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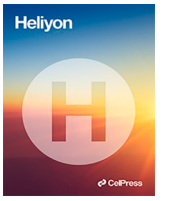

Research article

Digital design method of cultural heritage using Ancient Egyptian theological totem

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ABSTRACT

This study presents a design method for cultural heritage digitization using ancient Egyptian theological totems. The use of digital technology and multimedia in cultural heritage research has become an important means of cultural heritage inheritance, innovation, and dissemination with the deepening of the digital age. Ancient Egyptian theological totems were selected because their digitization is rarely discussed, although ancient Egypt has left very rich cultural heritage resources in various fields such as architecture, painting, music, and theology. The detailed digitization process was explained in three main dimensions: visual development, animation processing, and interactive design. Methods and design experiences were then summarized for each part. The study emphasizes that digital technology, as the most advanced technical means, plays a pivotal role in the inheritance, innovation, and dissemination of cultural heritage.

1. Introduction

In recent years, with the advent of the digital age, digitization has not only attracted increasing attention in the fields of museum studies and computer science, but also sparked a broader wave of enthusiasm in the fields of cultural heritage dissemination and art and design studies. Under the influence of digitalization, the dissemination of cultural heritage is gradually shifting from the traditional face-to-face communication with heritage sites to a digitalized mode that transcends temporal and spatial limitations. With the support of new digital technologies, the visual culture of images, interactive concepts, perception of virtual space, and cultural values can be integrated, allowing cultural heritage to break free from the constraints of its inherent material space and unleash more possibilities in a lighter, more fluid, faster, and more entertaining way [1].

One good example for the digitization of cultural heritage can be referred to Luciana Lazzeretti et al. [2], who conducted a study on the digitization of cultural heritage using the Uffizi Gallery in Florence as an example and pointed out that digitization is a constantly evolving phenomenon worthy of continued observation and exploration. Faced with increasing social and economic pressures in the museum sector, the Uffizi Gallery broke out of its predicament by implementing a variety of digital projects that greatly enhanced the promotion of Italian cultural heritage. One of these projects used touchscreens as a medium for high-resolution visualization and interactive digital artworks. The goal was to provide visitors with visual paintings or other unique cultural experiences in the cultural activities of Florence's institutions.

As one of the four ancient civilizations with a long history of five thousand years, ancient Egypt not only occupied an important position on the stage of ancient world history, but also had a great influence on the surrounding Mediterranean countries. The

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civilization of ancient Egypt has left a rich heritage for human society, whether in material culture or immaterial culture [3]. Especially in the civilization of ancient Egypt, the religion and theology of ancient Egypt is the core of civilization, to the extent that all aspects of architecture, art, music, ritual activities, astronomy and other areas revolved around the belief in theology. Therefore, starting research from the perspective of ancient Egyptian theological culture has a certain practical significance.

Through research of ancient Egyptian literature, most scholars, such as Jehane Ragai [4], Rolf G. Kuehni [5], and Lynn Swartz Dodd [6], have studied the symbolic meaning of colors in ancient Egypt. Some have used chemical analysis of color samples extracted from artifacts to infer the development of pigment production technology. A minority of literature has focused on Egyptian clothing culture [7], jewelry design based on Egyptian patterns [8], and geometric patterns in Egyptian architecture and interior design [9]. Regarding the digitization of Egyptian cultural heritage, A. Mandelli et al. [10] have used techniques such as structured light scanners, photogrammetry, and micro-mapping to create a digital 3D model of the coffin of the scribe Butehamon. ElSayed A. ElNashar et al. [11] have digitized the textile patterns of Egyptian decoration. However, very little research has been done on the digital animation and interactive design of Egyptian theological totems. Therefore, there is a need for further research on the digitization of Egyptian totemic cultural heritage.

In addition, the digitization of cultural heritage is actually a multidimensional process [12]. Juan Xu et al. [13]. used intelligent design technology to achieve the design of MG two-dimensional digital animation by integrating software technology, character design, scene design, color matching, storyboard design, animation processing, post-production and audio in eight dimensions. By taking advantage of the integration of multidimensional technologies, the MG digital animation demonstrated greater permeability and interactivity and was more contagious in information transfer. Teresa Pimentel et al. [14] also completed relevant research, using ancient embryonic writing and the Phaistos disk as visual symbols, on an interactive multimedia art installation based on the history of writing and typesetting, integrating the development of story content, visual graphic design, animation, installation of interactive equipment, and audio in five dimensions, thus creating new possibilities for the presentation of typesetting. It can be seen that the digitization of cultural heritage is not the repetition of a single technology, but the integration of multidimensional knowledge and technology.

Based on the above discussion, the present study will conduct an multi-dimensional research on the interactive digitization of ancient Egyptian totemic cultural heritage through the integration of four major dimensions: visual development, animation design, interaction design, and metaverse display design (as shown in Fig. 1), aiming to promote the widespread dissemination of ancient Egyptian totemic culture, and explore how traditional cultural heritage art installations transform, innovate, and develop in the context of multidimensional digitization. Fig. 2 shows the design flowchart of this study. In a progressive manner, Section 2 first describes the process of visual development of this case and general methods of cultural heritage digital visualization. Following that, Section 3 presents the process of achieving dynamic development based on static visual images and summarizes how to grasp the time rhythm of animation, the motion law of animation, the post-production special effects processing, and the audio expression methods in animation design. Section 4 demonstrates the process of interactive processing of animation and physical installation. Section 5 discusses an exhibition in a metaverse space. Finally, the main conclusions and limitations are summarized through the analysis of this design case.

2. Visual development

Vision generally refers to the comprehensive sensation of light, color, shape, and binocular vision. Visual expression of cultural heritage through digital art is a method of transforming cultural heritage into digital graphics and a primary way to present visual

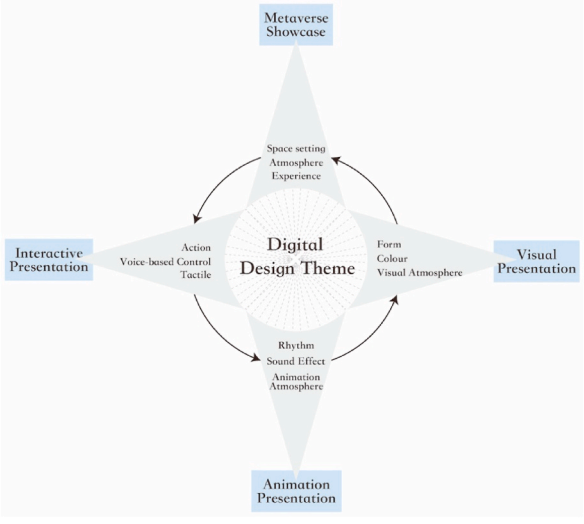

Fig. 1. The relationship between digital design theme and multi-dimensional presentation.

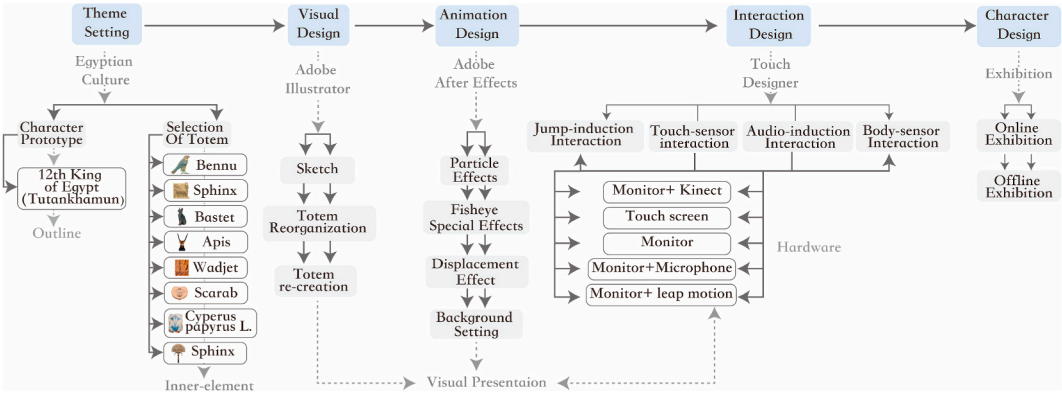

Fig. 2. Design flowchart.

design concepts. It generally includes form design and color composition. Form can be generally understood as the shape of an object, the spatial structure and the combination relationship between them, which leaves a psychological impression and spiritual reflection in the memory. Form refers not only to the physical aspect, but also to the spiritual and cultural level. In the visual development of digital art, the consideration of form generally includes three aspects: outer contour, inner contour and combined contour. The hierarchy and spatial sense created by each contour are also contents that must be carefully considered in the development of visual form.

