the role of picking out layer by layer and distributing the force to bear the weight, thus enabling the heavy roof to come out of the eaves deeply. HuLao pass digital restoration takes the existing arch of the Buddha Temple (Figure 33) as a reference.
3. Color Decoration Research Analysis

The vermilion and white color combination structure in China's architecture is a very long history of tradition. The color vermilion and white is also the most basic wood structure color of Tang Dynasty architecture; Tang "Fugue of the Hall of Containing Yuan" said, "Now the only thing left in this hall is the ironstone and the red and white wall skin"; Han Yu "new repair Tengwang Pavilion" described the outer eaves by the weather erosion "red and white of indecipherable". Vermilion and white color structure (seven Vermilion eight white) from the Tang Dynasty architecture "heavy lintel" structure (i.e., double appendage): appendage is used on the pillar to receive, connecting the horizontal members of the column head, appendage interrupted with a long white strip. The application of heavy lintel structure from the North and South Dynasties period until the middle and late Tang Dynasty, although the middle and late Tang Dynasty already advocated a single-layer appendix, the color composition of seven Zhu and eight white has been passed down. As a very important building in the Sui and Tang dynasties, it is presumed that the HuLao pass is vermilion and white and is a double-layered lintel.

IV. Digital semantic reproduction

1. Digital restoration of the Six Steeds of Zhaoling

According to their different characteristics and the description of the stone carving, the six steeds are modeled in 3D. Each of the six steeds has its dynamics on the stone carvings, and the stone carving of "Sa Luzi" is more different. "Shi FaChi" has five arrows in the hip and one in the back, but he continues to run. "The piebald is hit by five arrows, four in the back and one in the front, but still leaps at a gallop. The "Te lebiao" is different from the other war horses, showing a relaxed posture. Bai Tiwu is galloping on the frontier. The "Quan Maogua" was hit by nine arrows in a row in the running state but still insisted on galloping.
2. Digital restoration of Qiu Xinggong

After many historical documents are combined with the excavated artifacts, digital restoration is carried out using 3D modeling. First, the weapon he used is restored, and Qiu Xinggong is restored. The dynamic of Qiu Xinggong pulling arrows for Sa Luzi, a classic moment in the picture of the Six Stallions of Zhaoling, is reproduced.
3. Digital reproduction of Hulao Pass

Through structural analysis and material determination, the above structure is reproduced through a 3D model. To make the effect more realistic, it is necessary to more accurately combine the historical properties of the battle conditions and the era in which the materials and mapping are given.
V. Digital Dissemination of the Six Stallions of Zhaoling

The Six Steeds of Zhaoling cannot be exhibited in their original form due to their essential properties and the fate of their destruction and exile overseas. After the establishment of the semantic model, to better respond to the era of big data and to realize the audience's knowledge of the Six Steeds of Zhaoling more quickly, the Six Steeds of Zhaoling and its contextual story can be spread more widely and realize the vivid dissemination of its millennium cultural connotation. Based on Nielsen's interactive usability principle, the author explores the digital communication means suitable for the Six Steeds of Zhaoling. After research and analysis, the interaction can make up for the lack of digital representation of the Six Steeds of Zhaoling. Based on digital restoration, an online sharing and interaction platform is built based on the background of the big data era and the comprehensive use of various technical means. With the technical support of 3D modeling and the presentation of human-computer interaction, the platform focuses on the six steeds, their saddle accessories and elements related to Qiu Xinggong. Using 3DMAX.untiy and other technologies as a link
and the H5 web page and other digital mobile terminals as a platform, the six steeds of Zhaoling are disseminated in the historical context.

The interactive art performance supported by new media technology can attract more viewers to actively accept richer content and more diverse forms of documentation and visual art and enhance contemporary and interactive communication methods. The three-dimensional construction, video documentation and animation are integrated with technical means, combining motion and static. This new digitization of cultural heritage breaks the shackles of traditional exhibition forms. It allows for more efficient and rapid dissemination of the Six Steeds of Zhaoling and its related culture.

![Image](image_url)

**Fig 38 Interactive display diagram (single frame)**

**IV. Conclusion**

To digitally record and manage the data and information of the six steeds of Zhaoling, the 3D realism-based model was further processed and a 3D-based information management system was established based on semantic analysis. Based on the results of the semantic analysis of the above-mentioned research model, the 3D realism model was split into several parts and various components using Geomagic Studio software. The 3D information
management system was developed using TerraExplorer Pro software (version 7.0, Skyline, USA), and the data structure was designed and built using the semantic model and project tree tools in TerraExplorer Pro software, which describes all segment levels according to its model structure and components, and after the ground plan of the rockery was fixed, each The 3D model of each component is loaded into each data layer of the corresponding folder in the 3D information management system. On top of establishing the data structure and the 3D model, the six steeds and the associated background information such as name, component information, history, properties and many other background information are entered and edited in the information management system for further research and processing.

This study uses semantic modelling to break down and categorise the components of the Six Steeds hierarchically. Semantic modelling has previously been used in the study of 'architectural and landscape cultural heritage', however, the irregularity and ambiguity of the external structure of the buildings and rockeries is a principle that has been used in the past. The digital semantic reproduction of damaged and lost archaeological results is more difficult than that of buildings and rockeries and has been the subject of more digital measurement and scanning modelling in the literature. This is an innovative and advanced interdisciplinary theoretical approach to the reproduction and analysis of archaeological findings in the field.

In conclusion, this study presents a comprehensive digital investigation and semantic-based analysis of the Six Steeds of Zhaoling, incorporating a synthesis of documentary elements, to carry out a semantic digital reproduction of the semantics, and ultimately to digitally manage the data and models obtained. As many of the damaged archaeological results are inherently similar in character, most of them can be digitally and semantically reproduced using this research methodology.

Break the geographical barrier of the archaeological results of immovable cultural relics to make the archaeological results clearer, more comprehensive and more complete for
borderless dissemination. Using interactive technology and system simulation technology, it integrates multidisciplinary contents of history, art, human culture, journalism and communication, and economics. Revitalize historical relics and reproduce humanistic landscapes. Propose new ideas for the digitalization, visualization and artistic communication of cultural heritage.

**Declarations**

- **List of abbreviations**

  *Not applicable*

- **Availability of data and materials**

  *Not applicable*

- **Competing interests**

  *Not applicable*

- **Funding**

  This work was supported by Social Science Foundation of Shaanxi Province (2018K37) and Xi'an university of technology School Fund.

- **Authors' Contributions**

  Conceived and designed the experiments: Minnan Cang; Wei Zhou; (Corresponding author)

  Performed the experiments: Minnan Cang; Wei Zhou; Hui Zhang;

  Wrote the paper: Minnan Cang; Wei Zhou

- **Acknowledgements**

  *Not applicable*
References


[26] G. Vacca, M. Deidda, A. Dessi, M. Marras, Laser scanner survey to cultural heritage conservation and restoration, Melbourne, Australia, International


