Design of Children's Abacus Mental Calculation Mini-game Based on WeChat Mini Program from the Perspective of Human-computer Interaction

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Abstract: As an ancient and effective calculation tool, the abacus holds significant importance in the field of education. This research aims to integrate the abacus with computers, creating an electronic abacus. The traditional operation of moving beads up and down on the abacus is realized on the electronic abacus through human-computer interaction. The design of human-computer interaction enables more efficient and satisfying interaction experiences between users and the electronic abacus. Additionally, this research will combine computer graphics technology to develop an abacus simulation system, promoting the inheritance and development of the abacus. This represents a significant innovation in the ancient abacus, opening a new chapter in the history of Chinese abacus calculation.

Keywords: Electronic Abacus; Abacus; Software Development; WeChat Mini Program; Human-computer interaction

1. Introduction

1.1 Background

Abacus, known as "the world's oldest calculator", carries the wisdom of generations with its ability to perform calculations effortlessly. As a traditional form of folk knowledge and unique practice, abacus culture holds significant historical and humanistic value, passed down through the ages on the Chinese land. In 2013, Chinese abacus was inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity. [1]

Today, the international influence of abacus calculation is continuously increasing. According to incomplete statistics, there are at least 132 countries and regions worldwide engaged in various scales of abacus mental arithmetic education. Some abacus mental arithmetic educational institutions have promoted it to more than 100 countries and regions worldwide, and have built over 40 abacus culture museums (exhibition halls) around the world. [2]

1.2 The Benefits of Abacus

With the development of modern science and technology, the abacus is gradually fading out of practical use, while the derived mental arithmetic, known as soroban, is flourishing. [3] Long - term practice and theoretical research have shown that abacus- based mental calculation can improve people's computing ability, spatial ability, inductive reasoning ability, memory, attention, willpower, self-control, and has important cultural, scientific and educational values. Some researchers believe that through specific teaching practices, practicing mental arithmetic not only promotes children's computational abilities but also facilitates the development of other aspects of brain function and cognitive qualities. [4]

In today's era where research on the brain and mind occupies a strategically significant scientific field, mental arithmetic, particularly soroban, represents a distinct mental calculation skill, making the study of its neural mechanisms an important scientific inquiry. Numerous researchers both domestically and internationally have tirelessly explored this topic. Pioneering Japanese scientist Hatano utilized experimental methods to investigate the psychological mechanisms of soroban, discovering that soroban experts exhibit broader numerical memory compared to ordinary individuals. He speculated that soroban experts might rely more on visual-spatial representation strategies during

numerical working memory tasks, forming mental representations of abaci in their brains. Scholar Stigler from the University of Chicago confirmed through experiments that 11-year-old Chinese children, after undergoing soroban training, displayed enhanced mental calculation skills. Renowned scholar Miller found that prolonged soroban training can influence adults' spatial representation of quantities.

1.3 The Purpose of Game Design

The techniques of abacus calculation have accumulated cultural elements with Chinese characteristics. With the development of computers, the tangible abacus has continuously evolved into the intangible culture of abacus calculation. Therefore, we should utilize the vitality of online education via the internet and strive to find a path for the inheritance of abacus calculation that aligns with the internationalized era. By utilizing modern information technology, we can awaken the charm and appeal of abacus culture, producing content suitable for dissemination through emerging media such as the internet and mobile phones.

For this reason, our team has developed and designed a puzzle game based on abacus calculation. By developing this game, we aim to attract more people to take an interest in abacus calculation and to let children around the world understand and learn about the Chinese intangible cultural heritage of abacus techniques in an entertaining way. While promoting the dissemination of abacus culture, we also aim to help improve children's computational skills and mental agility.