Color generally includes three aspects: hue, brightness, and saturation. Color matching not only determines the hierarchy and spatial sense of the design to a certain extent, but also influences human behavior and emotions. Moreover, color usually has a symbolic meaning in cultural heritage. For example, the colors of ancient Egypt were closely associated with religious deities and had rich symbolic meanings. Therefore, it is important to fully consider the rationality of the four aspects of color and the symbolic meaning of color in digital visual development.

2.1. Form design

Outline design. The process of visual development is essentially an active operation of generating and solving problems, integrating knowledge to produce new ideas. The realization of the visual form in the early stages is limited in terms of concretization and complexity. Determining outline first is one of the feasible methods to quickly determine the optional visual prototype, which can

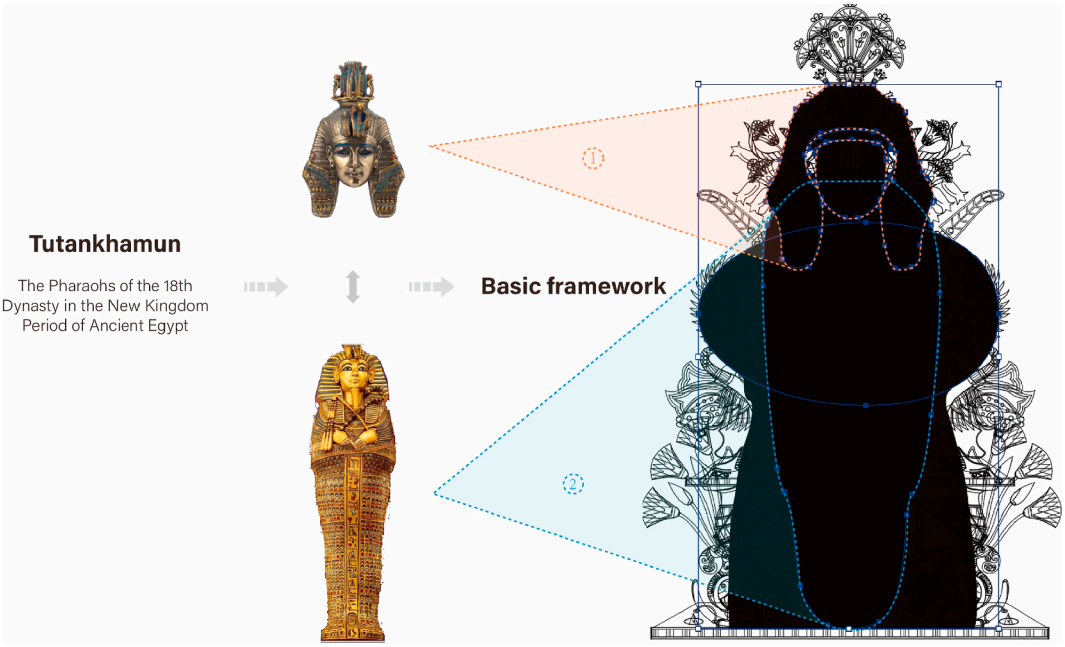

Fig. 3. Illustration of outline design.

establish a basic graphic structure and scope for the subsequent development of specific and complex visual forms.

Fig. 3 shows the outline design of this case using the above method. The main theme of ancient Egyptian art creation is to depict gods and kings [3]. From the first dynasty of ancient Egypt to the Ptolemaic dynasty in Greece, a total of 318 pharaohs have served, among whom Tutankhamun was a very representative king in the 18th dynasty. Therefore, the visual prototype elements of the outline will be extracted and graphically depicted from the human-shaped coffin of Tutankhamun. It has to be pointed out that the selection of visual elements is crucial for the initial process of digital visualization. Directly copying the selected elements' outline would result in a lack of visual innovation in the visual prototype. Therefore, while retaining the most significant visual characteristics of the elements, artistic processing is also needed to form a final visual prototype with both element characteristics and a unique visual style based on the principles of aesthetics.

For example, the initial idea of this design was inspired by the excavation experience from Tutankhamun's tomb. According to British historian Christina Rigges' [15], the excavation process was very brutal, almost chiseled out of the coffin piece by piece. In light of this historical background, this case hopes to express homage and reflection on Tutankhamun through the digital visualization form. Therefore, the outline design of the visual prototype is extracted and combined from the head portrait of Tutankhamun and the outline of his human-shaped coffin's body. However, as shown in areas 1 and 2 in Fig. 3, the outline image established by directly copying from the original elements is not only incomplete but also lacks the basic aesthetic appeal of visual graphics. Therefore, in this case, the principle of symmetrical aesthetics is used to extend the two arcs of the body's outline and complement the incomplete initial visual prototype with the difference in curvature, giving the final visual prototype a new visual form, not only with a simple upper and lower driving feeling but also with a new visual appeal.

Single module design. Single module design is the most essential part of digital visual development. It refers to the design of independently formable digital visual forms, which can be repeatedly used in the whole digital visualization to form a unified vision. Moreover, it has the flexibility of disassembly and the diversity of recombination, which can provide a good basis for the local displacement of digital animation. Lev Manovich [16] also proposed the method for the modularization of new media objects. He

