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A Development of Electronic Scoring System for Artistic Gymnastics Competitions Based on International Gymnastics Rules and Regulations

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Abstract

Background and Aim: In China, artistic gymnastics is one of the traditionally advantageous programs in competitive sports, and it has long been in the leading position in the world. It is considered that the quality and objectivity of the refereeing work in gymnastics are a rather complex problem. Therefore, to solve this problem, it is necessary to improve the rules of the competition, the preparation of the referees, the principles of formation of the team of referees, the control of the work of the referees, and the use of technical equipment. This research aimed to develop an electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations.

Materials and Methods: This research was a mixed-methods research, the process followed by these steps: First, research documents related to the international gymnastics rules and the electronic scoring system for artistic gymnastics competitions were studied. Second, five experts were invited to conduct in-depth interviews to create a draft components and system flowchart of an electronic scoring system for competitive gymnastics competitions, providing valuable insight into the current state of gymnastics scoring. Third, 20 experts were invited to conduct a Delphi consensus to screen the core indicators for the development of the electronic scoring system. In this step, an electronic scoring system for artistic gymnastics competitions was developed. Finally, nine experts were invited to confirm and improve the developed electronic scoring system for artistic gymnastics competitions through the connoisseurship method. This research used mean, standard deviation, median, and interquartile range to analyze the data. The criteria were median ≥ 3.50 and interquartile range ≤ 1.50.

Results: The results found that the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations comprised three first-level indicators: (1) Electronic scoring system user interface; (2) Scoring modules and data processing; and (3) Data transmission. Additionally, the system incorporates 20 second-level indicators to support these key components, ensuring a comprehensive and efficient scoring process tailored to meet international standards.

Conclusion: The electronic scoring system for artistic gymnastic competition responded to the rules and regulations of artistic gymnastics, was appropriate, practical, and acceptable among the users who were referees.

Keywords: Artistic Gymnastics; Electronic Scoring System; International Gymnastics Rules and Regulations

Introduction

Entering the new era, the rapid development of human information civilization, big data, artificial intelligence, information technology integration, and other lifestyles are becoming more and more diversified, and information technology equipment is changing our way of life. In recent years, the development of sports digital integration has been in full swing, and sports competition, venue management, sports medicine, and rehabilitation are continuing to promote industrial development model innovation, for "sports +" to explore more possibilities. General Secretary Xi Jinping in accelerating the construction of a strong sports country, an important discussion put forward, by 2035, to realize the modernization of the new pattern of sports development, improve the comprehensive strength of competitive sports, competitive sports to better, faster, higher, stronger, and enhance the ability to compete for the country. The text indicates the direction of modernization of competitive sports in the new era and the establishment of a modern competition system with Chinese characteristics. Promote the reform of the competition system, establish a sports competition system that adapts to the socialist market economy, conforms to the laws of modern sports, and is in line with international standards, and build a pyramid-type sports competition system with multi-sectoral cooperation and participation of multiple subjects. (Xi, 2019). China's Education Modernization 2035 mentions accelerating the modernization of education, building a strong education

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nation, focusing on improving the quality of education, and accelerating the transformation of education in the age of information technology. (China Education Center, 2024). Moreover, the State General Administration of Sports issued "the 14th Five-Year Plan for Sports Development", which explicitly proposes to promote the optimization of the structure of the sports industry and the high-quality development of sports undertakings and the sports industry using digital transformation and reform, to adapt to the practical requirements of the rapid development of information technology-assisted sports in various fields. Fourteenth. (General Administration of Sport of China, 2021).

The above policies were of great significance in guiding the development of Artistic Gymnastics, leading to the reform of the competition system, the establishment of a sports competition system that adapts to the socialist market economy conforms to the laws of modern sports and is in line with international standards, and the construction of a pyramid-type sports competition system with multi-sectoral cooperation and participation of multiple subjects. Artistic Gymnastics development, looking at the development of ideas, the need for top-level thinking ahead of the layout of the sports program, and gymnastics events as a "fulcrum", to promote the development of the Artistic Gymnastics program. Cross-view draws on the integration attributes of the development of the various programs of competitive sports and the development of the continued empowerment of gymnastics. Further, promotes the development and construction of Artistic Gymnastics competitions and gymnastics informatization. In Artistic Gymnastics competitions, to scientifically carry of the electronic scoring system is the core of this study. In China, artistic gymnastics is one of the traditionally advantageous programs in competitive sports, and it has long been in the leading position in the world. Since the 1984 Olympic Games, Artistic Gymnastics has won a total of 28 gold medals in the Olympic Games (Chinese Gymnastics Association, 2021).

In artistic gymnastics, the International Scoring Rules for Gymnastics are issued by the FIG for international competition and the promotion of gymnastics and apply to the Olympic Games, Youth Olympic Games, World Championships, Regional or Intercontinental competitions, and events with international participation (Zhao, 2020). In gymnastics, the referee is as important a subject on the field as the athletes and coaches. The referee team consists of the referee, recorder, supporting referees, etc. Different positions have different duties to fulfill to ensure the smooth running of the game. (Jiang, 2022).

As mentioned above, it is considered that the quality and objectivity of the refereeing work in gymnastics, as a subjectively determined scoring program based on the rules, and the results of its competitions in all types of sports, is a rather complex problem (Viner et al, 2003). To solve this problem, it is necessary to improve the rules of the competition, the preparation of the referees, the principles of formation of the team of referees, the control of the work of the referees, and the use of technical equipment (Wang, 2014) The design of scoring for artistic gymnastics programs, the application of system communication, and the scoring system for youth and children's gymnastics competitions have been studied. However, due to the continuous development and upgrading of gymnastics rules, it is no longer suitable for the application of the current rules.

Based on the requirements for the realization of multiple values in sports development in the new era, it has become a development trend to promote the reform of the competition system of competitive sports. In the process of the continuous development of artistic gymnastics, with the continuous changes in the rules of the competition, the way of judging work and scoring means. In the context of the transformation of sports informionization in the new era, the development of artistic gymnastics events needs to keep pace with the times, stand in the perspective of the competition, and promote its innovation and development from the top-level design thinking, from the fundamental, global and deep-level perspective (Guo, 2020).

The researcher is pursuing a doctoral program in physical education and understanding of the International Gymnastics Rules and the pattern of play in artistic gymnastics competitions in the new period of rule development, the methods of constructing the electronic scoring system construction, as well as covering most of the factors related to the electronic scoring system of gymnastic competitions. Therefore, this research aims to construct an electronic scoring system for artistic gymnastics competitions based on

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international gymnastics rules and regulations, to improve the accuracy and efficiency of scoring, and enhance the transparency and fairness of competitions. Due to limitations in time and financial resources, this research focuses specifically on developing an electronic scoring system for artistic gymnastics competitions in Guangdong Province, adhering to international gymnastics rules. The study targets referees in Guangdong Province as its primary subjects. The findings aim to facilitate the broader adoption of electronic scoring systems in gymnastics competitions, enhancing refereeing efficiency across various levels. Moreover, it aspires to inspire further scholarly work to refine and expand on this framework, ultimately contributing to the standardization and modernization of scoring systems in gymnastics.

Objectives

1. To construct the electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations.
2. To develop a standardized structure and indicators of the electronic scoring system for artistic gymnastics competitions and collect the optimal design path of the system.
3. To confirm the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations.

Literature review

1. Current Development of Artistic Gymnastics

1.1 Current Status of Artistic Gymnastics Competition System

In China, gymnastics has developed so far, started in 1980 when Huang Yubin won the first Rings world championship at the Artistic Gymnastics World Cup in Toronto; then in 2008, the Chinese gymnastics team won both the men's team and women's team championships; the 2016 Rio Olympics ended without gold; and the 2020 Tokyo Olympics in Japan, where Chinese athletes Zou Jingyuan, Liu Yang, and Guan Chenchen won the Parallel Bars, the Rings, and the Balance Beam, respectively. Artistic Gymnastics has gone through different stages, and to promote the reform and development of gymnastics in the future, it is necessary to keep abreast of the current situation and hot trends of gymnastics research, grasp the latest developments of the world's artistic gymnastics program, and judge the future development trend. For the current Olympic cycle, by the international rules of gymnastics established by the Fédération International de Gymnastic (FIG), Gymnastics competitions are divided into men's and women's divisions, and the competition can be divided into four phases, there are four stages of competition: qualifying, team final, individual all-around final, and individual singles final. The program specifies that the order of competition will be in order of qualification, team finals, individual all-around finals, and individual singles finals. In the competition, the athletes complete different difficult movements on the prescribed equipment, and strive to complete difficult and wonderful movements, while at the same time focusing on displaying the beauty of the movement and the beauty of the human body. Therefore, the continuous improvement of the international gymnastics competition system brings opportunities for the innovation of Artistic Gymnastics in China. Coaches who correctly understand and successfully utilize the competition rules can take the lead in the competition and master the golden key to win the competition (Huang, 2018)

Zhang and Zhong (2017) highlight the advantages of using electronic scoring systems in gymnastics competitions. These systems automate the process of data entry and result tabulation, reducing human error, especially in multi-event or simultaneous competitions. By streamlining score verification, electronic systems ensure faster and more accurate results, which are crucial for athletes, organizers, and audiences. This also prevents potential biases that can arise from manual scoring and eliminates subjective interference, enhancing fairness and transparency. Ultimately, the adoption of electronic systems allows for quicker publication of results and ensures reliable, accurate outcomes.

1.2. Components of Scoring for Artistic Gymnastics Competitions

After World War II, sports interaction activities as one of the effective tools to strengthen the friendship and understanding of countries, the development of the scoring method of artistic gymnastics

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program to date, also experienced a different period of development and evolution and gradually improved the refinement of the promotion of fairness, justice, openness, and more unity of the development of the gymnastic competition (Yu, 2002). The components of scoring for artistic gymnastics competitions are as follows:

1.2.1 Difficulty Score (D-Score): The D-score reflects the level of difficulty of a gymnast's routine, determined by the difficulty of individual elements and the connection bonuses between them. Each element in the Code of Points has a designated difficulty value, and the sum of the top eight highest-scoring elements (or ten in some categories) contributes to the D-score. Connection bonuses reward gymnasts for linking high-difficulty elements seamlessly. This component ensures that routines emphasize technical complexity and creativity (FIG, 2022).

1.2.2 Execution Score (E-Score): The E-score evaluates the gymnast's execution, artistry, and performance. Starting at a perfect score of 10, deductions are made for errors such as lack of precision, improper form, or steps during landings. This scoring component is subjective and heavily relies on judges' expertise to assess the overall quality and aesthetics of the routine. Emphasis is placed on grace, control, and adherence to the stylistic requirements of each apparatus (Hiley & Yeadon, 2016).

1.2.3 Artistry and Presentation: Particularly relevant in women's artistic gymnastics (WAG) and floor routines, artistry includes elements like choreography, musical interpretation, and the gymnast's ability to engage the audience. Judges consider the fluidity of transitions, expression, and alignment with the character of the routine. The artistry deductions are applied if routines appear mechanical, overly rushed, or lack originality (Loveridge & Kotian, 2019).

1.2.4 Penalties and Neutral Deductions: Neutral deductions are taken for violations unrelated to technical execution, such as stepping out of bounds, exceeding time limits, or incorrect attire. These penalties are subtracted directly from the final score and serve as an incentive for gymnasts to adhere strictly to competition regulations (FIG, 2022). For example, stepping outside the designated floor exercise area results in a 0.1 deduction for each violation.

1.2.5 Final Score Calculation: The gymnast's final score combines the D-score and the E-score, with any neutral deductions applied afterward. The system ensures a balance between technical difficulty and execution quality, promoting routines that are both challenging and well-performed. Advances in electronic scoring systems have improved accuracy and transparency in calculating these scores, fostering consistency in international competitions (Bradshaw et al., 2012).

2. