

3D Modeling and Animation Design of Flying Apsaras in Dunhuang Frescoes

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3D Modeling and Animation Design of Flying Apsaras in Dunhuang Frescoes

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Abstract

With rich content and long history, flying Apsaras in Dunhuang frescoes is precious material for studying the artistic style and artistic modeling of ancient Chinese murals. This article aims to explore the 3D modeling and video animation design of flying Apsaras in Dunhuang frescoes, which not only provides Dunhuang Museum with digital cultural heritage content and popular science materials, but also helps develop cultural heritage protection methods and encourages further exploration of Chinese historic art.

Keywords: Dunhuang frescoes, Flying Apsaras, 3D modeling, Animation

1 Introduction

3D animation image is a special medium used by museums to record and disseminate history, which has irreplaceable value and significance for the digital protection of material cultural heritage. This article carries out the research on the artistic image of Dunhuang flying Apsaras, and uses 3D technology to interpret flying Apsaras dance with musical accompaniment. In the interactive design, the use of lens and animation is conducive to the dissemination and popularization of flying Apsaras culture, so that more people can feel the cultural charm of flying Apsaras in both physical and virtual museums.

Dunhuang was the main traffic route between central plains and western regions along the Silk Route in ancient times. In addition to the prosperity of economic trade, there were frequent cultural exchanges in Dunhuang [1]. As a

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result, many foreign cultures collide and merge with local cultures here. Countless craftsmen and supporters expressed their faith in Buddhist culture by creating caves in Dunhuang. Mogao Grottoes is a collection of Chinese architectures, murals and painted sculptures of various periods, with the largest scale, the richest content, and the longest history. As a manifestation of the localization of Buddhist culture, Dunhuang art has local aesthetic concepts and ideologies, which is capable of carrying Buddhist culture [2]. Mural painting, one of the important components of grotto art, combines painting art and religious art, and contains numerous character images and colorful content plots, which is not only the precious material for studying the artistic style of Chinese national painting and Buddhist aesthetics, but also the vital reference for today's art creators to inherit and carry forward the national painting heritage and create new national forms of art [3]. Among them, the representative Buddhist cultural modeling pattern is Dunhuang Flying Apsaras that is unique in style and regular in features [4]. There are as many as 4,500 flying Apsaras in Dunhuang Mogao Grottoes frescoes, which renders a fascinating view of Buddhist country [5]. In museums, images with flying Apsaras as the theme increasingly become a visual entry point for people to understand Dunhuang culture [6]. Flying Apsaras animation reconstructs the art of flying Apsaras to reflect the dynamic art of flying Apsaras. The animation is based on the art works of painters, and the animation is compiled in the virtual space on the screen to give the flying Apsaras "vitality". The animation uses visual symbols to realize the transmission of information and the transformation from virtual concepts to real images [7]. In animation art, the common core of traditional hand-drawn animation or emerging digital 3D animation, as well as interaction or virtual reality is to realize the dialogue between the virtual world and the real world [8].

With the popularization of mobile Internet, the increase of broadband speed, and the faster and more convenient transmission of information and data, the cultural heritage of Dunhuang Flying Apsaras has entered digital protection. By applying digital media technology to animation creation, traditional culture can be radiated with new "vitality". Animation has the advantages of breaking through the limitation of time and space, interestingness, wide audience, as well as diversified and efficient communication channels. The animation themed on Dunhuang flying Apsaras culture fully demonstrates the artistic characteristics, which is conducive to the protection, inheritance and development of Dunhuang culture. Dunhuang flying Apsaras digital animation gives life to static images through artistic processing and technical processing, thus forming moving images and bringing pleasure to viewers, which is of great innovative significance [9].