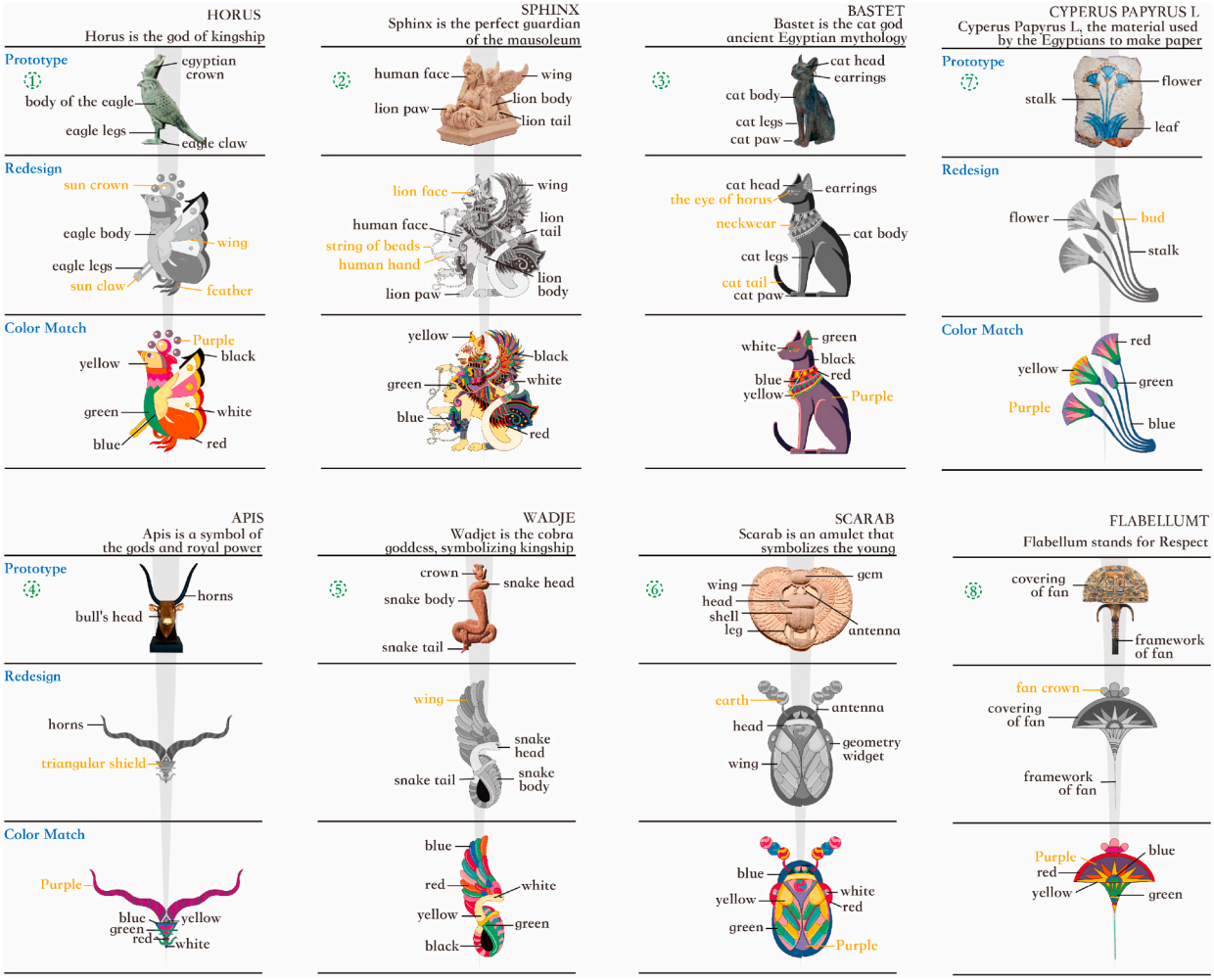

Fig. 4. Evolution of elements in single module design.

believed that these discrete individual modular elements, after being collected, could form larger scale objects while still retaining their original features and independent characteristics. In our case, the forms of various Egyptian gods were re-designed to create eight sets of single module forms. As show in Fig. 4, they are composed of four images of Egyptian gods (Horus, Bastet, Apis, Wadjet) and four forms of animals and plants related to theology (Sphinx, Scarab, Nymphaea tetragona, Flabellum).

In the initial stage of designing a single module form, a purposeful collection of cultural and creative resources is essential. It is crucial to select design elements that are conducive to the creation of cultural value and to the shaping of stories. In-depth understanding of the historical background and connotation of the selected design elements is also a focal point that needs to be repeatedly scrutinized in single module design. Choosing representative deities with historical significance from this vast cultural heritage knowledge resource as the elements of a single-module form design is one of the best methods to accurately grasp the key points of the ancient Egypt and quickly exclude information resources that generate less meaning. After that, there should be a clear grasp of the primary, secondary, and tertiary relationships of the selected elements. The primary element, as the largest carrier of cultural heritage propagation, should occupy a prominent position in the single-module image design of digital visualization, followed by the secondary element. The tertiary element generally only serves a decorative function.

Based on the study of ancient Egyptian gods, Sphinx is a composite statue consisting of the head of Hetepheres II and the body of a crouching lioness. It is the guardian of tombs. After the image of the Sphinx was transmitted to Greece, wings were added to the lion body [3]. Because of its relationship with the king as a guardian and the world-renowned status of the lion-headed human statue, it was selected as the primary element.

Horus, in Egyptian theology, has different images and meanings. He is the guardian deity of the pharaohs and the symbol of kingship [17]. Bastet is the cat goddess in ancient Egyptian mythology, playing the role of the sacred mother and nurse of the king, blessing pregnant women and the deceased, and presiding over families and happiness [18]. Apis is the god of fertility and production in ancient Egypt, the incarnation of Ptah or Osiris, and has the shape of a bull. Wadjet is the cobra goddess, the guardian of northern Egypt, who can bring death to enemies of the royal family. She is considered the sacred mother of the king and the symbol and guardian of Lower Egypt [19]. Scarab is usually shaped like a golden tortoise and is a talisman in ancient Egypt, symbolizing the young sun god and reflecting the rebirth of life from the underworld. Decorations of this element have been unearthed from the tombs of Setatolunit (daughter of Sesostris II), Meililite (wife of Sesostris III), and Psusennes I [3]. Based on the indirect supporting relationship between Horus, Bastet, Apis, Wadjet, Scarab and the king, they were set as the secondary elements.

Nymphaea tetragona is one of the most common elements in ancient Egyptian decorative art, resembling a lotus flower, which is a sacred flower of the ancient Egyptians. It is often used in the jewelry worn by ancient Egyptian kings or in temples and tombs, symbolizing the sun, beauty, and purity [11]. Flabellum is a fan used in Catholic rituals, which was found in Tutankhamun's tomb and represents respect for the monarchy. Both of these elements are commonly used as decoration in historical contexts and were therefore designated as tertiary elements.

The process of single module design not only determines whether the characteristics and connotations of cultural heritage can be accurately transformed, but also contains many methods for solving visual problems. These methods generally involve the deliberate application of exaggeration, abstraction, overlap, addition, or subtraction to the prototype elements [8]. Exaggeration used in single-module form design usually involves deliberately increasing or decreasing the visual characteristics of prototype elements based on a rich imagination and objective reality to enhance visual effects. Abstraction usually refers to the process of deleting irrelevant continuous details in prototype elements and capturing only the basic characteristics of the elements. Its advantages are to clearly show the hierarchical relationship of the single-module form and enhance its recognizability. The overlapping method generally uses symbols outside the prototype elements to intervene in the prototype to change its shape and enhance the diversity of the prototype elements. The addition or subtraction method usually adds or subtracts elements according to the proportion of prototype elements. It should be noted that these methods cannot be applied like formulas but need to be flexibly applied crosswise according to different design problems, design elements, designers' design experience and aesthetic ability.

Fig. 4 is shown to further explain the above-mentioned methods. For the design of the module 2, as the main level, the element of lion's head was first added to overlap with the combination of lion's body and human face, so as to enhance the visual richness of the sphinx while maintaining its characteristic features. Second, the base of the original sphinx was deleted, and a rhythmic string of pearls was added to enhance the dynamic feeling of jumping and flying. For the module 1, which is set as an intermediate level, the crown worn by the original Horus head was deleted and the sun element, which symbolizes life and power, was added to enhance its cultural significance. Moreover, in order to create a dynamic feeling for the originally static Horus, unfolded wings, outwardly tilted eagle legs, polygonal eagle claws, and flowing tails are added to enhance its vividness. Finally, for the design of the secondary level module 7, the methods of exaggeration and addition were used to make a simple bend in the lotus stem and add a flower bud enhancing the visual sense of plant life. The other intermediate modules 3, 4, 5, 6 and the secondary module 8 also use several of the four basic methods to recreate elements. In short, the more complete a form of a single module is, the more its features are likely to participate in the whole [20].

Integrated Design. The integrated design of a single module form is a process based on the analysis and comprehensive operation of cultural heritage information, which mainly operates at both the design level and the cultural level. At the design level, it is necessary to consider the arrangement of the story, the relationship between the main, middle, and subordinate levels, and the composition method. Reasonable story arrangement can form more attractive digital visual content; integrating the relationship between the main, middle, and subordinate levels can highlight the visual center and capture the viewer's attention. A reasonable composition is a specific method to achieve the above goals, and this part of the process is particularly important. At the cultural level, it is still necessary to consider how to effectively transform the information of cultural heritage into the integrated design, so as to achieve the transmission of cultural connotations and spirits beyond the entity.