1.4 Feasibility of Game Promotion

Relevant statistics show that China has a large population of mobile internet users, and using mobile phones for internet access has become a daily routine for most people.[4] In addition, data indicates that in 2017 alone, the user base for traditional cultural applications under the "Internet+" initiative in China reached 286 million people, with a growth rate of 56.8%. As traditional cultural products under the "Internet+" initiative continue to improve, the popularity among users will continue to rise, and the user base for traditional cultural applications under the "Internet+" initiative is expected to maintain a rapid growth momentum in the future. In the wave of economic globalization, culture is also moving towards globalization, and traditional cultural cultivation is receiving increasing attention from various sectors both domestically and internationally.[5] Although digital intangible cultural heritage (ICH) app products have emerged continuously with the popularization of mobile internet, they mainly focus on popularizing and promoting ICH knowledge and digital preservation. There is still significant room for improvement in user engagement and public benefit. [6] Therefore, the abacus puzzle game we designed can be considered a relatively novel addition to this field.

Furthermore, currently, foreign research on dynamic effects in interactive interfaces is relatively mature, and the design principles of dynamic effects in major design companies are gradually improving. It can be observed that dynamic effect research has become a current trend, but there is still a lack of understanding of how dynamic effect designs in interactive interfaces can better cater to the cognitive characteristics of children. [7]

In summary, the development of this game not only aligns with the trend of internet development but also caters to the current trend of digitalizing intangible cultural heritage platforms, thereby having certain significance for distribution and promotion.

2. System Architecture

The system is developed using JavaScript language and based on the WeChat Mini Program framework developed by Tencent.

The framework comprises two parts: the View layer and the App Service layer. The View layer is responsible for rendering the page structure, while the App Service layer handles logic processing, data requests, and interface calls, running on two separate threads.

The View layer uses WebView for rendering, and the logic layer runs on JSCore.

Communication between the View layer and the logic layer is facilitated through the system layer's JSBridge. The logic layer notifies data changes to the View layer, triggering page updates, while the View layer notifies triggered events to the logic layer for business processing.

The specific process is shown in Figure 1:

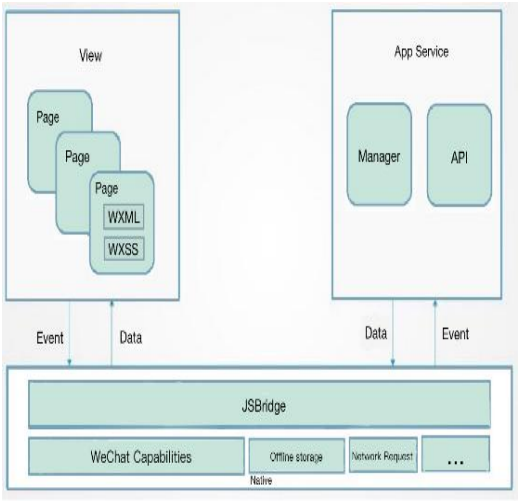

Figure 1. System Structure Diagram

3. Game Flow

The game consists of various stages in Figure 2:

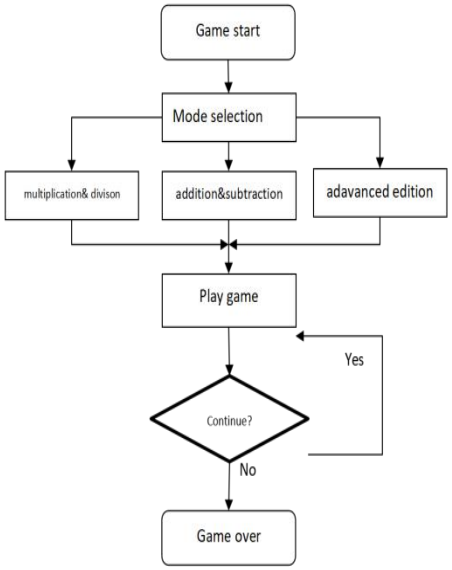

Figure 2. Game Flow Chart

3.1 Game Interface

The game features a unified main interface available in both English and Chinese versions to cater to different audience demographics. It offers three modes: addition & subtraction, multiplication & division, and advanced edition (a mix of both). Upon selecting a mode, the system randomly displays addition, subtraction, multiplication, or division problems on the screen. Players need to use the abacus to calculate the final answer and fill it into the designated gap to proceed to the next level.

The interface transitions between screens are achieved through click-to-jump events. The positions of the beads on the abacus are also determined by code, and the beads' upward and downward movements are implemented through click interactions. When the abacus is manipulated to calculate the correct answer and fill in the blank space, the game level automatically advances to the next stage.