In the Western Han Dynasty, Dunhuang was one of the four counties in the Hexi region, located in the western part of Gansu (the western end of the ancient Hexi Corridor). After Zhang Qian's envoy to the western regions, China had frequent contacts with various countries in the western regions, forming the increasingly prosperous Silk Route. Gradually, Dunhuang became

a base for political, economic and cultural exchanges at that time [10]. During the Jin dynasty, the development of Dunhuang culture reached a peak. Due to the close exchanges between Dunhuang and Chang'an and other cities from Wei Dynasty to Sui and Tang Dynasties, Dunhuang had always maintained cultural ties with central plains. Located in a special location, Dunhuang's diverse cultures collide with Chinese traditional culture, forming a distinctive Dunhuang art [11].

In the 1st and 2nd centuries AD, Buddhist culture flourished in India. Since then, Buddhism spread from the East and began to influence Central Asia [12]. Among them, Dunhuang is the only way for Buddhism spreaders. Therefore, the prosperity of Buddhism made Dunhuang an influential Buddhist city. In the second year of the Jianyuan era during the Pre-Qin Dynasty, Shaman-lezun excavated the first grotto. Since then, the Dunhuang grotto art with strong Buddhist atmosphere developed and emerged [13]. In order to create the Buddhist world, the craftsmen and painters worked together to complete the cave construction. Therefore, the art works of Dunhuang grottoes have consistency and integrity. Thanks to the special geographical environment and timely protection, the Dunhuang grotto art becomes the cultural heritage with long history, rich content and complete system, which has a pivotal position in the history of Chinese art [14].

As a historical relic in a specific cultural period in China, Dunhuang frescoes has important research value in history, archaeology, religious documents, architecture, and art, becoming a source of inspiration for a large number of art creators [15]. Among them, flying Apsaras is an indispensable decorative element in Buddhist art. With the spread of Buddhism in different regions and the integration of various cultural places, the creative images of flying Apsaras have their own characteristics. Flying Apsaras were introduced into Dunhuang along the Silk Route. In the process from Afghanistan, western regions, Yumenguan Pass, Yangguan Pass to Mogao Grottoes, the continuous absorption and integration of local art places finally formed flying Apsaras with Chinese characteristics. Dunhuang flying Apsaras art expresses the aesthetic concept, cultural atmosphere, and artistic development process of its era and region.

Flying Apsaras belongs to Buddhist plastic art. Derived from Indian mythology, it is the androgyny of "Gandhanra" and "Kinnara", with the duty of serving Buddha and Sakra, playing music and scattering flowers. Because it can sing and dance and emit fragrance, it is also called the God of Aroma and Music [16]. Later, flying Apsaras were widely used in various Buddhist buildings, especially as an important decorative pattern in grottoes, expressing people's yearning for heaven and freedom [17]. The earliest record about it is in Records of the Temples of Luoyang, "There is a golden chariot carrying Buddha statues, three feet above the ground, as well as umbrella with golden bells and seven pearls hanging on all sides. Decorated with flying Apsaras playing and dancing, it looks like it's in the clouds." This refers specifically to the immortals in the heavenly palace who worship Buddha, music and dance [18].

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Earlier than the art of Buddha statues, Indian flying Apsaras developed simultaneously with Indian Buddhist art, which is characterized by the rhythmic body curves. In the second century BC, flying Apsaras appeared in decorative carvings, dome frescoes, and story images. This image is mainly located on top of Buddha statues, pagodas, and Bodhi trees, with flowers or offerings in hands. It shows the attributes of flying through streamers and dynamic body posture. There are various forms of expression, such as holding a flower in hands, putting hands together, or playing a musical instrument. The upper part of some large relief towers is carved with groups of flying Apsaras flying towards the stupa.