In integrated design, the arrangement of the story generally involves narrative methods, including chronological order, reverse order, and insertions. There is no fixed template, and designers must use specific methods based on different themes. Unlike in the literary field, the presentation elements in 2D digital visualization are highly restricted and typically only allow for the narration of stories from top to bottom or from bottom to top, from left to right or from right to left, or by depicting changes from points to surfaces or from surfaces to points according to the structure of the graphics. For the present case shown in Fig. 5, within the limited visual range, layering is used to narrate the story in a bottom-to-top sequence. This is because ancient Egyptian reliefs and paintings often employed a "layered division" rule. This rule involves dividing the flat area that needs to be carved or painted into several layers or columns using line segmentation to express changes in time, space, and events, etc [3]. For example, the limestone fragment of the Scorpion King's standard head carving (E3632) and the Narmer palette carving both use this technique [21].

Following this rule, the equilateral triangle selected for the drawing frame was divided into three layers. It was divided into lower limbs, trunk, and head and neck from the perspective of human anatomy; into foreground, middle ground, and background from the perspective of spatial structure. Further from the perspective of narrative development columns, it was set into the first column of "Gate of crossing" formed by Bastet and Wadjet gods as the king's guardians. Because the first column is on the lower visual line of the integrated vision and far from the visual center, elements 3, 5, and 6 are used as the main elements in the intermediate level, with secondary element 7 used as decoration. The second column was the "Gate of the Mind" guarded by the Sphinx, allowing exploration of the king's inner world. This layer was the visual center, so the element 2 was selected. The final column is the "Gate of Memory", guarded by Horus, and the king's legendary life can be rediscovered through the memories stored in his brain. As the top layer, the third layer is not the visual center, so the main element of the intermediate level, Element 1, is used, with the secondary Element 8 used for decoration.

In addition, using compositional methods to treat relationships between primary, secondary, and tertiary elements is a challenge in integrated design. Traditionally, the basic composition methods generally include symmetrical composition, centered composition, oblique composition, three-part composition, three-point composition, frame composition, S-shaped composition, triangular composition, and full-page composition. Among the variety of composition methods, selecting an appropriate composition method to suit the theme requires a return to the cultural level itself. For example, in the cultural heritage information resources of ancient Egypt,

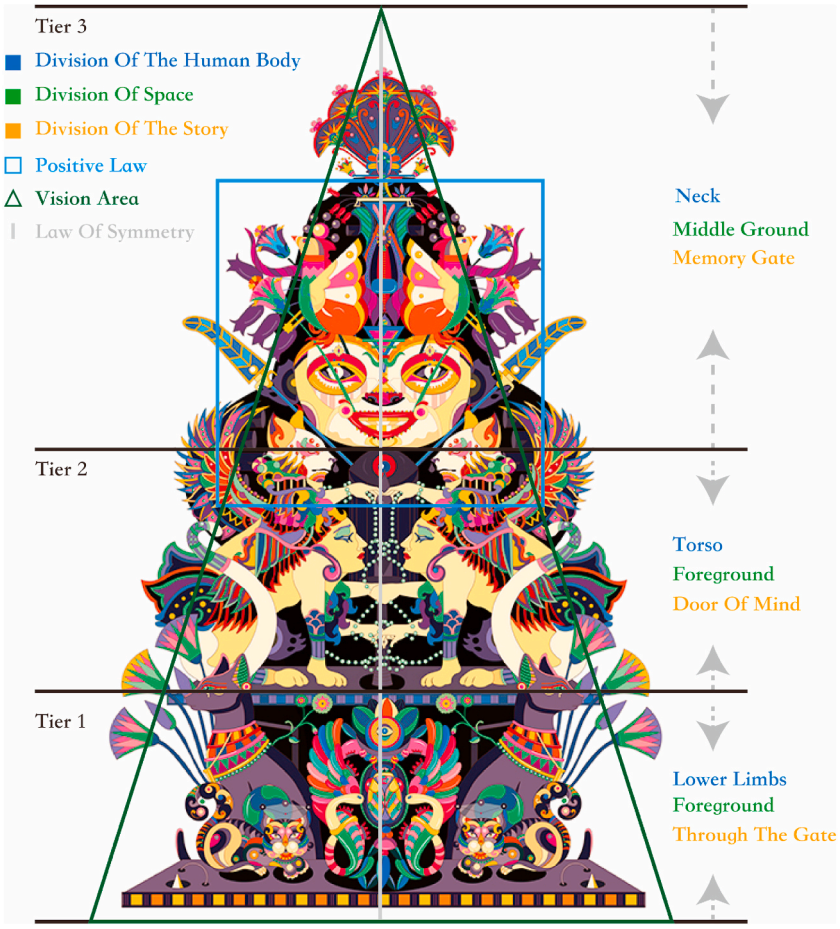

Fig. 5. Illustration of the integrated design.

artistic creation in ancient Egypt from the pre-dynastic period to the Roman era developed certain creative principles, such as “frontal law”, “symmetrical law”, “scattered perspective”, “grid method or grid proportion method”, “filling method”, “graphic-text alternation law” and so on [3]. In this case, when choosing a composition method, designers should preferably adopt the methods preserved in the cultural heritage of ancient Egyptian art or related methods to further highlight the culture of ancient Egypt.

As shown in Fig. 5, triangular composition, frontal law, and symmetrical law, were used to handle the relationships between primary, secondary, and tertiary elements. First, an isosceles triangle was selected as the drawing area. This is because the pyramid, an important symbol of ancient Egyptian cultural heritage, is known as one of the Seven Wonders of the World and is shaped like a triangle. In addition, the stability law of a triangle can achieve a balance of forces in visual equilibrium. As perceptual psychologist Rudolf Arnheim said, “Balance is still the ultimate goal that every self-realizer wants to achieve, and it is also the ultimate goal of all tasks and problems he wants to solve.” [20] According to the representation of figures in Egyptian reliefs and paintings, people are usually depicted in frontal view, with their heads, bodies, and legs all maintaining a frontal and vertical position, while the images of animals such as cows and sheep are shown in profile. This is a combination of realistic and idealistic artistic creation [3]. Therefore, the frontal law was applied by setting the main character King in this case depicted in frontal view, while the forms of other animals and plants shown in profile. Finally, the law of symmetry in ancient Egyptian art, which is in accordance with the law of frontality was chosen for this case. An invisible central axis was established in the picture from left to right, dividing it into two equal parts, thus forming a balanced structure as a whole.

2.2. Color selection

Color selection is also a crucial issue to be discussed in visual development after completing the development of visual form. Different color choices can greatly influence the effectiveness and expressiveness of the design itself, and affect the overall style of digital art [22]. In the meantime, color selection will also have a significant impact on the visualization of cultural heritage. This is because when color is applied to the dissemination of information about cultural heritage, it plays a role similar to language and carries specific symbolic meanings. Therefore, in developing digital visualizations of cultural heritage, color selection cannot be based solely on the designer’s intuitive expression but requires a rational process that involves studying the color information of cultural heritage.

Each cultural heritage possesses specific colors that have been assigned particular meanings by history. By gathering these colors together, an exclusive color system for that cultural heritage can be formed, and the selection of colors will not deviate from the cultural heritage itself. For instance, in ancient Egypt, studies of ancient texts have shown that white, black, red, green, blue, and yellow are commonly used colors in the Egyptian color system, and each color contains specific symbolic meanings [5]. White is often used to describe sacred objects and represents purity [3]; Black represents fertile soil, as well as night, death, and the underworld; Red has a sublime meaning in Lower Egypt and is commonly used to depict the king’s crown. However, red also has the connotations of wilderness, danger, disorder, and evil, which is often used in Egyptian paintings to depict the desert, foreigners, and the aggressive god Set. Green represents new life, growth, and the protector of life. Talismans and the skin of gods who are reborn after death are often depicted in green [23]. Blue is the color of the heavens and represents the rule of the gods; yellow is considered to be the flesh of the gods and is believed to be an eternal and indestructible substance [3]. Purple was not included in the commonly used color spectrum of ancient Egypt due to the expensive cost of purple pigments at the time. However, purple symbolized royal color in ancient Egypt, and there were purple sofas and curtains in the palace of Cleopatra [24].