The game interface diagram is shown in Figure 3 and Figure 4

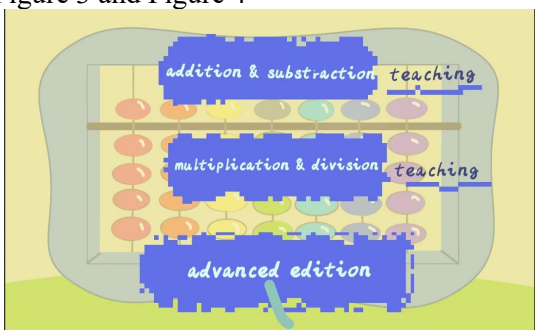

Figure 3. Main Interface of the Game

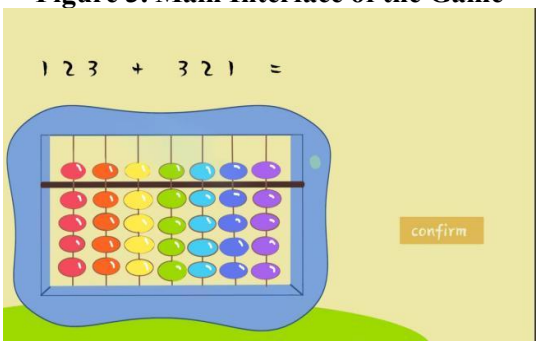

Figure 4. Game Level Interface

3.2 Game Levels

- Addition & Subtraction: Familiarizes players with basic abacus operations and algorithmic thinking using addition and subtraction rules.
- Multiplication & Division: Introduces higher difficulty levels involving multiplication and division, essential parts of using the abacus.
- Advanced Edition: Combines addition, subtraction, multiplication, and division, offering a comprehensive practice experience.

4. Key Technical Research

4.1 Abacus Formulation

In the abacus simulation system, we abstract the traditional abacus into a matrix structure and combine it with the principles of human-computer interaction design, enabling users to interact with the abacus through a graphical interface intuitively. The modeling of the abacus matrix will employ modern software development techniques to achieve

precise simulation of the abacus calculation process.

The traditional abacus is rectangular in shape, enclosed within a wooden frame, and consists of vertically aligned rods commonly referred to as "frames." Typically, it ranges from nine to fifteen frames. Each frame contains a horizontal beam with two beads above (each representing five units) and five beads below (each representing one unit). Calculation involves positioning and manipulating beads after locating them, allowing for various arithmetic operations such as addition, subtraction, multiplication, and division [8].

Modern abacus designs vary in shape and material. They are predominantly made of wood or plastic and feature a rectangular frame containing rows of beads aligned vertically. A horizontal beam divides the beads into upper and lower sections, commonly referred to as "frames", with typically 9, 11, or 13 frames. In each frame, there are two beads above the beam (each representing five units) and five beads below (each representing one unit) [8].

The abacus used in this program is also rectangular in shape. It is designed with seven frames to cater to both overseas and domestic children. Each frame contains a horizontal beam with a single bead above (representing five units) and four beads below (each representing one unit). This abacus simplifies the process of positioning and manipulating beads, making it more suitable for children to learn and use as beginners.

4.2 Abacus Modeling

In the abacus simulation system, we abstract the traditional abacus into a matrix structure and integrate human-computer interaction design principles, allowing users to interact with the abacus through a graphical interface intuitively. The modeling of the abacus matrix will utilize modern software development techniques to achieve precise simulation of the abacus calculation process.

Each row of the matrix represents a layer of beads on the abacus, where row 0 represents the beads in the upper deck position, and rows 1, 2, 3, and 4 represent the beads in the lower deck positions respectively.

We use 0 and 1 to represent the state of the beads, where 0 indicates that the bead has been moved down, and 1 indicates that the bead is in the initial position.

For beads in the upper deck position, the weight of 1 is 5, while for beads in the lower deck positions, the weight of 1 is 1.

