

Interactive Experience Design of Finger Exercises Based on Leap Motion

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ABSTRACT

This study presents an innovative approach to enhance the interactivity and immersion in the dissemination of traditional Chinese medicine (TCM) culture by integrating Leap Motion gesture recognition technology with TCM finger exercises. By drawing on the core movements of TCM finger exercises, a gamified interactive system is created using Leap Motion technology, featuring scenarios such as exploring virtual herbal mazes and collecting sachet formulas. Using Unreal Engine, gesture control, character animations, and a dynamic knowledge card feedback mechanism are implemented to establish an immersive environment for popularizing TCM culture. The experimental findings demonstrate that this interactive design significantly boosts participants' engagement and learning enthusiasm, effectively resolving the problems of insufficient interest and low information transmission efficiency in traditional dissemination models. Through the dynamic integration of gesture movements and virtual scenes, the system not only enables the intuitive dissemination of TCM knowledge but also helps alleviate hand strain symptoms among modern people through the practice of TCM finger exercises, reflecting the in-depth integration of the concepts of "education through entertainment" and "preventive treatment of diseases". This research confirms the applicability of Leap Motion technology in the inheritance of TCM culture and offers a reusable technical framework for the digital transformation of TCM popularization venues.

Keywords: Hand strain, Leap motion, TCM finger exercises, interactive design, gamification.

INTRODUCTION

In the digital era, hand strain has shown a high prevalence rate and a trend toward younger onset: the prevalence among individuals aged 12–24 has increased from 20% to 34%, while the diagnosis rate of carpal tunnel syndrome among 31–35-year-old office workers has reached 48%, primarily attributed to average daily electronic device use of 12.1 hours. Although Traditional Chinese Medicine (TCM) finger exercises can prevent strain through movements such as flexion–extension and rotation, their passive dissemination model faces challenges including low entertainment value and inefficient knowledge transfer.

To address this, this study proposes integrating Leap Motion gesture recognition technology with TCM finger exercises to develop a gamified interactive system using Unreal Engine. Focusing on the "dynamic gesture–virtual scenario" coupling mechanism, this design not only enhances user engagement through real-time gesture control but also transforms TCM health-preserving movements into immersive experiences, achieving simultaneous cultural dissemination and health intervention. This approach offers a novel methodology for the digital transformation of TCM.

1. SEVERITY AND YOUNGER TREND OF HAND STRAIN

The high incidence and younger trend of hand strain in modern society pose a severe challenge to public health. As shown in Table 1, the prevalence of hand strain among adolescents aged 12–17 is 20%, rising to 34% in the 18–24 age group. Among Generation Z (born 1995–2010) in workplaces under 30 years old, the 2024 diagnosis rates for carpal tunnel syndrome and tenosynovitis reached 48%, significantly higher than the 28% rate for those over 35 (Table 2). This trend is closely linked to digital device dependency.

As "digital natives," Generation Z has work behaviors deeply intertwined with electronic devices. Data reveal that Generation Z spends over 7 hours daily on computers, and when this time is combined with the time spent on smartphones in 2023, it results in a total daily device usage of 12.1 hours—far exceeding other age groups (e.g., 6.8 hours/day for those over 35, Table 2). Professions such as programming and design involve up to 12,000 daily mouse clicks, tripling the risk of tenosynovitis

compared to non-office workers. The 48% prevalence among 31–35-year-olds (Table 1) and their 5–9 hours of daily high-intensity operation further confirm the linear relationship between workload and strain severity. Smartphone usage exacerbates intergenerational hand strain: 2023 saw an average daily smartphone usage of 12.1 hours (Table 3), with 64 minutes spent on frequent swiping actions on short-video platforms, significantly increasing thumb joint stress. Among 12–18-year-olds, 55% of those gaming continuously for over 3 hours exhibited early tenosynovitis symptoms (Table 1). China's wrist guard market grew from ¥850 million in 2015 to ¥1.47 billion in 2023 (6.5% annual growth), projected to reach ¥1.56 billion in 2024 (Tables 2, 3). Generation Z's hand strain incidence rose from 28% in 2015 to 45% in 2023, paralleling the growth of the protective gear market, reflecting a passive response to health issues (Table 3).