The color selection should focus on these aforementioned colors, taking into account the “syntax” principles of color matching to make reasonable allocations of color proportions, create visual centers, and enrich the background hierarchy. As shown in Fig. 6, six

Cluster	Pixels	Name	HEX	Meaning
	46.47%	253,253,254 pale grey ΔE=0.7	#FCFBFA	Holy and pure
	16.15%	106,81,119 jupiter ΔE=2.4	#6C5579	Identity and status
	12.38%	29,17,23 very dark rose Δ E=2.6	#1F161E	Abundance and resur-rection
	10.21%	224,193,97 creme de banane ΔE=1.7	#E2C063	Eternal and indestructible
	8.46%	211,73,78 faded red ΔE=2.0	#D3494B	Exorcism
	6.32%	123,178,116 faded green Δ E=4.6	#6EB176	Life, prosperity and health

Fig. 6. Proportional analysis of color composition.

colors, white, purple, black, yellow, red, and green were used as the main color scheme to make reasonable allocation of color proportions. It is consistent with the ancient Egyptian color spectrum. Except for white with the highest proportion because of the blank paper, purple ranked first in the overall color distribution, accounting for 16.15% of the total, followed by black with 12.38%. The dark color system (the background part) accounted for 28.53% of the total color proportion, on the other hand, the light color system (the main part) had yellow accounting for 10.21%, red accounting for 8.46%, and green accounting for 6.32%, totaling 24.99% of the total color proportion. The difference between the two was only 3.54%, thus is generally balanced. The neutral dark color system moves down and the light color system moves up, which can prevent the overall visual color tone from becoming chaotic due to unbalanced color proportion allocation. It is important to understand that colors interact and influence each other. The role of a color is not determined by its own properties, but rather by the relationships it forms with surrounding colors that give it a specific mission.

In terms of creating a visual center (Fig. 7), the most direct method is to use the complementary relationship between colors to emphasize the focus. In this case, the complementary relationship between purple and yellow is used to create a spatial separation between the background and the main subject, and a strong contrast is created between the large area of bright yellow in the visual center and the purple-black background, highlighting the visual center. In addition, the use of pure color can also emphasize a convex point, which was often used by the Post-Impressionist painter Paul Cézanne. In this case, a red circular center has been established as the visual center. Although the area of this center is very small, it can still attract the viewer's attention. In addition to these two methods, reducing the overall purity and brightness of colors in areas outside the visual center can also achieve the effect of emphasizing the visual center. In this case, the hair ornament and the base of the king's head are not part of the visual center, so a lighter shade of purple is used to visually weaken these areas.

In addition, the handling of background color is also notable in color coordination, as good background processing can enhance the spatial layering and richness of digital visuals. In general, colors of the same hue but different brightness can be used to address related

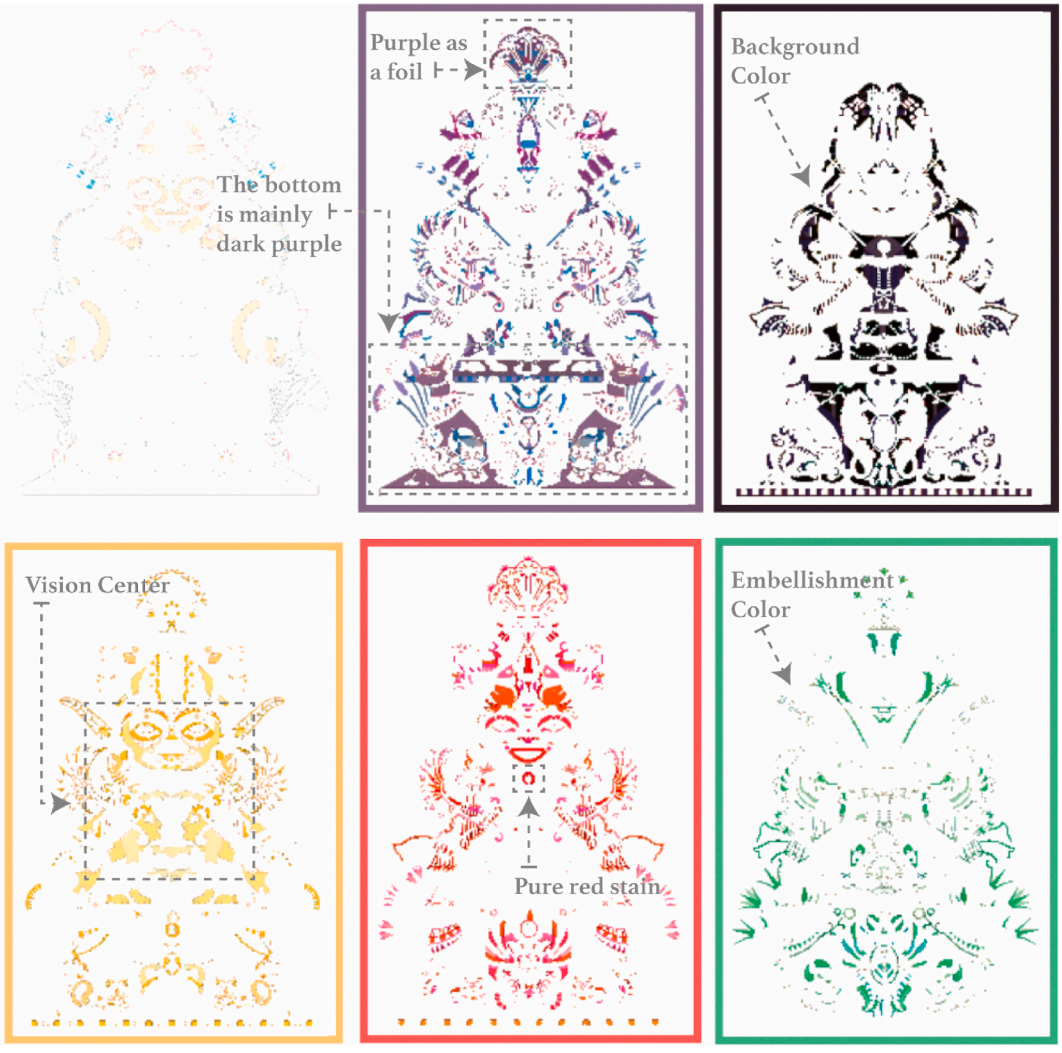

Fig. 7. Cluster partition of color composition.

issues. In this case, the difference in brightness between deep purple and light purple is used to create a "black-deep purple-light purple" color scheme for the cylindrical locks and fire wheels in the background, creating a layered visual space in the dark-toned background by using different shades of purple.

3. Animation design of static visuals

When the presentation of cultural heritage in digital form involves animated interactions, the static visual image must be processed accordingly. This process includes consideration of the animation's duration, trajectory, special effects, sound effects, and other related factors.

The animation's duration. Setting the duration is critical to animation's success, as it affects the creation of certain effects and atmospheres [25]. Psychologically, people need immediate feedback, and even a 1/10 s delay can cause discomfort. If the duration is too long, people are likely to abandon the activity and pursue other activities, thus negating the designer's efforts to satisfy the viewers' demands [26]. To avoid such problems, designers can create a design table to avoid excessive design and potential loss of audience interest. In this case, the duration of the animation was set to 32 s, taking into account the limited attention span of the viewer for a digital animation interaction device. As shown in Fig. 8, the schedule was first used to determine the order of the shots in the animation, followed by determining the length, action, and rhythm of each shot. For example, the first 2–3 s of the timeline were for the animation's introduction, which had a fast-paced action to quickly introduce the animation's theme. The transition shots from 3 to 6 s were set at a slower pace to ensure smooth transitions between shots. The climax of the animation from 7 to 27 s was the longest because it contained the most content to be presented. Finally, the epilogue of the animation from 28 to 30 s was kept short to avoid dragging the viewer's attention.