To meet the constraints of abacus operations, we have established the following rules: beads in the upper deck position can only appear in row 1, and row 0 always remains 0; beads in the lower deck positions must have continuity between 0 and 1. This means that if a bead in the lower deck area is in the raised position, then all the beads above it must also be in the raised position.

Figure 5 illustrates the initial state of the abacus matrix. Through this matrix modeling method, we can accurately simulate the operation process of the traditional abacus in the computer and perform various mathematical calculations. [9]

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure5. Initial State of the Abacus Matrix

The weight vector for bead rows, B, is: B = [5 1 1 1 1]

The weight vector for bead columns, C, is: C = [100 101 102 … 1012] ^{T}

4.3 Key Technologies Applied

4.3.1 Human-computer interaction:

Human-computer interaction technology plays a crucial role in abacus simulation systems. Through human-computer interaction, users can interact with the system conveniently and efficiently, thereby better understanding and applying the principles of the abacus.

In system design, we have adopted an intuitive and user-friendly interface to ensure that users can easily navigate and enjoy using the system. The interface design takes into account user habits and psychological expectations, making the operation process natural and smooth. For example, we provide clear buttons and indicators so that users can easily understand the current operation status. We have also designed a concise and clear interaction process to ensure that users can quickly get started without feeling confused.

Additionally, we have implemented interactive

learning functions to help users gradually master the use of the abacus through guided operation prompts and real-time feedback. Users can choose different learning modes and difficulty levels based on their learning progress and needs to better improve their abacus skills. In terms of system implementation, we applied web front-end and WeChat mini-program development technologies to realize various functions. [10]

These design principles and technical means of human-computer interaction make our designed abacus simulation system a user-friendly and powerful learning tool, providing users with an efficient and enjoyable learning experience.

4.3.2 Computer graphics design

Computer graphics design plays a crucial role in the creation of the abacus simulation. Through computer graphics technology, we can achieve the drawing of the abacus interface and the dynamic display of bead states, presenting users with intuitive and vivid visual effects.

In system design, we have adopted modern graphics drawing techniques and rendering to ensure the beauty and smoothness of the system interface. We used “Draw World Pro” to realize the drawing and rendering of the abacus interface. With the "Draw World Pro" tool, we achieved efficient and rapid graphic processing, presenting users with a realistic and lifelike abacus simulation effect.

Additionally, we utilized the computer animation technology inherent in WeChat mini-program development to achieve dynamic changes and motion effects of beads on the abacus. Through reasonable animation design and interactive effects, users can clearly observe the state and calculation process of each bead on the abacus, thereby better understanding the working principle of the abacus.

In the process of system implementation, we referenced relevant computer graphics theories and techniques, such as graphic rendering, lighting effects, and texture mapping, as well as the usage methods and practical experience of modern graphics software, to ensure that the system can achieve the expected visual effects and user experience. [11]

Through the aforementioned computer graphics design, our abacus simulation graphics provide users with an intuitive and vivid learning tool, helping them better understand the principles and applications of the abacus.

4.3.3 Software development

During the development process of this system, we chose to develop based on the WeChat mini-program development platform to achieve a cross-platform, lightweight application. WeChat mini-program is a lightweight application development mode based on the WeChat platform, characterized by rapid development and convenient dissemination, which is very suitable for the abacus simulation system we designed.

We utilized the development tools and interfaces provided by WeChat mini-program to quickly build the front-end interface and interactive functions of the abacus simulation system. Through the development framework and APIs of WeChat mini-program, we can easily implement functions such as user interface design, event handling, and data transmission, and can smoothly realize data interaction and social sharing with the WeChat platform.

In terms of backend development, we utilized WeChat's cloud development and cloud storage services to build the backend services of the system. By using functions such as cloud functions and databases, we realized the storage and management of user data and the logical implementation of system functions.

Through software development based on WeChat mini-program, the abacus simulation system we designed can be quickly deployed and disseminated on the WeChat platform, providing users with a convenient and efficient learning tool. [12]

5. Game Promotion Direction

As mentioned earlier, this abacus puzzle game combines traditional intangible cultural heritage with the internet, aiming to inherit and develop abacus skills in the new era, while also providing a tool for intellectual development for children worldwide. Below, we will outline the directions for the continued promotion and development of the game from various aspects.

