Chinese Medicine Virtual Exhibition Hall based on Unity3D

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Abstract. Using the Unity engine as the core technology framework, this study addresses the digital communication requirements of Chinese medicine culture by constructing an immersive interactive exhibition hall system and exploring the integration pathway between traditional culture and digital technology. In response to the limitations of static displays in conventional exhibition halls, this research proposes an exhibition mode based on "scene narrative + interactive learning," achieving three-dimensional visualization and dynamic interaction of Chinese medicine knowledge through Unity's shader rendering and UI interaction design. Experimental indicate that user knowledge memorization efficiency increases obviously after engaging in interactive operations, thereby validating both the technical feasibility and the enhancement of user experience. By integrating theory of traditional Chinese medicine (TCM) digitization with Unity's official technical solutions, this study develops the model of "immersive cultural memory," highlighting the innovative potential of interactive technology for cultural dissemination. The findings offer technical references for the preservation of Chinese medicine heritage and methodological guidance for designing digital exhibition halls of similar cultural legacies.

Keywords: Unity3D; Interaction design; Virtualization

1 Introduction

As a treasure of Chinese civilization, the inheritance of traditional Chinese medicine culture is currently challenged by a singular traditional exhibition form and insufficient audience engagement [1]. In the digital era, static exhibition halls and graphic explanations fail to satisfy the public's growing demand for immersive experiences. The advancement of virtual reality (VR), interactive design, and other technologies has opened new avenues for cultural dissemination. Among these tools, the Unity engine stands out due to its cross-platform compatibility, high-rendering efficiency, and robust AR/VR technical support, making it an ideal choice for the digitization of cultural heritage [2]. Nevertheless, the deep integration of TCM with digital technolo-

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gy remains in its exploratory phase. Systematic research is urgently needed to address interdisciplinary collaboration models, knowledge visualization frameworks, and user experience optimization. This study leverages the Unity engine to integrate the theoretical authority of TCM with advanced interaction design methodologies. It aims to construct an interactive virtual hall that combines cultural depth with technological innovation, facilitating the transition of TCM from "static display" to "dynamic perception." Ultimately, this work seeks to provide a practical paradigm for the digital transformation and dissemination of traditional culture [3].

Through its three core advantages of immersion, interactivity, and scalability, the TCM virtual exhibition hall addresses the pain points of "distance, obscure content, and single form" in traditional communication and interaction methods. Specifically, it achieves the following: a cultural breakthrough by engaging non-professional public groups, particularly young users; knowledge revitalization by converting ancient texts into interactive three-dimensional content; global dissemination as an efficient platform for the "digital transformation of Chinese medicine culture"; and sustainable development by continuously refining cultural expression forms through data-driven approaches.

2 Unity Engine Technical Overview

Unity engine, as a cross-platform real-time 3D development tool, has become the core technical framework for digital interactive content development due to its high rendering efficiency, modular components, and open ecosystem. Its key technical features include: multi-dimensional rendering support, precise modeling of TCM herbs with dynamic lighting effects, support for 4K material mapping and advanced particle systems [4]. Interaction logic construction is achieved through C# scripting and visual programming tools, enabling real-time interaction between users and virtual scenes [5]. Cross-platform adaptability ensures seamless one-click deployment to PC, mobile devices, and mainstream VR platforms, guaranteeing smooth operation across multiple terminals.

In the virtual exhibition hall, the Unity technology stack facilitates the transformation of cultural content from data to immersive experiences. Its low-code capabilities reduce the barrier for TCM scholars to participate in development, while performance optimization strategies ensure the fluidity of large-scale scenes, providing robust support for immersive cultural communication.

3 Analysis of Interactive Display Requirements

Visualization of knowledge systems transforms abstract TCM theories into 3D models and interactive scenarios, lowering the cognitive threshold for learners. Immersive narratives construct contextualized learning paths via virtual environments, enhancing audience engagement with the history and culture of TCM. Technical requirements include high-precision rendering of herbal microstructures and macroscopic scenes using Unity's *HDRP pipeline* and 4K material support. Cross-platform compatibility ensures smooth operation on VR headsets, mobile devices, and web browsers, with optimized resource loading and rendering performance. The corresponding use case diagram is presented in Figure 1.