Design of motion trajectories. Motions are the key part of animation. Refining the rules of motion and mastering dynamic space to create smooth animation is the basic standard of animation. There are two basic methods for designing motion trajectories, which are keyframes setting and kernel convolution [27]. Keyframes setting refers to use the time axis of keyframes making an object move

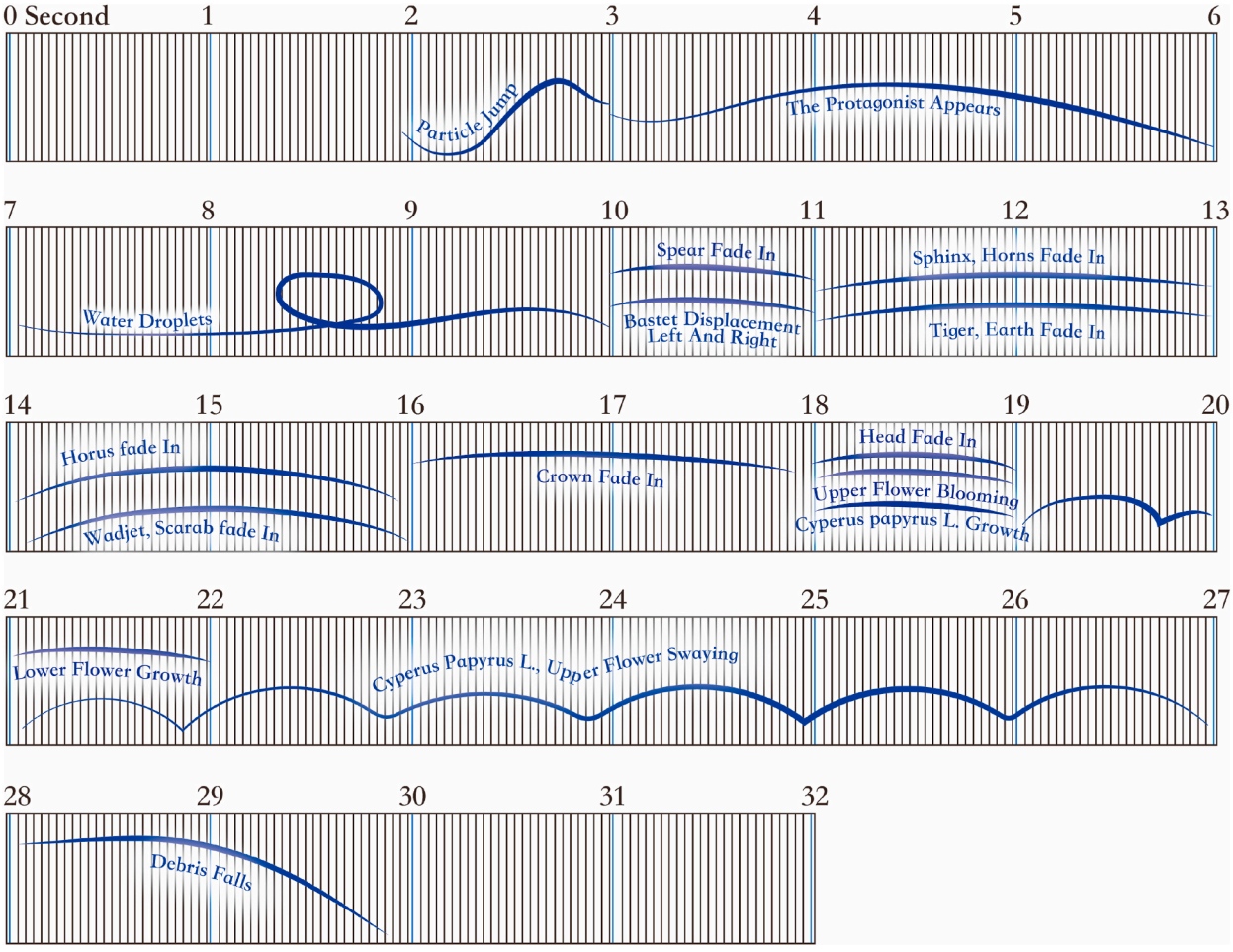

Fig. 8. Time schedule of the animation.

from point A to point B at a specific time, and then bounce back to point C. Kernel convolution refers to inputting image A and using convolution to fill or delete the boundary of the motion trajectory to form image B, and then output image B. Both methods require a rough plan for the sequence of actions, such as the specific actions to be used at the beginning, middle, and end of the animation, and ensuring that the actions match the story background.

The case studied in this work also used these two methods. The use of particle-jump actions (Fig. 9) for the main character's entrance at the beginning created a sense of mystery in the universe, and thus stimulated the audience's curiosity. The transition to the middle was achieved by water droplet piercing actions. The main actions in the middle section involved the displacement of individual modules in sequence to create a scene of the resurrection of gods and spirits, reflecting the prosperity and vitality of ancient Egypt. Actions of fragment falling and disappearing in the ending expressed regret for the disappearance of ancient Egypt's prosperity, in line with the historical ending described in chapter 24 of "Asclepius": When the time comes, the people of Egypt will worship the gods with loyal minds and diligent reverence, but it will all be in vain. All their sacred worship will be in vain, and it will disappear silently, for the gods will return from the earth to heaven, and Egypt will be abandoned [28].

Application of special effects. In the production of cultural heritage digital animation, special effects are often added to create a visual impact. These special effects usually rely on computer software such as After Effects, which provides designers with many special effects plug-ins to help create stunning visual scenes and textures. In addition to knowing the different parameters of the plug-ins that result in different animation effects, it is also necessary to repeatedly adjust the parameters of the plug-ins to achieve the desired animation effect. Some special effects including CC Ball Action and CC Lens were used for this study. The judicious use of sound effects can also help to transition and connect animation shots and promote emotional transitions.

4. Interaction design

Human-computer interaction and virtual reality have become the most representative new technologies in the current digital age. These technologies not only create interesting physical experiences for the dissemination of cultural heritage, but also establish an infinite network space for the dissemination. Although physical interaction design and virtual reality technology both belong to the field of interaction, they involve different aspects. In this work, physical interaction design refers to the use of engineering technology to establish an intimate connection between people and digital animation with a focus on the physical level. Virtual reality design refers to create a virtual space for cultural heritage visualization, so that cultural heritage can be disseminated to network as much as possible, focusing on the network level.

Physical interaction design. The first step of physical interaction is to determine the form of physical interaction. There are many forms of physical interaction, such as games, applications, and interactive devices. Designers need to clarify the form of human-computer interaction based on the digitized content of cultural heritage. The interactive devices were used in this case as the presentation of cultural heritage digitization was mainly based on graphical visualization. The second step is to determine the physical and visual configuration for interaction. Different physical devices can help designers to present different interactive experiences. For instance, five different functional physical devices were selected in this work for visual configuration during interaction: a multi-functional digital screen, a Kinect 3D body-sensing camera, a touch panel, a microphone, and a Leap Motion body-sensing controller.