Under the profound influence of Indian Buddhist art, the flying Apsaras in Dunhuang, China has a strong exotic style in its artistic style. The clay sculpture and wood carving flying Apsaras of the Kingdom of Khotan (now Wada), as an attachment to the large sculpture, is influenced by Greek culture and Gandhara art, and its shape is similar to the Brahma image of Kucha mural. The flying Apsaras of Shanshan (also known as Loulan) has a Western style, and its coloring skills can highlight the characteristics of Eastern Buddhist art. Flying Apsaras of Qiuci (now Kuche) generally appear on the roof of the cave and on both sides of the Buddhist niches. In the early stage, it was mainly affected by external factors. Later, it merged with the culture of central plains and formed its own unique style. Flying Apsaras of western regions emphasizes clean and powerful lines and the rendering of three-dimensional texture. There are flying Apsaras in various poses, such as holding orbs, musical instruments or flowers. Usually, they are arranged in an orderly and decorative way to cover the wall of the cave. The flying Apsaras of Gaochang (now Turpan) have strong lines and diverse postures, which together with nature (such as the sun, moon and stars) constitute the universe [19].

Flying Apsaras in Dunhuang, China is a manifestation of the internalization of multiple cultures. In the early stage, influenced by the culture of western regions, the style was quite exotic. Under the influence of the local culture of central plains, the shape of flying Apsaras changed. The portrait and costume modeling changed based on the Han nationality, and the technique of heavy line outline and flat painting was adopted to show the local characteristics. Flying Apsaras' delicate face, graceful posture, complicated clothing, flying streamers and dynamic postures contrast with the surrounding patterns, which has a strong decorative meaning [20].

Buddhism has the characteristics of solemnity and sacredness. In order to show the beauty of the Buddhist world, the Buddhist scriptures will exaggerate the dignity and solemnity of the Buddhist world. Sutra Illustration Paintings spread the obscure scriptures in an easy-to-understand form. In Indian Mahayana Buddhism's Saddharma Pundarika Sutra, the act of supporting flying Apsaras is described: "First, flower; second, incense; third, jewelry; fourth, wiping incense; fifth, coating incense; sixth, burning incense; Seventh, Silk hanging streamer; eighth, clothes; ninth, play music; tenth, clasp hands." Flying Apsaras represents the admiration of Buddha by private supporters [21].

Flying Apsaras usually appear in a symmetrical form in the composition or are drawn in the blank space of the picture. Divided by location, flying Apsaras can be divided into caisson flying Apsaras, suspended ceiling flying Apsaras, gable slope flying Apsaras, shrine-top or outside-shrine flying Apsaras, backlight flying Apsaras, dharma assembly flying Apsaras, and ring flying cave Apsaras. “Holding the hibiscus flowers in her hand, the beautiful fairy walks gracefully in the sky. The snow-white clothes are dragging the wide long belt, blowing in the wind, and rising into the sky lightly.” This is the perfect portrayal of the artistic conception created by flying Apsaras [22].



Fig. 1 The Flying Apsaras in Cave 161, Mogao Cave, Tang Dynasty **Fig. 2** Scattered Flowers and Flying Apsaras in Cave 25, Yulin Cave, Tang Dynasty **Fig. 3** Six-armed Flying Apsaras in Cave 39, Mogao Cave, Tang Dynasty

According to the interpretation of the Buddhist scriptures, functions can be divided into offering ritual music, scattering flowers, and dancing (see Figure 1). The light flying Apsaras flies in the fairy palace among the clouds. They have different things in their hands, such as offering vessels, flower and fruit offerings, flower vessels, trays, and various musical instruments [23]. According to the shape, flying Apsaras can be divided into child flying Apsaras, naked flying Apsaras, six-arm flying Apsaras, dual flying Apsaras, four flying Apsaras, and flying Apsaras group. The missionary child flying Apsaras sings, dances and scatters flowers among the clouds. As for the naked flying Apsaras, the upper body or whole body is naked, making a volley flying gesture with fluttering clothing belts. Six-arm flying Apsaras belongs to Esoteric Buddhism multi-arm flying Apsaras (Figure 3). Flying Apsaras with multi arms, eyes or heads are relatively rare. The dual flying Apsaras, four flying Apsaras, and flying Apsaras group fly in the radiance of the Buddha in symmetrical, encircling, or disorderly patterns, forming a beautiful picture [24].

