

Digital Presentation of Cultural Relics and Gesture-Based Interactive Design: A Case Study of the "Five Stars Rise in the East and Benefit China" Brocade Armguard

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Abstract

Against the backdrop of the continuing development of digital museum exhibitions, the presentation of cultural relics should no longer remain a simple superimposition of high-resolution images, three-dimensional models, and explanatory text. Addressing the complex hierarchy of artifact information, the high threshold for audience comprehension, and the tendency of interactive displays to become formalistic, this study takes the "Five Stars Rise in the East and Benefit China" brocade armguard as its research object. By integrating cultural relic information visualization, embodied cognition, and gesture-interaction design, it develops an interactive display prototype based on TouchDesigner and MediaPipe. The research proceeds from four aspects: artifact-information extraction, interaction-action mapping, visual-feedback mechanisms, and evaluation dimensions and problem correction. It proposes a design path of "overall viewing-local approach-knowledge comprehension-feedback correction." The study argues that gesture-based interaction can serve as a method for information organization and viewing guidance in the digital exhibition of cultural relics. Through motion mapping and visual feedback, it helps audiences better understand patterns, texts, and other information, thereby enhancing the effectiveness of cultural heritage communication and utilization.

Keywords: Digital cultural relics, Information visualization, TouchDesigner, Gesture interaction

1 Introduction

In recent years, digital technologies have been widely applied to museum exhibitions. Electronic screens, online galleries, three-dimensional scanning, projection mapping, and immersive imagery have opened new channels for the communication of cultural relics. Existing studies indicate that knowledge graphs and visualization methods can transform complex knowledge relationships into observable and analyzable structures [1]; the underlying logic of real-time interaction technologies such as gesture recognition involves pattern classification and machine learning, and statistical learning theories such as support vector machines provide an early foundation for understanding such recognition technologies [2]. Research on digital teaching and the flipped classroom likewise emphasizes that the value of technological intervention lies not in merely adding media formats, but in reconstructing the learning process around tasks, resources, interaction, and feedback [3]. In practice, however, some digital exhibitions still remain at the stage of simply transferring cultural relics onto screens. Although audiences can view clearer images, they continue to receive information passively and at a distance. For artifacts with complex patterns and profound historical contexts, adding more text or visual effects alone cannot solve the more fundamental problems of not knowing where to look first or how to interpret what is seen.

Cultural relic information visualization stresses the classification, management, interpretation, and sharing of information, requiring exhibition design to shift from the accumulation of materials to the organization of knowledge structures. This view is consistent with the information-visualization principle of “overview first, zoom and filter, then details on demand”: viewers should first form an overall impression, then move into local details, and finally obtain explanatory information as needed. Accordingly, the central question of this study is not how to produce a technical demonstration, but how gesture interaction can establish a meaningful correspondence among bodily action, visual feedback, and knowledge about a cultural relic.

The “Five Stars Rise in the East and Benefit China” brocade armguard integrates inscriptions, cloud motifs, auspicious animals, astronomical ideas, and Han-dynasty weaving techniques, making it a highly representative textile artifact. Its value lies not only in its refined imagery, but also in the historical meanings, technological achievements, and cultural symbolism it carries. The National Cultural Heritage Administration included the “Five Stars Rise in the East and Benefit China” brocade object in the first catalogue of cultural relics prohibited from exhibition abroad [4], demonstrating its exceptional conservation value and significance for public presentation.

2 Theoretical Foundations and Research Logic of Cultural Relic Interaction Design

A. Digitalization of Cultural Relics and Information Visualization

Early work on the digitalization of cultural relics primarily focused on data acquisition, modeling, preservation, and database construction, with research priorities often centered on image accuracy, model restoration, and archival storage. With the development of digital humanities and information design, scholarly attention has gradually shifted toward how cultural relic information can be interpreted, read, and communicated. Chen et al.'s methodological study of CiteSpace knowledge graphs shows that visualization is not merely graphic presentation; it can also organize and explain complex knowledge relationships, research trajectories, and information structures. Trocchianesi and Bollini similarly emphasize that design in the digital humanities is not limited to interface beautification, but serves as an important method for organizing complex cultural content, establishing knowledge paths, and supporting exploration [5]. The goal of information visualization is to enhance cognition through visual externalization, rather than compressing all available material into a single screen. Card, Mackinlay, and Shneiderman describe information visualization as the use of visual forms to support thinking [6], while Shneiderman's information-seeking principle suggests that designers should establish hierarchical entrances from overview to detail [7]. These ideas provide the methodological basis for the information structure used in this study: the opening interface establishes object recognition through the complete armguard and its principal motifs, after which zooming, hotspots, and explanatory panels progressively unfold information about patterns, inscriptions, and craftsmanship.