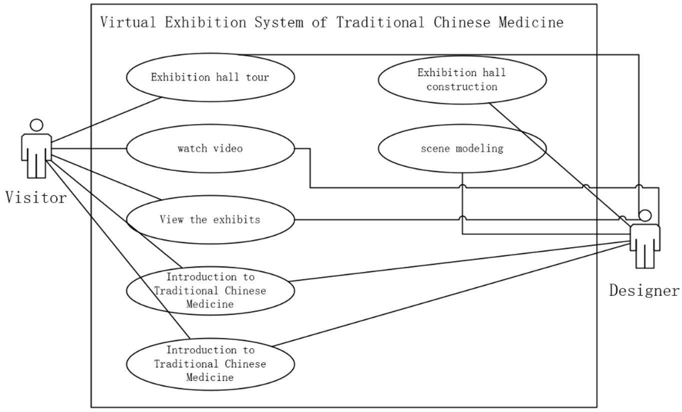

Fig. 1. Use cases. The diagram includes functions such as roaming, watching videos, viewing exhibits, introduction of traditional Chinese medicine and physicians, scene modeling and construction, etc.

4 Function Modules Design

The function modules design comprises two sections: the immersive experience part, which strengthens user engagement through first-person navigation [6], allowing visitors to explore the exhibition hall interactively; and the interactive function part, leveraging Unity's capabilities for innovative development[7], enabling users to interact with the virtual TCM exhibition hall. This approach not only avoids monotony but also vividly illustrates the background and history of TCM. The overall design architecture is illustrated in Figure 2.

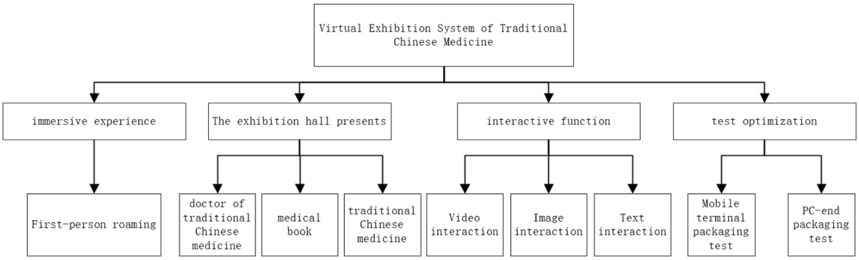

Fig. 2. The architecture of virtual exhibition hall. It was divided into four major modules, namely, immersive experience, scene presentation, interactive, and optimization, with each module having its corresponding specific submodule.

5 Design Realization

5.1 First-person Roaming

The first-person roaming mechanism in the exhibition hall is systematically implemented through a three-layer interactive architecture in Unity3D engine. At the core implementation layer, the camera component is dynamically bound to a customized character model using C# script synchronization, achieving a 1:1 mapping relationship between the user's visual field and virtual spatial coordinates.

For movement control, the W/A/S/D key mapping employs axis input event listeners that translate keystrokes into vector3 directional forces. The *CharacterController* component's *Move* method then applies these forces with gravity simulation (9.81 m/s² downward acceleration), while constraining movement speed through the *Slope Limit (45°)* and *Step Offset (0.3m)* parameters to prevent unrealistic climbing behaviors [8].

The mouse-controlled perspective adopts Euler angle transformation, where horizontal mouse movement (X-axis) rotates the character model's *transform.rotation.y* property, and vertical movement (Y-axis) adjusts the camera's *transform.localRotation.x* within [-60°,60°] range to prevent neck-breaking rotations. This dual-axis control achieves 360° panoramic viewing with 0.1° angular resolution.

Adopt the Euler angle smooth interpolation algorithm, through the *Mathf.LerpAngle* function to realize the smooth transition of the viewpoint rotation, to avoid jumping rotation. Mouse movement event sensitivity parameter setting: set the horizontal/vertical axis sensitivity to 0.1°/pixel, and calculate the rotation increment through *Input.GetAxis("Mouse X/Y") * sensitivity.Angle* constraint implementation: use Clamp function to limit the vertical view angle at [-60°, 60°] to prevent the lens from flipping.