2 Method Overview

The 3D model can save data records for the disappearing Dunhuang murals, and the modeling is convenient for experts to study. The 3D animation made on the basis of the model can also be displayed and publicized in the

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museum. This innovative artistic creation digitally collects or converts the Flying Apsaras image in Dunhuang murals, and organically combines Dunhuang Flying Apsaras culture with the real society in combination with literature records, relevant research results and other materials and interpretation of the times. The animation with Dunhuang Flying culture as the theme fully shows the artistic characteristics of Dunhuang Flying, meets the appreciation needs of the public, and is conducive to the protection, inheritance and development of Chinese traditional culture. This process enriches the display media of the Flying Apsaras image of the mural, reconstructs and translates it with animation audio-visual language, and the viewer follows the dynamic picture to intuitively appreciate the moving posture and rhythm beauty of the Flying Apsaras image in the Dunhuang mural.

In the late 1980s, Dunhuang Academy launched the “Digital Dunhuang” project. At the technical level, data networks, computer media, and digital technologies are used for the digital protection of documents, cultural relics and caves for the purpose of reproduction, preservation, analysis and research, and cultural dissemination. Fan Jinshi, Dean of Dunhuang Academy, put forward the idea of “Digital Dunhuang”. More specifically, by permanently storing the cultural relic’s information of the Dunhuang Grottoes in the digital cloud, viewers can access the relevant materials of the cultural relics of the caves through the Internet and mobile terminals [25].

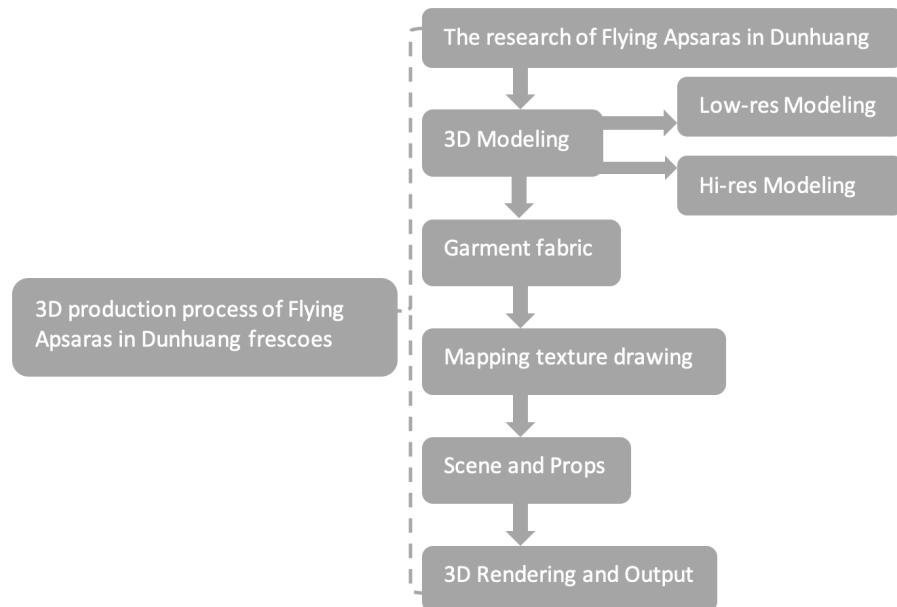


Fig. 4 Production Process

The creative protection that combines 3D design and traditional culture has connotations of the times in terms of subject matter, content, and form. As the

carrier, art and cultural works can bring “vitality” to Dunhuang culture. Dunhuang culture has realized comprehensive science popularization through the dissemination of the museum’s digital platform. The digital creation protection of Dunhuang culture is the rational use of the existing Dunhuang cultural heritage. The two-pronged model of protection and development has opened up the path of digital media to inherit history and culture. The information of flying Apsaras in Dunhuang frescoes, such as formation, styling characteristic elements and the law of evolution of the times, can provide theoretical support for the creative protection of Dunhuang flying Apsaras theme animation [26]. The application of Dunhuang flying Apsaras art in animation creation is analyzed from the aspects of expression, characters, props, scene design, overall color matching and lens language [27]. Through the audience’s feedback on the dissemination of two-dimensional 2D, three-dimensional 3D, and new media forms, the application of flying Apsaras animation art form in the creative protection of cultural heritage can be deeply analyzed. Through reading and analyzing relevant documents and pictures, the art of flying Apsaras in Dunhuang is deeply summarized. Based on the art design theory, the patterning law is obtained, which provides a theoretical basis for experimental creation [28].