To address these challenges, this study proposes integrating TCM finger exercises with Leap Motion technology to explore their potential in hand strain prevention. TCM finger exercises, as traditional therapies, enhance blood circulation and improve hand muscle/tendon flexibility and strength through finger flexion, rotation, and other movements, thereby alleviating fatigue and preventing strain-related disorders.

TABLE 1. Hand Strain Prevalence and Common Conditions Across Age Groups

Age Range	Surveyed	Cases	Prevalence	Daily High-Load Activity (Hours)	Common Conditions
12 - 17	40	8	20%	3 - 5	Mild finger pain, hand fatigue, occasional wrist discomfort
18 - 24	50	17	34%	3 - 6	Tenosynovitis, mild wrist pain, muscle tension
25 - 30	60	27	45%	4 - 8	Aggravated tenosynovitis, early carpal tunnel syndrome, finger joint pain
31 - 35	50	24	48%	5 - 9	Carpal tunnel syndrome, tendinitis, hand numbness
36 - 40	40	20	50%	6 - 10	Early arthritis, muscle strain, restricted joint mobility
41 - 45	30	16	53%	5 - 8	Arthritis, recurrent tenosynovitis, weakened grip
46 - 50	20	12	60%	4 - 7	Severe arthritis, joint deformation, hand dysfunction
51 - 55	15	9	60%	3 - 6	Intensified joint pain, muscle atrophy, reduced flexibility
56 - 60	10	6	60%	2 - 5	Severe joint deformation, self-care difficulties, chronic pain

Source: Author created

TABLE 2. Hand Health and Device Usage: Generation Z vs. Comparison Group

Metric	Data Source	Generation Z (2024)	Comparison Group (35+)
Daily Device Usage Duration	QuestMobile	13.3 hours	6.8 hours
Hand Strain Incidence	National Health Commission	48%	28%
Wrist Guard Purchase Intention	《China Wrist Guard Market Report》	62%	34%
Daily Gaming Duration (Teens)	《Youth Health White Paper》	5.2 hours	-

Source: Author created

TABLE 3. Generation Z Hand Strain Trend, Device Dependency, and Wrist Guard Market Correlation

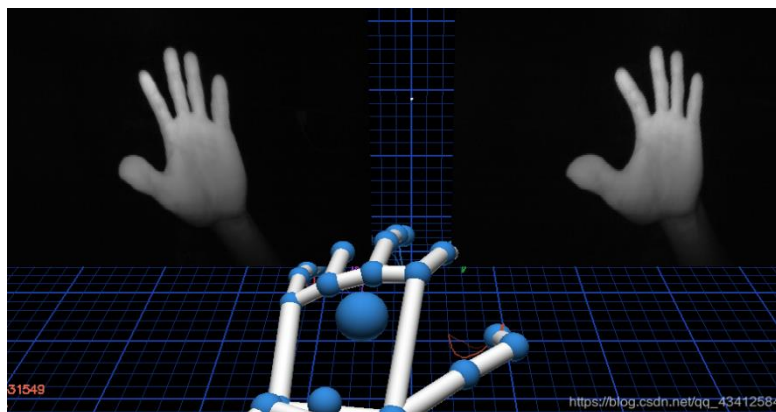
Year	Gen Z Hand Strain Rate (%)	Gen Z Device Usage (Hours/Day)	Wrist Guard Market (¥Billion)
2015	28	5.0	8.5
2016	30	5.5	9.2
2017	32	7.9	9.8
2018	34	8.3	10.6
2019	36	8.7	11.5
2020	38	9.1	12.4
2021	40	9.6	13.4
2022	42	7.2	14.3
2023	45	12.1	14.7
2024	48	13.3	15.6

Source: Author created

LEAP MOTION HARDWARE ARCHITECTURE AND GESTURE RECOGNITION PRINCIPLES

The Leap Motion device employs two high-resolution infrared cameras and three LEDs for precise gesture tracking. Infrared LEDs emit specific wavelengths to illuminate the user's hands, generating clear images in infrared environments. Using binocular vision principles, the cameras capture hand images from different angles to obtain 3D positional and shape data, enabling accurate gesture recognition.

During image processing, the device first applies stereo vision algorithms to calibrate camera parameters and relative positions. Stereo matching generates disparity images, and triangulation produces depth maps (Figure 1). A gesture segmentation algorithm extracts initial hand positions and initiates real-time tracking.



Source: https://blog.csdn.net/qq_43412584/article/details/107585121.
Figure 1. Leap Motion Hand Gesture Recognition

Preset gesture models and rules analyze finger bending, palm orientation, hand motion direction, and speed. By matching these features with known patterns, gesture meanings are identified. Notably, the device supports multi-gesture and compound gesture recognition, enabling natural and intuitive interactions.

With high-precision cameras, advanced algorithms, and adaptive machine learning, Leap Motion holds broad prospects in virtual reality, augmented reality, gaming, and smart assistance.

INTERACTIVE DESIGN PRACTICES BASED ON LEAP MOTION TECHNOLOGY

Introduction and Core Movements Extraction of TCM Finger Exercises

During our research, we noticed that hand overuse diseases are becoming more common in modern society, especially among people who do long-term fine hand operations, like office workers and craftsmen, and a small number of teenagers. To effectively prevent these diseases, we studied various hand health methods and finally chose TCM finger exercises as the preventive measure. Combining TCM finger exercises with modern technology, such as using Leap Motion for gesture recognition and interaction, can further increase their popularity and user experience.

Based on relevant literature and TCM finger-exercise videos, we've summarized the core movements of TCM finger exercises (as shown in Figure 2): (1) Finger-joint flexion activities, or "three-grabs-upon-waking" in TCM, including half-grab, full-grab, and solid-grab. Each grab should be done 30-50 times daily, which can boost hand blood circulation and improve joint flexibility and coordination; (2) Finger-joint extension, the opposite of flexion, meaning stretching the clenched fist; (3) Opposition activities, where the thumb tip touches the tips of the other four fingers in turn; (4) Finger rotation, with each finger rotating clockwise and counterclockwise 360°, tracing a circle with the fingertip; (5) Palm-pressing activities: place hands together, fingers naturally interlaced, left hand gently pressing the right hand backward, then switch.



Source: The hand meridian diagram is from <https://shorturl.at/YkuZs>; Others: Author created.
Figure 2. TCM Finger Exercise Movements and Hand Meridian Diagram

In this research, we used Leap Motion to collect hand - motion data from users doing TCM finger exercises. Its sensor has a precise coordinate system but a limited range. However, when the user's hand direction doesn't match the sensor's, or is too close/far, the camera's view is blocked, leading to inaccurate hand - info capture by the Leap Motion sensor. To ensure accurate gesture recognition, we selected and designed TCM finger - exercise movements, choosing proper gestures as key interaction points. During system development and based on user feedback, we found that repeated hand - gripping and finger - opposing can cause user fatigue. Thus, we picked five main actions from TCM finger exercises (see Table 4).

TABLE 4. TCM Finger Exercise Gesture Function Summary

Input	Processing	Output
Finger Flexion	Flexion angle <30° → Fist state	Move Forward
Finger Extension	Flexion angle >30° → Extension state	Pause
Fingertip Opposition	Thumb-index distance <2cm	Collect Item
Finger Rotation	Index rotation ≥180° (held 1s)	Continue Experience
Palm Pressing	Palms together (distance <5cm, symmetric)	End Experience

Source: Author created

Gamification Design Strategy for Gestural Interaction

In the process of constructing a gamified experience, we ingeniously integrated the traditional element of traditional Chinese medicine sachets into the core experience. In the main part of the game, the participants' task is to collect various sachet recipes. The history of traditional Chinese medicine sachets can be traced back to ancient China, originating from people's pursuit of health and disease prevention. In this interactive design practice, we used five Qingyang sachets (as shown in Figure 3), with the most common cloth tiger sachet serving as the design prototype. We digitized it using 3D software and placed it at the exit of the maze in the form of a Non-Player Character (NPC). When the participants have collected all the sachet recipes and exited the maze, the cloth tiger sachet will appear, indicating the success of the experience.