5.1 Enhancing User Experience

After launch, we will analyze user feedback and game data to continuously optimize the game's interface design, interaction flow, and

gameplay experience to improve the game's smoothness. Furthermore, continuously enriching the game content is also a future direction of our efforts. We will introduce more challenging and innovative abacus problem types, add special levels or challenge modes such as time-limited challenges, and ranking modes.

In commonly encountered games on the market, many utilize emotional engagement to retain users. By implementing reward systems, games effectively stimulate user participation, enhance user retention rates, and enable users to continuously receive intangible cultural heritage knowledge throughout extended gameplay. [13]

5.2 Strengthening the Educational Functionality

We will introduce an introduction to the history of abacus in the tutorial section and add new user guidance in different sections to enrich users' understanding of abacus while helping them learn and apply abacus skills systematically. Additionally, through surveys, we found that current abacus applications are mainly concentrated in the field of education. Therefore, we can consider cooperating with schools to develop special features for school education, such as teacher management systems and student answer analysis. By offering this game as an auxiliary tool for classroom teaching, we aim to promote the inheritance and development of abacus in the field of education.

5.3 Increasing the Social Interactivity of the Game

In the future, the game will consider introducing social features that allow users to collaborate or compete with friends or other players, thereby enhancing the game's social interaction and fun. Also, technology use in education and traditional game use separately could raise students' sociomathematical norms. [14] By displaying the highest records through leaderboards, we aim to stimulate users' competitive desires, increase their participation, and enhance user engagement.

5.4 Increasing Promotion Efforts

Intangible cultural heritage audiences are relatively niche in society. Existing small games featuring intangible cultural heritage often focus on specific aspects or regions of the heritage. While this approach allows for detailed showcasing of the heritage, it also fragments the already limited target audience into smaller groups, reducing the user base. This not only poses challenges for future operations but also limits the dissemination of the heritage, diminishing its overall impact. The size of the user base directly affects user experience. A small user count not only reduces the level of user interaction but also lowers the quality of user experience in terms of group identity and satisfaction. [15]

Currently, the game only supports two languages, Chinese and English. In the future, we will consider developing multilingual versions to facilitate users from different countries. Additionally, we hope to expand the game to other platforms such as app stores and web versions and utilize other social media for promotion to further broaden the game's influence and the dissemination of abacus skills. [16] For instance, we can provide real-time information through WeChat official accounts.

6. Conclusion

As a treasure of Chinese traditional culture, the abacus has always carried the mathematical wisdom of the Chinese nation since ancient times. Also, Abacus-based mental calculation (AMC) has been shown to be effective in promoting math ability in children cause the development of (early) numerical cognition builds on children's ability to understand and manipulate quantities and numbers. Despite efforts to protect and inherit abacus culture to a certain extent, the inheritance of intangible cultural heritage of abacus faces severe challenges and difficulties in the modern societal context. Effective measures need to be taken to actively promote the inheritance and development of abacus culture.

Currently, there are two main types of dissemination methods for intangible cultural heritage (ICH). One is the traditional way, which does not involve the internet. The other is digital dissemination, which has emerged with the advent of the internet and innovations in digital technology, leading to various novel dissemination methods. Games have the function of dissemination. By combining digitization with gaming, it can become an effective means of dissemination. Digital game

dissemination utilizes digital technology-based games as a medium to achieve participatory, immersive, and feedback-oriented effective dissemination.

This project aims to promote traditional Chinese abacus culture through a puzzle game based on WeChat Mini Program, providing stability and convenience. Its simple interface and abacus model make it easier for children to use. Compared with existing abacus mini-games, we aim to address the shortcomings of current intangible cultural heritage mini-games. Meanwhile, our minimalist and child-friendly design and content align with modern aesthetic preferences.

In the future, we hope to continuously upgrade the game based on user feedback and demands, increase the game's publicity, and fully leverage the advantages of intangible cultural heritage abacus. This will help promote the integration of abacus with other fields and further popularize the intangible cultural heritage of abacus.

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