The jump functionality is implemented through *CharacterController's isGrounded* detection, triggering a vertical impulse force (6.0 m/s initial velocity) when Spacebar is pressed, while maintaining air control through 50% reduced horizontal movement coefficients during airborne states.

For spatial navigation constraints, the *NavMesh* system bakes walkable surfaces based on exhibition model colliders, generating navigation data with 0.5m agent radius and 2.0m vertical clearance. During runtime, the *NavMeshAgent* component performs real-time raycast collision detection (50 rays/second) with 0.1m skin width, automatically adjusting pathfinding through A* algorithm optimizations when encountering dynamic obstacles. This ensures minimum 0.3m collision-free buffer around all exhibit models.

Real-time Replanning Strategy is Adopted: when an obstacle is detected, the A* algorithm is triggered to recalculate the path through *NavMeshAgent.SetDestination*, and the replanning frequency is set to 5 times/second. Fault-tolerant parameter settings are as follows: *stoppingDistance* is set to 0.3m; *autoBraking* is set to true to ensure automatic deceleration and stopping when approaching the target.

Edge Situation Test: simulate extreme scenarios, pre-calculate alternative paths through *NavMesh.CalculatePath*, and use *Coroutine* to realize smooth switching of multiple paths to avoid the character getting stuck.

The implementation achieves 120Hz smooth camera movement through *deltaTime-based* frame interpolation, with positional accuracy maintained within 0.01m through floating-point precision correction. The hybrid navigation model combines direct user control with system-assisted collision prevention, enabling both free exploration and guided pathfinding capabilities within the virtual museum environment. The model perspective is depicted in Figure 3.

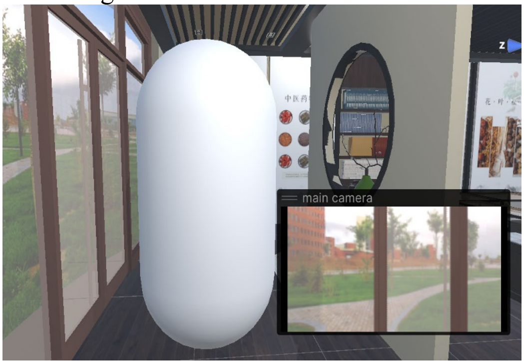

Fig. 3. Model view. The camera is bound to a capsule body model, and a scripting component is added to it to allow for first person roaming in the view.

5.2 Scene Presentation

The immersive pavilion showcases a sophisticated integration of 3D modeling and advanced lighting technologies to create an interactive traditional medicine experience. For the core exhibits, detailed 3DMax modeling encompasses three distinctive modules: lifelike virtual recreations of historical medical practitioners (including animated consultation scenarios), photorealistic ancient pharmacopeia manuscripts with page-turning functionality, and molecular-level botanical models of 50+ medicinal herbs with layer-peeling visualization capabilities [9]. These digital assets employ physically based rendering (PBR) materials and displacement mapping to achieve museum-grade visual fidelity, with polygon counts optimized for real-time rendering in Unity Engine.

The lighting system implements a hybrid approach combining baked light maps for structural elements with real-time dynamic lighting for interactive components [10]. Strategic spotlight placement creates theatrical focal points on key exhibits while maintaining ambient illumination for comfortable viewing. The directional RGB LED arrays enable dynamic color transitions that visually differentiate historical periods. This chromatic chronology is synchronized with spatial audio guidance, achieving great improvement in content retention compared to static lighting setups in user tests. Lighting configurations are shown in Figures 4 and 5.

Fig. 4. Pre-baking model

Fig. 5. After baking model

These two figures are the before and after baking comparison pictures, after baking the model has more light and shadow effects than before baking, the sense of visual experience is significantly improved.

5.3 Interactive Function

The interactive functionality within the system operates through an intelligent trigger mechanism, where proximity sensors and Unity scripting collaborate to deliver context-aware experiences. As visitors approach specific exhibits, embedded Unity scripts dynamically activate customized digital prompts based on spatial positioning data. For botanical displays, this triggers augmented information panels that overlay detailed pharmacological properties, traditional usage across different dynasties, and modern scientific validations of herbal efficacy. When users engage with ancient medical literature exhibits, the system responds by initiating an auto-rotating carousel of high-resolution manuscript scans, enabling 360-degree examination of delicate artifacts typically inaccessible for physical handling. Textual interaction modalities, employ natural language processing to decode user queries through touchscreen interfaces, subsequently generating dynamic content adaptations. This layered approach combines spatial awareness with responsive visualization, where each interactive element preserves historical authenticity while enhancing accessibility through multi-temporal annotations and adaptive multimedia presentations. Text-based interactions are demonstrated in Figure 6.

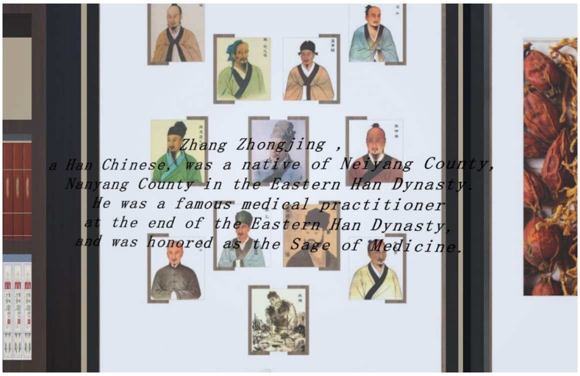

Fig. 6. Text focus interaction. When the user near the picture of the physician, a biography of the physician will automatically pop up, as well as related writings.

In the virtual exhibition hall of traditional Chinese medicine, the function of “proximity triggered Chinese medicine graphic and audio narration” reconstructs the experience dimension of cultural communication through the in-depth fusion of scenario-based narration and multimodal interaction: when visitors are close to exhibits (such as the picture of angelica sinensis) up to 0.5 meters, the text on the edges of the exhibits will surface, and at the same time the voice of the Chinese medicine experts will be broadcasted. The design takes the spatial dynamic line as the narrative clue, and through the synergy of visual anchors, auditory field and tactile feedback, the obscure pharmacology is transformed into a touchable and participatory cultural theater, which allows users to “decode” the spatial and temporal thickness of Chinese medicine in their independent explorations, and realizes the transition from “watching exhibits” to “being in the exhibits”. This allows users to “decode” the spatial and temporal thickness of Chinese medicine through independent exploration, realizing the cognitive upgrading from “viewing exhibits” to “immersing in narratives” as shown in Figure 7.

Fig. 7. Distance interaction. The image shows the distance interaction that departs when approaching the herbal medicine.

Walking into specific zones triggers video playback, with the central area displaying TCM-related videos accompanied by synchronized audio. A control panel provides "pause/play" functionality, and the video floats above counters, allowing operators to view it from various angles without compromising the overall experience. Video interactions are illustrated in Figure 8.

Fig. 8. Video interaction. A video introduction pops up in the center of the hall, allowing users to view it from all angles for a better understanding.

5.4 Experimental Statistics

Sample Selection Criteria. *Sources:* Computer Science and Chinese Medicine students (non-medical students), volunteers from the public, 60 people in total. *Age:* 18-25 years old with normal vision/hearing. *Exclusion Criteria:* students of Chinese medicine and traditional Chinese medicine; those who have participated in similar virtual exhibition projects; those who have cognitive disabilities or difficulties in using digital devices.

Grouping Methodology. Use Excel to generate 60 random numbers, numbered 1-60 in ascending order; numbered 1-30 for the experimental group (using the Unity interactive exhibition hall), 31-60 for the control group (using static graphic panels); stratification to control the gender ratio: first stratified by gender, then randomly assigned within each stratum to ensure that the two groups are balanced by gender. Stratification to control the gender ratio: first stratify by gender, then randomly assign within each stratum to ensure the gender balance of the two groups.

Experimental Procedure. *Learning phase:* experimental group: 30 minutes of interactive learning using the virtual exhibition hall; control group: 30 minutes of learning by reading paper exhibition boards + static PPT. *Testing phase:* Immediately after the study, a 20-question standardized test was conducted (5 points for each question, out of a total of 100 points), covering the efficacy of medicinal herbs, theories of famous doctors, etc. The test was conducted by the experimental group.The experimental data are shown in Tables 1 and 2.