Source: <https://cj.sina.com.cn/articles/view/1885560902/70636046019013f4j>
Figure 3. Five Types of Qingyang Embroidered Sachets

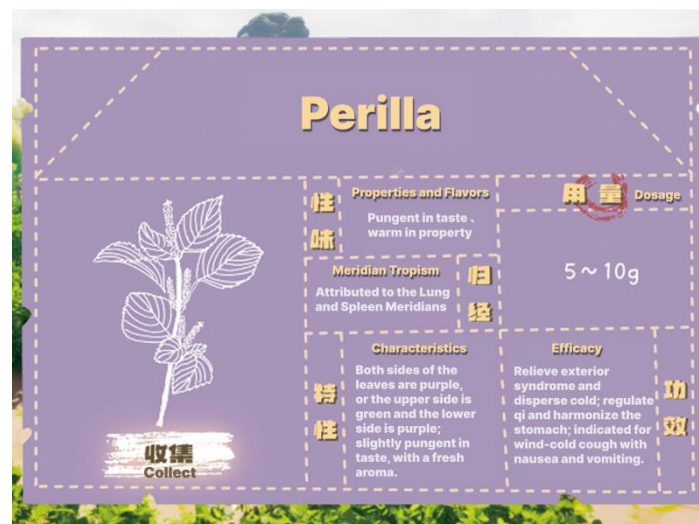
To enhance interactivity, we designed a game mechanism (Figure 4) where participants control and adjust character movements using gripping gestures. This allows for better character control and lets participants unconsciously practice TCM finger exercises during the game. This design helps participants exercise their finger flexibility and experience the benefits of TCM finger exercises in a relaxed setting. Thus, we successfully integrated traditional Chinese medicine knowledge with modern gaming for cultural inheritance and increased participant engagement.



Source: Author created

Figure 4. Design Transformation of TCM Finger Exercises

In our virtual maze, herbs for mosquito - repellent sachets grow in their real - plant forms across different areas. These seven herbs are mugwort, perilla, clove, agastache, tangerine peel, mint, and honeysuckle. To boost interactivity and learning, we used Unreal Engine's box - trigger tech. When participants approach these herbs in the maze, the system triggers a mechanism, showing a card - like UI window with herb - related knowledge (Figure 5).



Source: Author created

Figure 5. Perilla - Chinese Herbal Knowledge Card

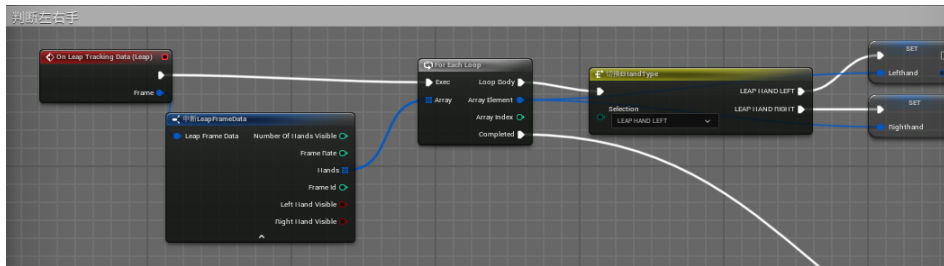
In the "Leap Motion controller" blueprint of Unreal Engine, the "get hand data" node periodically extracts hand 3D coordinates, posture, and motion information from the sensor. After the "data processing" node parses the raw data, it extracts key parameters (such as palm position and finger joint angles). Leap Motion's "hand model" data structure can analyze the position and rotation of each phalanx of every finger. Based on the characteristics of TCM exercises, predefined gesture - judgment rules are established: a five - finger joint angle of less than 30 degrees indicates a fist, while an angle greater than 30 degrees indicates an extension. Subsequently, the "gesture recognition" node matches real - time data with preset features, for example, triggering a "clench" signal when the left - hand five - finger joint angle is less than 30 degrees. To improve recognition stability, a "gesture duration" parameter is introduced to filter out transient jitter interference. Finally, the "function execution" node maps gesture signals to interaction instructions: a fist triggers character movement, and an extension triggers a stop. This process

achieves closed - loop control from data acquisition to functional response, ensuring precise gesture - to - virtual - operation conversion.

Implementation of Gesture Interaction

The Blueprint system in Unreal Engine enables dynamic knowledge transfer through multi - sensory interaction, with visual scripting and event nodes controlling variables. This design achieved its goal using Unreal Engine 5's character Blueprints, level Blueprints, and UMG UI Blueprints.

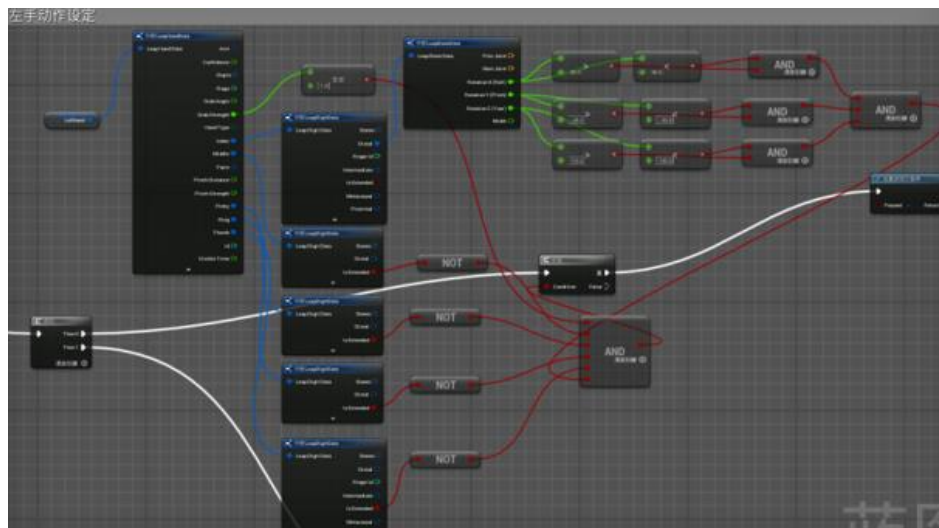
The gesture - interaction module is implemented with Blueprint - style programming. Using Leap Motion's API, it's integrated into Unreal Engine 5 for accurate hand - info capture, enabling specific finger - motion settings for left and right hands. Once the sensor detects hand data, it processes and splits the data of both hands, promoting them to separate variables for effective differentiation in later loops (as shown in Figure 6).



Source: Author created

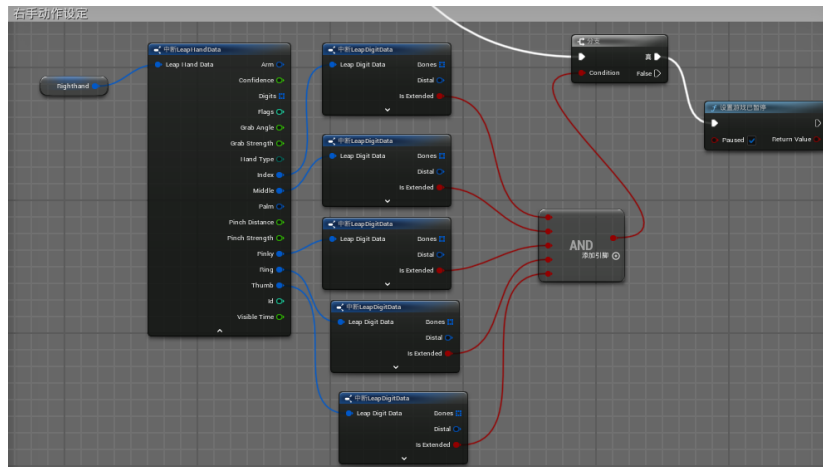
Figure 6. Class Blueprint for Distinguishing the Left and Right Hands of Participants

In the "Leap Motion controller" Blueprint of Unreal Engine, the "get hand data" node periodically extracts hand 3D coordinates, posture, and motion information from the sensor. After the "data processing" node parses the raw data, it extracts key parameters (such as palm position and finger joint angles). Leap Motion's "hand model" data structure can analyze the position and rotation of each phalanx of every finger (as shown in Figure 7 and 8). Based on the characteristics of TCM exercises, predefined gesture - judgment rules are established: a five - finger joint angle of less than 30 degrees indicates a fist, while an angle greater than 30 degrees indicates an extension. Subsequently, the "gesture recognition" node matches real - time data with preset features, for example, triggering a "clench" signal when the left - hand five - finger joint angle is less than 30 degrees. To improve recognition stability, a "gesture duration" parameter is introduced to filter out transient jitter interference. Finally, the "function execution" node maps gesture signals to interaction instructions: a fist triggers character movement, and an extension triggers a stop. This process achieves closed - loop control from data acquisition to functional response, ensuring precise gesture - to - virtual - operation conversion.