B. Intelligent Interaction with Cultural Relics and Embodied Cognition

An interactive experience with cultural relics is not only an operational relationship between an individual and a machine; it also includes coordinated behavior among visitors and between visitors and the surrounding space. Research by vom Lehn, Heath, and Hindmarsh on museum viewing behavior shows that looking, pausing, and communicating in exhibitions are often influenced by companions and nearby visitors [8]. Hornecker and Stifter likewise note that interaction design for public museum installations must consider visibility, collective participation, and on-site stability [9]. For this reason, the present design avoids relying on overly complicated individual operations and instead adopts movements, grasping, and dwelling-actions that are relatively easy to understand.

Theories of embodied cognition and embodied interaction further indicate that cognition is not an abstract process detached from the body, but is formed through the joint action of movement, sensation, and environment. Dourish regards embodied interaction as an important foundation for understanding relationships between people and computational systems [10], while Hornecker and Buur discuss the relationships among body, space, and social interaction from the perspective of tangible interaction [11]. In the museum context, reaching, approaching, dwelling, and grasping can become entrances into knowledge about cultural relics. At the same time, visitors' acceptance of an interactive system, their experiential perception, and their knowledge comprehension do not form a simple linear relationship. Future research may draw on mediation-effect testing and model-development methods to analyze

the pathway among interaction mode, experiential perception, and knowledge comprehension [12][13].

C. Gesture Recognition and the Construction of a Real-Time Visual Platform

At the technical level, MediaPipe provides a relatively low-cost implementation route for camera-based real-time perception applications. The MediaPipe framework proposed by Lugaresi et al. supports cross-platform perception-pipeline construction and real-time inference [14], while MediaPipe Hands, proposed by Zhang et al., predicts hand-skeleton landmarks from a single RGB camera and is suitable for real-time scenarios such as AR and VR [15]. TouchDesigner is well suited to video input, node-based data mapping, three-dimensional rendering, and real-time visual feedback; its official documentation positions it as a development environment for real-time media systems and interactive installations [16]. Although this study does not directly train a classifier, statistical learning theories such as support vector machines provide a useful basis for understanding the pattern-classification logic behind gesture recognition. Connecting MediaPipe hand-landmark data to TouchDesigner therefore offers a low-cost interaction solution suitable for course prototypes and small- or medium-scale exhibition projects.

3 Implementation Path of the TouchDesigner-Based Interactive System

A. Ontological Characteristics of the Cultural Relic

The “Five Stars Rise in the East and Benefit China” brocade armguard was excavated at the Niya site in Xinjiang and has attracted widespread attention because it bears the inscription “Five Stars Rise in the East and Benefit China.” From the perspective of information display, this type of textile artifact requires the simultaneous presentation of patterns, structure, material, and textual information. The relational organization emphasized by knowledge graphs and information visualization helps transform these dispersed contents into information levels that can be read, selected, and interpreted. This also indicates that the artifact should not be treated merely as a flat image in exhibition design; the relationships among its pattern structure, textile layers, and inscriptional information must also be addressed.

It should be noted that the function and naming of this brocade remain open to further scholarly discussion. Huang Jinqian, considering its form, dimensions, and archaeological context, has argued that the textile may not have functioned as an armguard [17]. This study retains the widely used designation “brocade armguard,” but avoids presenting its function as an absolute conclusion. Instead, it treats the object as a composite of textile heritage, auspicious imagery, inscriptional information, and craft structure. This adjustment avoids the lack of academic caution found in earlier versions that emphasized only the object’s “preciousness.”