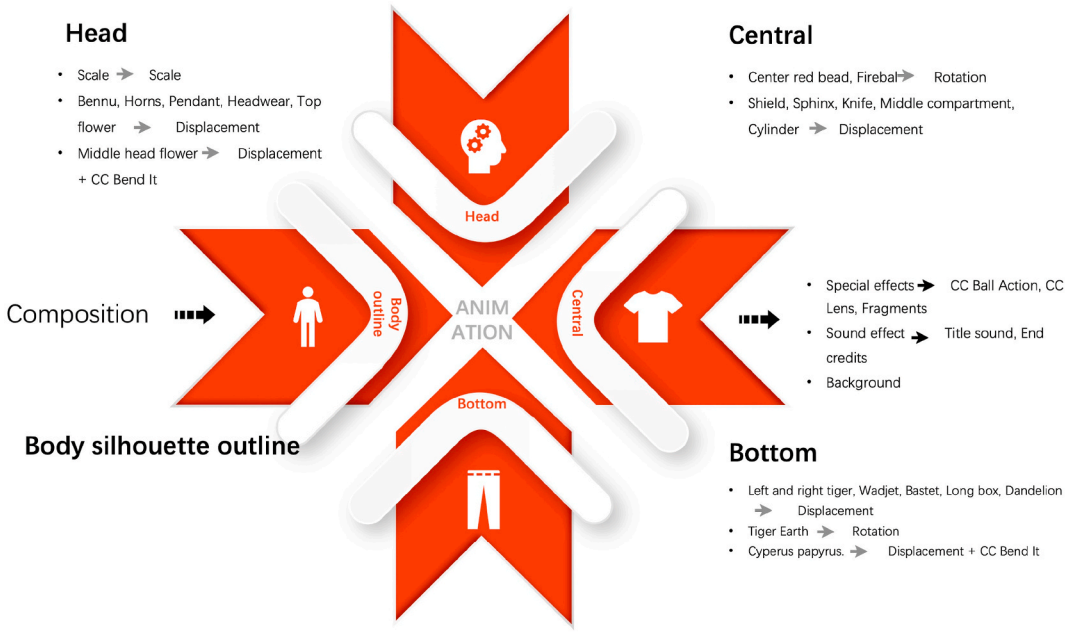

Fig. 9. Settings of motion actions and special effects.

The third step is to set the interactive content that each device needs to perform after clarifying the purpose of presenting this content. Five digital display screens were selected for the presentation. As shown in Fig. 10, these five display screens were set up with interactive behaviors based on the images in the figure. They respectively conveyed the five themes of “Rebirth of Ancient Egyptian Kings”, “Traveling through Time and Space”, “Meditation”, “The Heyday of Ancient Egypt”, and “The Disappearance of Ancient Egypt”, with a different interactive language for each screen.

The last step is to design touchpoints where users and cultural heritage visuals can interact. Five interactive touchpoints were set as shown in Fig. 11. The first touchpoint is triggered when the user jumps at the center of the screen to move the particle image along with the user’s jumping action, conveying the content of “Rebirth of Ancient Egyptian Kings”. The second touchpoint is triggered when the user’s finger touched the screen to move the screen image through the transition of water droplets, thus conveying the content of “Travel Through Time and Space".The third touch point is triggered when the user speaks and then voice is captured by the microphone allowing the user to control the movement speed of the visual image, thus conveying the scene of " The Heyday of Ancient Egypt ". The fourth touchpoint triggered when the user performs a push action. The image executes the effect of the fragment falling and disappearing presenting the content of “The Disappearance of Ancient Egypt".

It has to be pointed out that although physical interaction has been used in the process of digitizing cultural heritage to enhance its appeal, increase user engagement, and expand the dissemination of cultural heritage, its form often requires users to physically enter real-world spaces, thereby limiting the scope and speed of cultural heritage dissemination. A solution to this problem could be the use of virtual reality technology to create metaverse spaces and enable the dissemination of cultural heritage through networked platforms without the constraints of time and space.

Metaverse setting. The establishment of a metaverse is a digital virtual space created by combining network, computer, artificial intelligence, video, display, and other technologies, which can interact with the real world and showcase cultural heritage [29]. It is applicable to most modern network development platforms and is a digital means that can maximally promote the development of cultural heritage in a broader and deeper direction. In creating a metaverse for cultural heritage, designers must not only model objects at various levels, but also highly simulate real social scenes and create various functional areas in the metaverse environment, such as architectural areas, entertainment areas, work areas, consumption areas, leisure areas, and exhibition areas.

The design of functional zones in the metaverse space for our case is explained here. A modern exhibition hall of ancient Egyptian cultural heritage was established, and four areas were set up according to the linear order from outside to inside, from the first floor to the top floor: the press hall, the exhibition hall, the interactive experience center, and the guest center. Different areas have different functions. The outdoor press hall (Fig. 12-a) serves as a venue for user and media interaction and Q&A sessions. The other three are all inside the main building (Fig. 12-b). The abbreviation of the name of the Egyptian King “Tutankhamun”, “TuTan”, has been integrated into the appearance of the building to emphasize the theme of ancient Egyptian cultural heritage. The exhibition hall (Fig. 12-c) is located on the first floor as a display area. The interactive experience center (Fig. 12-d) is located on the second floor and used primarily to display digital designs of ancient Egyptian cultural heritage. It consists of three parts: the design introduction area, the rest area, and the interactive experience area. The design introduction area focuses on the design background, ideas, and process of the article case study, providing users with cultural guidance and support. The interactive experience area can simulate physical interactions in the real world, allowing users to experience physical interaction projects in the metaverse solely through the network. The small rest area focuses on humanized design, making it convenient for users to take a break in the middle. The guest center (Fig. 12-e) is equipped with basic leisure facilities such as sofas and coffee tables, making it convenient for users to rest and chat.

5. Conclusions

This study studied the design methods for the digitization of cultural heritage based on the ancient Egyptian theological totem culture. The research elaborated the design ideas and methods from multiple dimensions such as visual development, animation design, and interactive design, and then summarized the design experience. Conclusions are drawn as follow.

- The visual form and color selection are the key part in the visual development of cultural heritage digitization. For the visual form, it is necessary to consider the graphic outline, the single module form, the integration of single module forms, and the hierarchy and

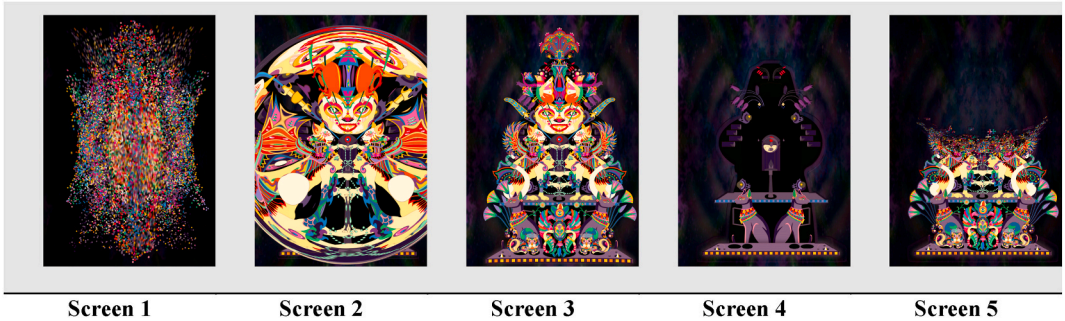

Fig. 10. Interactive digital visual presented in different screens.