3 Production Process

Based on the art design theory, the patterning law is obtained, which provides a theoretical basis for experimental creation. At the same time, through observing the pictures of Dunhuang caves and the digital results of Dunhuang, the application ideas are clarified. By comparing the Dunhuang flying Apsaras in ancient and modern creations, the animation flying Apsaras modeling is analyzed and summarized, thus providing preparations for basic elements such as 3D flying Apsaras characters and decorative props [29]. The final output is a digital virtual work suitable for museum media [30]. Finally, 3D animation creation is used to represent the Rebound pipa in Dunhuang flying Apsaras, and provide practical content for digitizing Dunhuang. The specific process is shown in Figure 4.

3.1 Modeling

According to the modeling of Dunhuang flying Apsaras “Rebound pipa” [31] (Figure 5, 6), details are reflected, such as skin texture, surface bump, and depth change. Digital sculpting software Z-brush sculpts models of up to 1 billion polygons to present an intuitive workflow (Figure 7). In 3D modeling, the method of baking the high mold and the low mold is adopted to ensure the detail of the model. In more detail, the detail of the high mode creates the light and shadow effects under the given light and dries out the normal map (simulating the model’s surface bump texture), which is then mapped to the low mode with fewer faces in Maya. In this way, the low modulus can be

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reduced by more than half, and the details made up of millions of faces can be obtained.



Fig. 5 Playing the Pipa in Mogao Caves, **Fig. 6** a Flying Apsara playing the pipa in Dunhuang Cave 44 - Luoyang Garanji Cave 329 of the Mogao Caves at Dunhuang



Fig. 7 Carving details with Z-Brush (such as hair of Flying Apsara)

3.2 Garment fabric

In order to simulate the movement effect of the clothing in the flying Apsaras animation, the following steps are performed, including character modeling based on the design drawing, Z-brush sculpting details, Maya's N-cloth, setting the collided objects, constraints, and modifying the parameters of the stage. Moreover, the 3D fashion design software Marvelous Designer is used (Figure 8). Intuitive pattern style, real-time calculation speed, multi-layer fold

effect, and rich material library, texture and environment provide guarantee for designing exquisite 3D clothing in a short time. In addition, it is compatible with other 3D software, making the import and export of models more convenient.