Methodologically, the study follows the path of literature review-object decomposition-interactive translation-prototype reflection. First, research on digital cultural heritage, information visualization, and museum interaction is

used to establish the theoretical foundation. Second, the form, motifs, inscriptions, and craftsmanship of the brocade are decomposed into information units. Third, information at different levels is translated into operable gesture tasks. Finally, shortcomings in the proposal are examined from the perspectives of usability, stability, and cultural accuracy. Although this path cannot replace empirical user testing, it makes the design process more explainable and verifiable, shifting it away from purely subjective creativity.

B. Extraction of Information Levels

Cultural heritage objects often contain a high density of information. Presenting all content simultaneously on a single interface can increase reading pressure and weaken the recognition of key information. Visitors are usually first attracted by the overall form and color of an object; without further guidance, however, they may remain at the superficial level of considering the pattern visually appealing or the inscription unusual. Therefore, before interaction design begins, the heritage information is first decomposed hierarchically so that complex content can be viewed, selected, and understood step by step.

As shown below, the displayed information is divided into three levels: overall form, local motifs, and inscription interpretation. The overall-form level primarily supports object recognition, allowing visitors to quickly identify the outline, proportions, and basic visual characteristics of the display object after entering the system. This level should not carry excessive explanatory text; instead, a complete image and model rotation establish an initial impression and provide a basis for subsequent local observation. The local-motif level further guides visitors from overall viewing toward detail recognition. Cloud motifs and auspicious-animal imagery are configured as triggerable information areas. By approaching, gripping, or holding with the hand, visitors can actively select motif details of interest, creating a transition from “seeing” to “approaching.”

Table 1. Levels of cultural relic information and their interactive translation

Information level	Main content	Interactive translation
Overall focus	Compound outline, wearing relationship, and overall pattern layout	Display the complete model when triggered; support hand-controlled rotation for further observation
Local motifs	Cloud motifs and auspicious-animal imagery	Set pattern hotspots; display explanations after a grasp gesture
Inscriptional meaning	Explanation of the inscription and auspicious symbolism	Trigger concise explanatory panels and avoid lengthy evaluation-based reading



Fig. 1 Model display and local-pattern triggering interface

C. Design Objectives

The design objective of the project can be summarized as “see first, approach next, and understand last.” “See” refers to establishing the overall form so that viewers can quickly recognize the display object upon entering the interface. “Approach” refers to local magnification and pattern hotspots, guiding attention toward specific motifs. “Understand” refers to explanatory text, craft animation, and visual feedback that help viewers connect images and inscriptions with historical context. This path draws on the information-visualization logic of overview-zoom-detail and also responds to museum-learning research that emphasizes the combined influence of personal, social, and physical contexts on the viewing experience [18].

As shown below, to prevent interaction from becoming meaningless movement, the system binds each gesture to a specific cognitive purpose. Lateral palm movement serves viewpoint adjustment; the grasp gesture simulates the everyday experience of bringing an object closer for inspection; a landmark entering a hotspot represents the active selection of an information entrance; and releasing the hand returns the interface to a cleaner viewing state. In this way, bodily movements are no longer decorative operations but correspond directly to tasks of understanding the cultural relic.

Table 2. Gesture actions, system feedback, and cognitive purposes

Gesture action	System feedback	Cognitive purpose
Move palm left or right	The brocade model rotates slightly with the movement	Establish cognition of the overall form and edge structure
Grasp with the hand	The model enlarges or a local motif is selected	Lower the threshold for detail observation and emphasize cloud and animal motifs
Landmark enters a hotspot	A pattern explanation appears	Connect local imagery with its knowledge interpretation
Gesture dwell	The explanatory panel remains visible	Allow time for reading and discussion
Release the hand	The explanation retracts; particles or lines gradually dissipate	Create clear beginning and ending feedback and prevent interface clutter

D. Technical Workflow

The system consists of an input layer, a processing layer, and an output layer. The input layer uses an ordinary RGB camera to capture the viewer's hand and obtains 21 hand landmarks through MediaPipe Hands. With TouchDesigner as its core, the processing layer imports landmark coordinates into CHOP channels and calculates the palm-center position, degree of finger flexion, and spatial relationships between landmarks and hotspots. The output layer consists of model rendering, text panels, pattern animation, and particle feedback, producing effects such as rotation, zooming, information pop-ups, and feedback dissipation.

As shown below, compared with solutions that rely on large-scale motion-sensing equipment, this route has the advantages of relatively low cost and flexible deployment, making it suitable for course prototypes and preliminary research for small- and medium-scale exhibitions. It also introduces challenges in recognition stability. Changes in on-site lighting, background interference, hand occlusion, and the simultaneous appearance of multiple users may all affect landmark detection. Future deployment should therefore include interaction-threshold calibration, false-trigger filtering, and alternative operating paths.

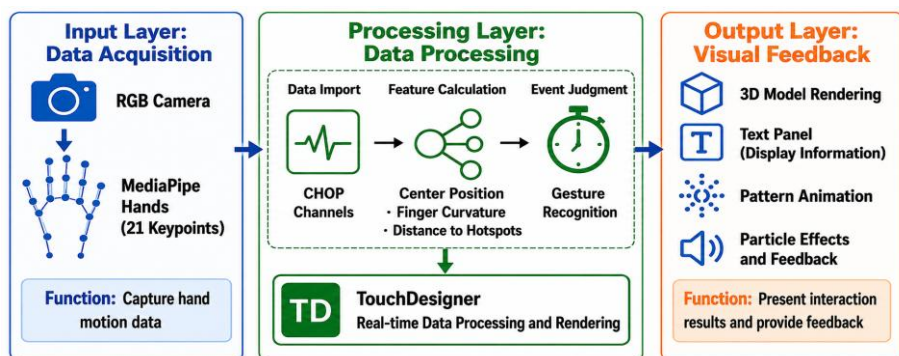


Fig. 2 Technical workflow based on TouchDesigner and MediaPipe

E. Visual Feedback and Information Presentation

As shown below, in the visual design, a dark background is used to emphasize the colors and lines of the brocade patterns, preventing a complex setting from weakening the cultural relic as the main subject. The complete form of the armguard is retained during the overall-display stage. During local triggering, borders, light effects, and text panels reinforce the currently active information area. Explanatory text is written in short sentences and focuses on three questions: what is it, why is it important, and how does it relate to the artifact as a whole. This avoids turning the interface into a long reading panel.

The study also moderates the excessively decorative motion effects used in the initial proposal. Particles, light effects, and animation no longer function as independent visual spectacles; instead, they provide information prompts, signal state transitions, and simulate craft processes. For example, when a motif is triggered, it is highlighted and accompanied by an explanation; in the weaving explanation, lines are generated progressively to indicate, in a restrained manner, that “information is being opened.” This treatment helps

maintain the solemnity of cultural relic presentation and reduces interference between interaction feedback and the artifact itself.

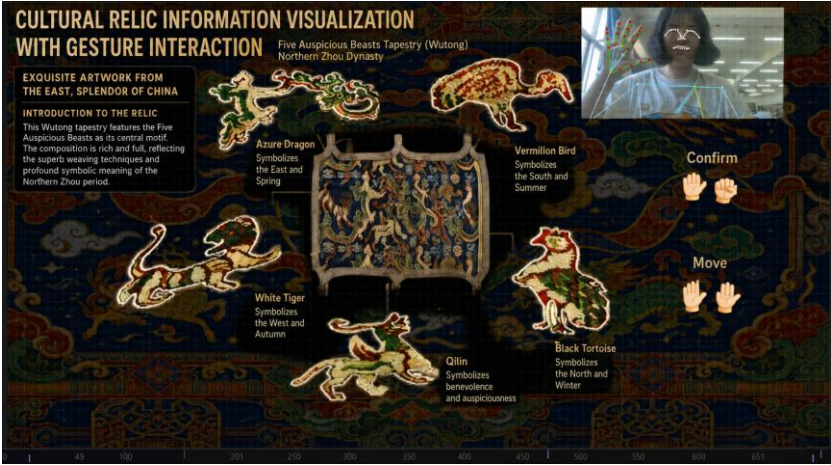


Fig. 3 Cultural relic information-visualization interface and gesture-interaction prototype

4 Communication Value and Evaluation Framework of Embodied Interaction

To strengthen the completeness of the research, the revised study defines four evaluation dimensions: usability, comprehensibility, stability, and cultural accuracy. Usability can be rapidly measured with reference to the System Usability Scale (SUS) [19]. Although the present study has not yet conducted a large-sample empirical experiment, clearly specified evaluation indicators provide a methodological entrance for subsequent testing. Further analysis of the mechanisms among gesture interaction, experiential perception, and knowledge comprehension may combine mediation-effect testing and model-development methods to establish relationships among variables.