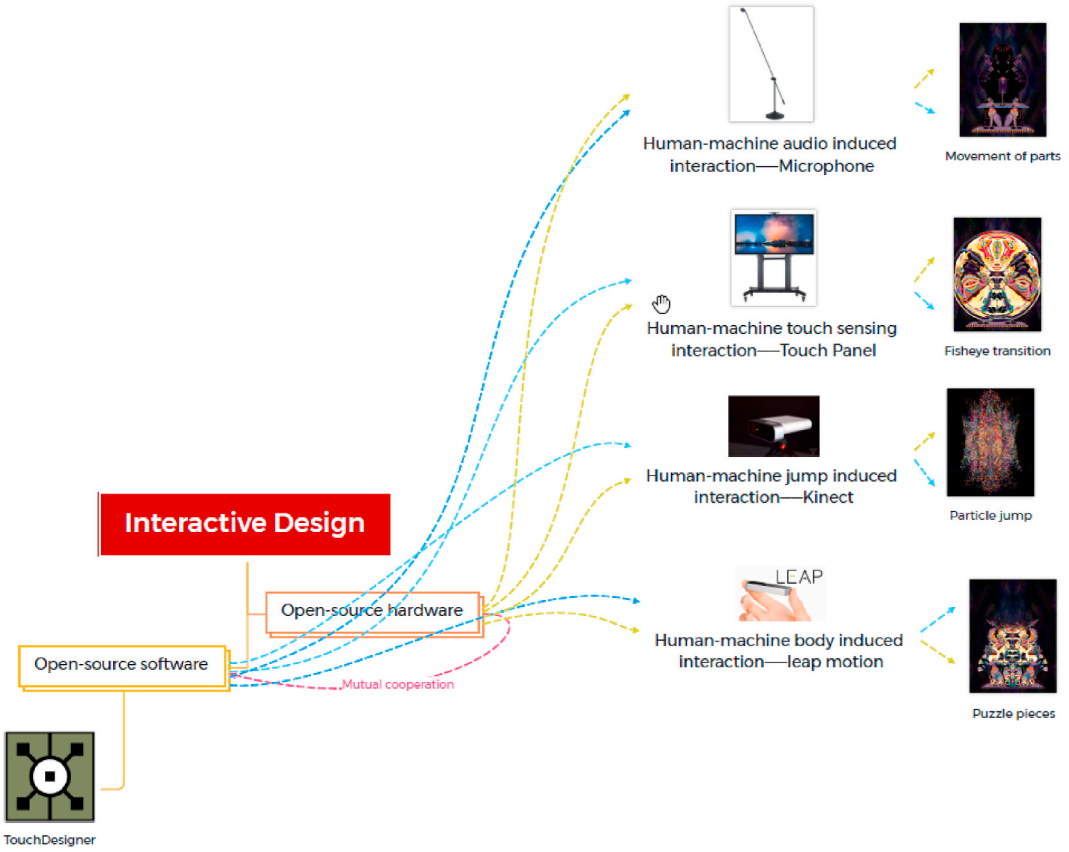

Fig. 11. Settings of touchpoints with software and hardware.

spatial sense between different forms. The outline sketch is one of the faster ways to determine the visual embryonic form. The design of the single module form must suit for cultural elements that have significant cultural value and significance.

- The integration design of the single module form must solve problems from the perspective of story arrangement, relationships between different levels, composition design, and cultural value transformation to achieve the transmission of cultural connotation and spirit. In addition, the color selection must establish a cultural heritage-specific color system based on the color resources of the culture itself.
- In the animation design, animation duration, motion trajectory, special effects application, and sound effects addition were discussed. Motion trajectory design is the core. Keyframes setting and using kernel convolution are the two general methods. Both methods require planning the rough order of actions to ensure that the action settings match the story background.

Physical interaction and metaverse are the two most representative new technologies for interaction design. In physical interaction, it is necessary to consider the form of interaction, the physical and visual configuration, the allocation of different devices for carrying cultural heritage, and the interaction touch points.

The limitations of this study are summarized here. Cultural heritage digitization is a process of multiple dimensional technologies and methods combined with each other. Different problems of cultural heritage digitization require different dimensional technologies to solve. This study only discussed visual development, animation design, and interactive design from the perspective of digitizing ancient Egyptian cultural heritage. Unexplored digitization methods will be experimented, analyzed, and summarized in the future.

Author contribution statement

Qiaoling Zeng: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mingu Lee: Juhyun Eune: Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. material/referenced in article.

Fig. 12. Settings of the metaverse.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Pei Jin, Yi Liu, Fluid space: digitization of cultural heritage and its media dissemination, Telematics and Informatics Reports 8 (2022), 100022.

[2] Luciana Lazzeretti, Andrea Sartori, Digitisation of cultural heritage and business model innovation: the case of the Uffizi gallery in Florence." Il capitale culturale, Studies on the Value of Cultural Heritage 14 (2016) 945–970.
[3] W. Liu, Egyptian Archaeology, Sanlian Publishing House, 2008.
[4] Jehane Ragai, Colour: its significance and production in Ancient Egypt, Endeavour 10 (2) (1986) 74–79.
[5] Rolf G. Kuehni, Color and colorants in ancient Egypt, Color Res. Appl. 5 (1980) 169–172.
[6] Lynn Swartz Dodd, et al., The ritual significance of colour: specialised pigments in a wooden Egyptian funerary statuette from the New Kingdom, J. Egypt. Archaeol. 95 (1) (2009) 83–104.
[7] Young-Sun Shin, Research on culture of costume in Coptic paintings in ancient Egypt-based on book research, Journal of Fashion Business 5 (5) (2001) 36–48.
[8] Eman Ramadan, Effect of Egyptian culture on the design of jewelry (cultural design based on ancient Egyptian patterns), Rupkatha J. Interdiscip. Stud. Humanit. 13 (2021) 4.
[9] Heba-Talla Hamdy Mahmoud, Geometric Patterns in Egyptian Architecture & Interior Design, 1, The Academic Research Community publication 1, 2017, pp. 11–15.
[10] Alessandro Mandelli, et al., The Digitalization of ancient Egyptian coffins: a discussion over different techniques for recording fine details, Int. Arch. Photogram. Rem. Sens. Spatial Inf. Sci. 42 (2019) 743–750.
[11] E. Elnashar, Zlatin Zlatev, Ilieva Julieta, Textile patterns based on ancient Egyptian ornaments, Appl. Res. Tech. Technol. Educ 4 (2016) 92–104.
[12] George Pavlidis, et al., Methods for 3D digitization of cultural heritage, J. Cult. Herit. 8 (1) (2007) 93–98.
[13] Juan Xu, Kai Liu, Yuan Yang, A novel MG 2D animation design method under the perspective of convergence media using intelligent design technology, Comput. Intell. Neurosci. 2022 (2022).
[14] Teresa Pimentel, Vasco Branco, Dynamic and interactive typography in digital art, Comput. Graph. 29 (6) (2005) 882–889.
[15] Christina Riggs, Egypt: Lost Civilizations, Reaktion Books, 2017.
[16] Lev Manovich, The Language of New Media, MIT press, 2002.
[17] George Rawlinson, History of Ancient Egypt, IV, 1879.
[18] Garry J. Shaw, The Egyptian Myths: A Guide to the Ancient Gods and Legends, Thames & Hudson, 2014.
[19] Joann Fletcher, The Story of Egypt, Simon and Schuster, 2016.
[20] Rudolf Arnheim, Art and Visual Perception, Stockholms Universitet, Institutionen för Konstvetenskap, 1960.
[21] wenpeng Liu, History of Ancient egypt, Chinses Academic, 2015.
[22] Japan Obesco Editorial Department, Principles of Color Design, China Youth Publishing House, 2009.
[23] Olivia Zom, Ancient Egyptian Art Is Rare, Jilin Publishing Group Co., Ltd., 2012.
[24] Gavin Evans, The Story of Colour: an Exploration of the Hidden Messages of the Spectrum, Michael O'Mara Books, 2017.
[25] Harold Whitaker, John Halas, Timing for Animation, Routledge, 2013.
[26] Don Norman, The Design of Everyday Things: Revised and Expanded Edition, Basic books, 2013.
[27] Ji-yong Kwon, In-Kwon Lee, An animation bilateral filter for slow-in and slow-out effects, Graph. Model. 73 (5) (2011) 141–150.
[28] Brian P. Hermetica Copenhaver, The Greek Corpus Hermeticum and the Latin Asclepius in a New English Translation, with Notes and Introduction, Cambridge University Press, 1995.
[29] Xuheng Xu, et al., Metaverse space ecological scene design based on multimedia digital technology, Mobile Inf. Syst. (2022) 2022.