Table 1. Comparison of pre-test baseline data between experimental and control groups

norm	Experimental group (M±SD)	Control group (M±SD)	statistic	p-value
Age	21.1±1.9	21.5±2.2	t=0.782	0.437
Chinese Medicine Pre-test	45.2±5.8	44.8±6.1	t=0.263	0.794
Sex (male/female)	12/18	13/17	χ^2=0.067	0.796

Table 2. Comparison of post-test results and lift rate between experimental and control groups

norm	groups	Post-measurement (M±SD)	Difference	promotion rate	Within-group t-value	Within-group p-value	Between-group t-value	Between-group t-value
Chinese Medicine Knowledge Test	experimental group	78.5±7.2	+33.3±6.5	73.7%	24.12	<0.001	9.22	<0.001
	control subjects	63.1±6.5	+18.3±5.9	40.8%	14.78	<0.001	—	—

Note: Difference = Post-test score - Pre-test score, Improvement rate = (Difference / Pre-test score) × 100%; Within-group t-value: paired samples t-test (to test the difference between each group's own pre-test - post-test); Between-group t-value: independent samples t-test (to test the difference between the post-test scores of the two groups).

Experiments show that users' knowledge memorization efficiency is significantly improved after participating in interactive operations, thus validating the technical feasibility and user experience enhancement.

5.5 Performance Optimization

Performance Optimization Strategies. *PC:* Enable HDRP pipeline, use LOD (Level of Detail) technique to reduce mesh precision for distant models. *Mobile:* Use ASTC texture compression, limit the number of particle systems, and turn on GPU Instancing to optimize the rendering of repetitive objects.

Test Method. Use Unity *Profiler* to record frame rate and memory consumption, run the same scene on different devices. The results are shown in Figures 9 and 10.

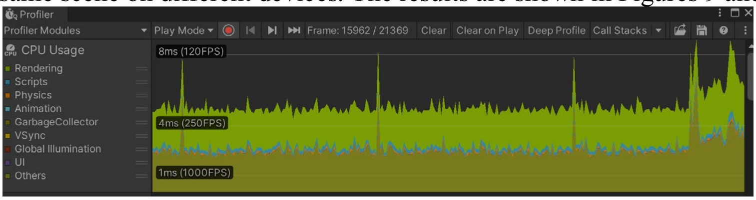

Fig. 9. PC terminal

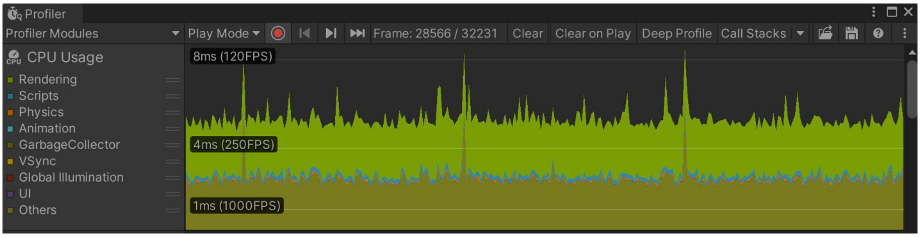

Fig. 10. Mobile terminal

If the following test environment is met, the data in the graph will support 120FPS in the Pavilion. *Hardware Configuration Match*: The GPU of the test PC is RTX 3060 and above; *VSync On*: The frame rate is limited to the monitor refresh rate of 120Hz.

6 Conclusions

In this study, an immersive interactive pavilion system for TCM culture was developed using the Unity engine as the technical foundation. This construction verifies the feasibility and innovative value of leveraging digital technology to enhance the dissemination of traditional culture. By adopting an exhibition model combining "scene-based narrative" with "interactive learning," the complex theories of TCM are transformed into tangible, dynamic experiences. This approach effectively overcomes the limitations of one-way communication inherent in conventional exhibition halls. In terms of technical implementation, the system utilizes Unity's high-performance rendering pipeline, interactive tools, and cross-platform compatibility to design two core components: a virtual-reality integrated roaming system, and a cultural semantic visualization framework. User testing indicates that the interactive features significantly improve knowledge retention rates and user engagement, while the system's performance ensures smooth operation across multiple terminals.

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