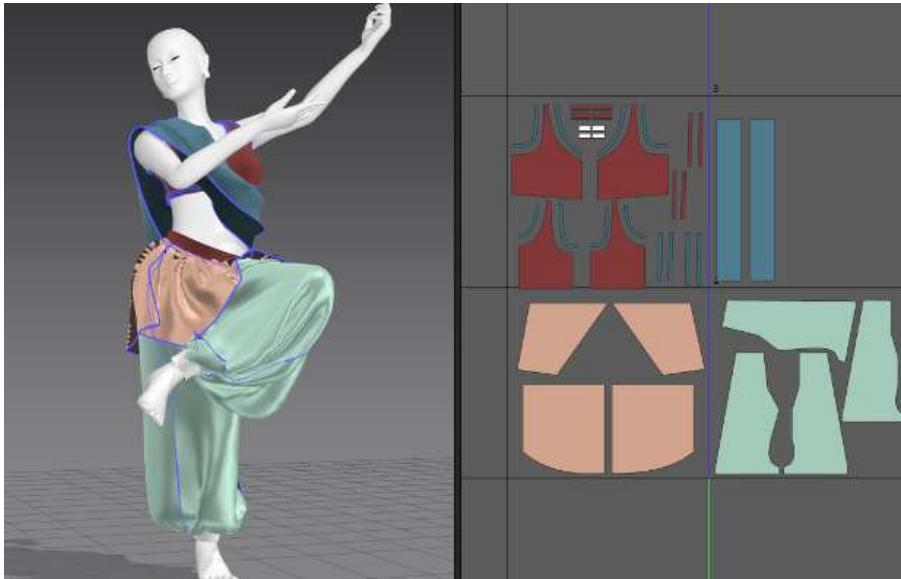


Fig. 8 Character modeling with fabric, made by Yuanzheng Li

3.3 Texture Drawing

The model is added with the proposed color or visual surface texture attributes. Texture refers to the color, pattern, surface roughness, luminescence, and refraction effects of an object. The texture picture format in Maya is highly compatible, including common formats such as PNG, JPG, PSD, and TIFF. The production steps specifically involve exporting UV maps, SP drawing maps, exporting map colors, normals, metallicity, roughness, and Maya map locations (Figure 9).

3.4 Scene and props

In order to render the realm of Buddha, the colorful and decorative landscape painting style is adopted, and the three-dimensional model is used to simulate the 3D space (Figures 10 and 11). Integrate the green landscape style in traditional painting to build three-dimensional mountains and stones. The lotus element is embodied as a lotus shaped floating platform, with a pool in the center. The wave light flows in the animation, which has the effect of supplementary light.



Fig. 9 3D model with texture made by Yuanzheng Li



Fig. 10 Scene and props :Lotus floating platform made by Yuanzheng Li



Fig. 11 Scene and props :mountain made by Yuanzheng Li

3.5 Animation

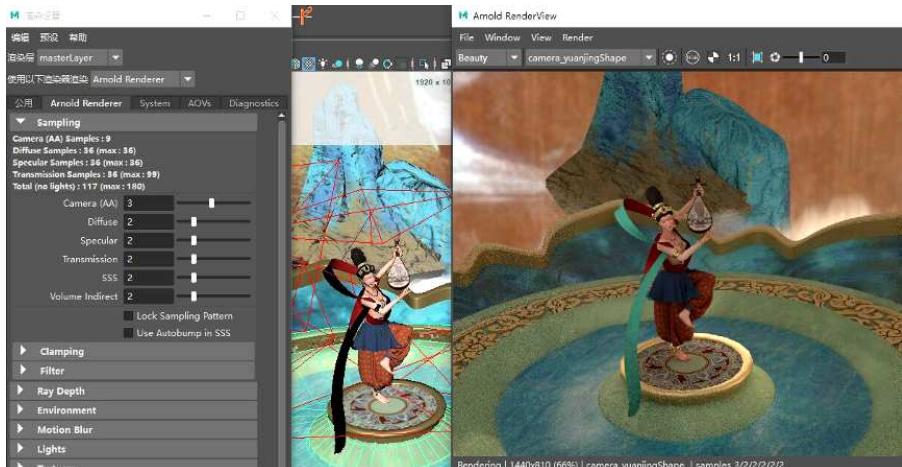
In dynamic animation, the creation of force field and the assignment of cloth attributes can automatically generate the effect of cloth flying in the wind. First make animation with Marvelous Designer to generate the initial state of the streamer: create a wind farm and adjust the parameters (size, attenuation, frequency, direction and shape). Use the animation module in Maya to pre render to adjust the position of the wind ball, then create a key frame for the position of the wind ball, and test the rendering again to simulate the initial state of the streamer. Using N-cloth, create the collided object, constrain the cloth to the model, key the solver attributes, and solve the corresponding animation according to the data (Table 1).

Table 1 Cloth Dynamics Settings

item	N-Cloth value	X-axis	Y-axis	Z-axis
Gravity	9.8	0	0	0
Gravity direction	0	0	-0.5	0
Air density	3	0	0	0
Wind direction	0	0.5	6	-3
Wind noise	0.2	0	0	0

3.6 3D rendering output

The animation project produced by 3D software finally needs to be rendered and uploaded to the network in the output video format, so as to achieve animation's visual effect. The export cache, material library and scene prop model are placed in the new project file together. The specific operation is to open the material panel in the scene, import the storage material library, and assign it to the object. Taking Arnold rendering as an example, the specific operations include creating an environment ball, attaching the drawn environment map, lighting the protagonist flying Apsaras separately, and optimizing the light and shadow effects (Figure 12).