Source: Author created

Figure 7. Settings for the Movements of the Right Hand



Source: Author created

Figure 8. Settings for the Movements of the Left Hand

Character Control and Animation

In this study, the participant's role is set as a student with a lively - colored costume. To realize running, walking, and jumping, an animation Blueprint is added. Key - frame animations and the character skeleton are imported into Unreal Engine 5, a third - person Blueprint class and game mode are configured, and the mesh in the Blueprint class is set as the imported character skeleton. A capsule component, arrow component, skeletal mesh component, spring arm component, and follow - camera component are added in the viewport. To ensure smooth transitions between the three actions, a blend space is created, and a float variable is added to get the character's movement speed, with speeds of 0, 100, and 500 corresponding to standing, walking, and running, respectively. Finally, the blend - space player is called in the character animation Blueprint state machine to output the corresponding action animations. To reduce the learning curve for gesture control, mouse control is included as an essential attribute. Traditional mouse - control directions and keyboard - based up/down/left/right and WASD - key controls for character movement are retained. Meanwhile, Unreal Engine 5's enhanced input function is utilized to customize TCM finger - exercise gestures for character movement control (as shown in Figure 9).

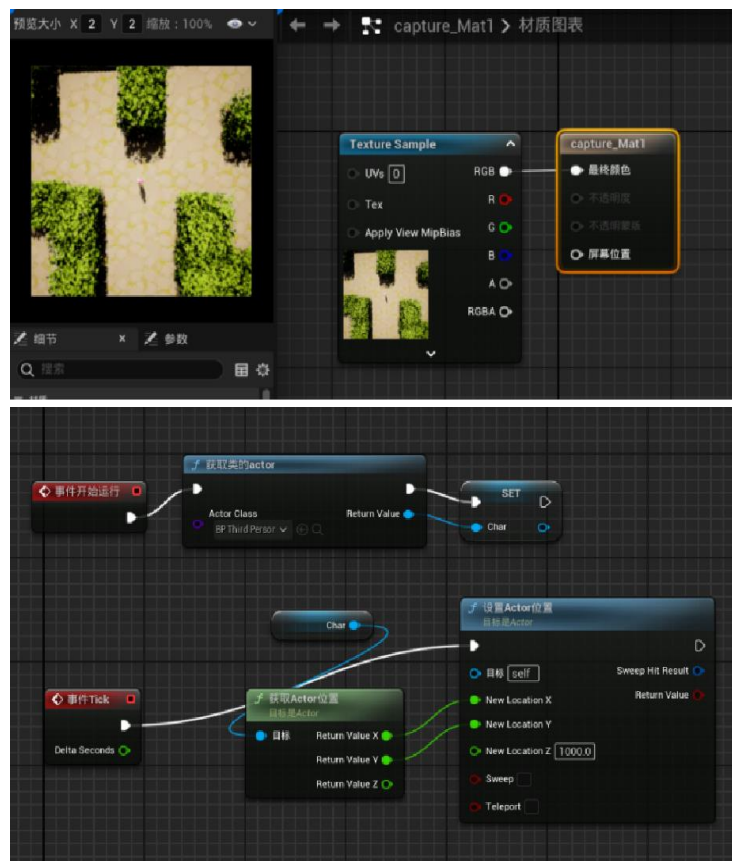


Source: Author created

Figure 9. Animation Blueprint for Character Movement

Implementation of Scenario-Specific Features

The real - time minimap in Unreal Engine relies on Actor - class Blueprints. Integrate a Scene Capture 2D component, set the camera to 90° orthographic projection for a top - down static view. Create a render target to map the captured scene image to a material, then bind this dynamic result to a UI component via the material editor for real - time minimap updates. Optimize spatial perception by precisely adjusting the capture camera's position and height based on the maze layout, and use the level Blueprint's logic module to synchronize the character's position with the map display (as shown in Figure 10).



Source: Author created

Figure 10. Blueprint Construction of Real-time Mini-map Function

The core logic of the herbal-collection task is done by multi-level tech collaboration. First, in the third-person character Blueprint, an integer variable is set to track remaining herbs, with a text-based user control dynamically converting the value to a visual element (e.g., "Remaining Herbs: 3/7") for real-time task-progress feedback. Then, a box-collision component is added to the herb model, and interaction scripts are written via the level Blueprint. When the character triggers a collision event with a finger-opposing gesture, the system automatically decreases the counter until it hits zero, activating the task-completion judgment. This design, coupling lightweight collision detection with gesture recognition, balances interaction efficiency and system performance.