Table 3. Prototype evaluation dimensions and subsequent testing methods

Evaluation dimension	Key question	Possible subsequent method
Usability	Can viewers quickly understand movement, grasping, and dwelling?	SUS, task-completion rate, and false-trigger counts
Comprehensibility	Can viewers remember motifs, inscriptions, and craft information?	Pre-/post-tests, interviews, and delayed-recall testing
Stability	Do lighting, occlusion, or multiple viewers affect recognition?	Frame rate, latency, and landmark-loss rate
Cultural accuracy	Are explanations accurate and do they avoid controversial absolute claims?	Expert review, literature verification, and terminology revision

From the perspective of design reflection, the proposal still has three limitations. First, although gesture recognition lowers the hardware threshold, real exhibition environments are complex. Practical deployment should not rely

solely on camera recognition; touch-screen buttons, automatic demonstrations, or voice prompts should be retained as alternative paths. Second, the accuracy of cultural relic information is more important than visual effect. Especially when dealing with the designation “armguard,” the interpretation of motifs, and astronomical concepts, the design should avoid excessive simplification or absolute statements. Third, the current prototype has not yet been tested with real visitors, and it therefore cannot precisely demonstrate improvements in knowledge retention, emotional connection, or cultural identification. This limitation must be stated explicitly in the conclusion rather than replaced by general claims of value.

The revision of the original proposal consequently focuses on four areas. First, overly lyrical statements of significance are reduced and replaced by arguments based on literature and design logic. Second, tables for artifact-information extraction, gesture mapping, and evaluation dimensions are added to make the design process more verifiable. Third, literature on digital cultural heritage, museum interaction, embodied cognition, and usability evaluation is supplemented to strengthen the research foundation. Fourth, the limitations section explicitly identifies insufficient prototype testing and risks in actual exhibition environments. Through these adjustments, the paper shifts from a “project description” toward “design research,” while retaining the specificity of case-based practice.

Regarding the boundaries of application, the proposal is better suited to the in-depth presentation of a single key artifact, teaching displays, or interactive-experience zones in temporary exhibitions. If applied to a large permanent exhibition, maintenance costs, queuing efficiency, accessibility, and simultaneous viewing by multiple visitors must also be considered. More explicit visual guidance should be provided for children, older visitors, and users unfamiliar with gesture rules. Conventional text-and-image explanations should remain available to visitors who are unable or unwilling to use gestures. In other words, gesture interaction should not replace all exhibition methods, but should serve as an additional entrance for the layered interpretation of cultural relic information.

5 Conclusion

Taking the “Five Stars Rise in the East and Benefit China” brocade armguard as a case study, this research examines the digital presentation of cultural relics and gesture-based interactive experience design. Beginning with artifact-information extraction, it translates overall form, local motifs, inscriptional meanings, craft structure, and historical context into different levels of interaction. TouchDesigner and MediaPipe are then used to establish mappings between gesture actions and information presentation. The study argues that gesture-based interaction can serve as a method for information organization and viewing guidance in the digital exhibition of cultural relics. Through motion mapping and visual feedback, it helps audiences better understand patterns, texts, and other information, thereby enhancing the effectiveness of cultural heritage communication and utilization. Future research should conduct experiments with real users, for example by establishing a static text-and-image display group and a gesture-interaction display group and comparing knowledge comprehension, dwell time, interest, and memory retention. Only by combining design proposals with empirical

data can research on digital cultural relic interaction move from merely “being displayable” toward “demonstrating its effectiveness.”

DECLARATIONS

Authors' information

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