**Fig. 12** 3D rendering output made by Yuanzheng Li

4 Discussion

This design focuses on the theme of Dunhuang Frescoes, takes Flying Apsaras rebound Pipa as the prototype for animation creation, combines 3D animation technology and holographic projection expression form, and combines traditional Flying Apsaras modeling with digital animation art. In order to make a breakthrough and innovation in the presentation form and better achieve

the communication effect, the animation design is upgraded in combination with the concept of diversity, interaction and autonomy. The design of flying Apsaras 3D animation is based on the prototype of playing-the-pipa flying Apsaras in Cave 44 of Mogao Grottoes in Dunhuang. The dynamic body shape, the fluttering clothes and the still image contained in the styling are in sharp contrast. The “L-shaped”, “U-shaped”, “V-shaped” and “S-shaped” body compositions in the Dunhuang character murals appear coherently in the animation and form a dynamic picture. The dynamic and static image of flying Apsaras makes the picture full of life [32]. The Dunhuang flying Apsaras animation is consistent with the mural scene in visual presentation, story interpretation and emotional expression. As a combination of Gandhanra and Kinnara, Flying Apsaras spreads Buddhist culture in the form of music and dance, and has always maintained this function during its evolution and development. Dunhuang flying Apsaras animation has a rich variety of musical instruments, which is related to the “music” culture of Dunhuang frescoes. As the main feature of Dunhuang frescoes, the model of “singing without playing” is obvious. Various musical instruments hung in the air with ribbons to sing, representing the wonders of the Buddha country and the worship of the Buddha. Generally speaking, flying Apsaras has a variety of musical instruments, rich colors, and unique forms [33].

In the virtual animation space, this exaggerated dance gesture greatly shows the rhythmic beauty of the human body. “Rebounding pipa” is not only a static dance image, but an interpretation of this theme series. The action sequence is to slide the pipa from the left side of the body to the right shoulder to “rebound the pipa”, “play the pipa horizontally” with the side of the body, “play the pipa on top of the head”, and finally “play the pipa on the bottom of the body” [34].

5 Conclusion

Dunhuang Flying Apsaras animation has a rich expression content, which integrates diversified elements such as images, technology, sound, and video. 3D short film practice flying Apsaras cultural animation creation protection. Computer 3D technology provides a broader space for artistic creation. The combination of art and technology is conducive to the protection, sharing and inheritance of Dunhuang flying Apsaras cultural research results, thereby expanding the scope of Dunhuang digital dissemination and speeding up the dissemination. In order to present the breakthrough and innovation of the form and the realization of the communication effect, the diversified and interactive concept is applied to the animation design, especially the expression and motion capture. In addition, creative experience forms are added to the interactive action design displayed with the audience to enhance the user's sense of immersion. For the digital collection and protection of flying Apsaras in Dunhuang frescoes, relevant literature records and research results of Dunhuang flying Apsaras culture are organically combined with 3D technology. Using

3D works as the carrier, the textual research of Dunhuang frescoes is incorporated, thereby increasing the “vitality” of flying Apsaras. Through the digital platform, the network dissemination of Dunhuang culture can be realized. The digital creation protection of Dunhuang culture is a reasonable application of the existing research on Dunhuang cultural heritage. The simultaneous advancement of protection and dissemination not only opens up a path for digital media to inherit historical culture, but also enhances cultural influence and appeal.

Abbreviations

3D: Three-dimensional

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Availability of data and materials

The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' contributions

All authors took part in discussion of the work described in this paper. YC wrote the first version of the paper. YZL did part of the experiments described in this paper. QYZ revised the paper in different versions of it. All authors read and approved the final manuscript.

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