The UI system is built with control Blueprints, covering design and functionality. The design module uses a drag-and-drop editor to integrate images, buttons ("Click to Start", "Instructions", "Exit"), and progress bars into a theme-fitting interface. The event graph encodes interaction logic through Blueprint nodes, like binding the "Start" button click to a level-jump function, the "Exit" button to a process-termination command, and the "Instructions" button to dynamic loading of the guide interface. With variable scripts and event-driven responses, user operations are precisely mapped to system functions, ensuring immediate and reliable interactions.

CONCLUSION

This study demonstrates the effectiveness of integrating Leap Motion with TCM finger exercises in enhancing cultural dissemination and health intervention. Gamified strategies improved immersion and learning efficiency, validating the "dynamic gesture-virtual scenario" coupling model. Future work may optimize gesture recognition and extend this framework to other traditional therapies, advancing TCM's innovative propagation.

REFERENCES

- Al-Timemy, A.H., Khushaba, R.N., Bugmann, G., & Escudero, J. (2016). Improving the performance against force variation of EMG controlled multifunctional upper-limb prostheses for transradial amputees. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 24(6), 650 – 661. <https://doi.org/10.1109/TNSRE.2015.2445634>
- Alimanova, M., Borambayeva, S., Kozhamzharova, D., Kurmangaiyeva, N., Ospanova, D., Tyulepberdinova, G., ... & Kassenkhan, A. (2017). Gamification of hand rehabilitation process using virtual reality tools: Using leap motion for hand rehabilitation. In *2017 First IEEE International Conference on Robotic Computing (IRC)* (pp. 336-339). IEEE. <https://doi.org/10.1109/IRC.2017.76>

- Ameur, S., Khalifa, A.B., & Bouhleb, M.S. (2016). A comprehensive leap motion database for hand gesture recognition. In 2016 7th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT) (pp. 514-519). IEEE. <https://doi.org/10.1109/SETIT.2016.7939924>
- Bachmann, D., Weichert, F., & Rinkenauer, G. (2018). Review of three-dimensional human-computer interaction with focus on the leap motion controller. *Sensors*, 18(7), 2194. <https://doi.org/10.3390/s18072194>
- Bellotti, F., Berta, R., De Gloria, A., D'ursi, A., & Fiore, V. (2013). A serious game model for cultural heritage. *Journal on Computing and Cultural Heritage (JOCCH)*, 5(4), 1-27. <https://doi.org/10.1145/2399180.2399185>
- Dichev, C., Dicheva, D., Angelova, G., & Agre, G. (2015). From gamification to gameful design and gameful experience in learning. *Cybernetics and Information Technologies*, 14(4), 80-100. <https://doi.org/10.1515/cait-2014-0007>
- Fernández-González, P., Carratalá-Tejada, M., Monge-Pereira, E., Collado-Vázquez, S., Sánchez-Herrera Baeza, P., Cuesta-Gómez, A., Oña-Simbaña, E. D., Jardón-Huete, A., Molina-Rueda, F., Balaguer-Bernaldo de Quirós, C., Miangolarra-Page, J.C., & Cano-de la Cuerda, R. (2019). Leap Motion controlled video game-based therapy for upper limb rehabilitation in patients with Parkinson's disease: a feasibility study. *Journal of NeuroEngineering and Rehabilitation*, 16, Article 133. <https://doi.org/10.1186/s12984-019-0593-x>
- Hsu, C.L., & Chen, M.C. (2018). How does gamification improve user experience? An empirical investigation on the antecedences and consequences of user experience and its mediating role. *Technological Forecasting and Social Change*, 132, 118-129. <https://doi.org/10.1016/j.techfore.2018.01.023>
- Han, D.Y., Ma, X., Xing, X.K., & Wang, Y.S. (2023). Effects of resistance training combined with finger exercise guidance on joint swelling and pain in patients with rheumatoid arthritis. *Medicine & Theory and Practice*, 36(17), 3038-3040. <https://doi.org/10.19381/j.issn.1001-7585.2023.17.060>
- Khademi, M., Mousavi Hondori, H., McKenzie, A., Dodakian, L., Lopes, C. V., & Cramer, S. C. (2014). Free-hand interaction with leap motion controller for stroke rehabilitation. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems* (pp. 1663-1668). <https://doi.org/10.1145/2559206.2581203>
- Kim, M.J., Heo, J.M., Kim, J.H., Park, S.Y., & Chang, J. (2014). Development and evaluation of Leapmotion-based game interface considering intuitive hand gestures. *Korean Society for Computer Game*, 27(4), 69-75. <https://www.dbpia.co.kr/pdf/cpViewer>
- Losa, M., Morone, G., Fusco, A., Castagnoli, M., Fusco, F.R., Pratesi, L., & Paolucci, S. (2015). Leap motion controlled videogame-based therapy for rehabilitation of elderly patients with subacute stroke: A feasibility pilot study. *Topics in Stroke Rehabilitation*, 22(4), 306-316. <https://doi.org/10.1179/1074935714Z.00000000036>
- Liarokapis, F., Petridis, P., Andrews, D., & de Freitas, S. (2017). Multimodal serious games technologies for cultural heritage. *Mixed Reality and Gamification for Cultural Heritage*, 371-392. https://doi.org/10.1007/978-3-319-49607-8_15
- Lu, W., Tong, Z., & Chu, J. (2016). Dynamic hand gesture recognition with leap motion controller. *IEEE Signal Processing Letters*, 23(9), 1188-1192. <https://doi.org/10.1109/LSP.2016.2590470>
- Marin, G., Dominio, F., & Zanuttigh, P. (2014). Hand gesture recognition with leap motion and kinect devices. In 2014 IEEE International Conference on Image Processing (ICIP) (pp. 1565-1569). IEEE. <https://doi.org/10.1109/ICIP.2014.7025313>
- Mortara, M., Catalano, C.E., Bellotti, F., Fiucci, G., Houry-Panchetti, M., & Petridis, P. (2014). Learning cultural heritage by serious games. *Journal of Cultural Heritage*, 15(3), 318-325. <https://doi.org/10.1016/j.culher.2013.04.004>
- Mou, X.Q., & Yu, D.S. (2023). How does the body become a medium? An analysis of game practices in e-fitness communities from the perspective of actor-network theory. *Xinwen Jizhe (Journalist)*, (7), 78 - 88, 100. <https://doi.org/10.16057/j.cnki.31-1171/g2.2023.07.008> [in Chinese].
- Mitgutsch, K., & Alvarado, N. (2012). Purposeful by design? A serious game design assessment framework. In *Proceedings of the International Conference on the Foundations of Digital Games* (pp. 121-128). <https://doi.org/10.1145/2282338.2282364>
- Norman, D. (2003). *The Design of Everyday Things*. CITIC Press. Retrieved from https://www.academia.edu/download/60393656/Ch1_The-Design-of-Everyday-Things20190825-87342-1wyevvu.pdf (accessed 18 February 2025).
- Pirker, J., Pojer, M., Holzinger, A., & Gütl, C. (2017). Gesture-based interactions in video games with the leap motion controller. In *International conference on human-computer interaction* (pp. 620-633). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-58071-5_47
- Sluÿters, A., Sellier, Q., Vanderdonckt, J., Parthiban, V., & Maes, P. (2023). Consistent, continuous, and customizable mid-air gesture interaction for browsing multimedia objects on large displays. *International Journal of Human - Computer Interaction*, 39(12), 2492-2523. <https://doi.org/10.1080/10447318.2022.2078464>
- Valentini, P.P., & Pezzuti, E. (2017). Accuracy in fingertip tracking using Leap Motion Controller for interactive virtual applications. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 11, 641 - 650. <https://doi.org/10.1007/s12008-016-0339-y>
- Wozniak, P., Vauderwange, O., Mandal, A., Javahiraly, N., & Curticapean, D. (2016). Possible applications of the LEAP motion controller for more interactive simulated experiments in augmented or virtual reality. In *Optics Education and Outreach IV* (Vol. 9946, pp. 234-245). SPIE. <https://doi.org/10.1117/12.2237673>
- Wang, Z.R., Wang, P., Xing, L., Mei, L.P., Zhao, J., & Zhang, T. (2017). Leap Motion-based virtual reality training for improving motor functional recovery of upper limbs and neural reorganization in subacute stroke patients. *Neural Regeneration Research*, 12(11), 1823-1831. <https://doi.org/10.4103/1673-5374.219043>

Zhang, Z.H. (2022). Serious games for cultural heritage learning: A discussion based on participation mechanisms. *Zhuangshi (Decoration)*, (5), 94 - 97. <https://doi.org/10.16272/j.cnki.cn11-1392/j.2022.05.024> [in Chinese].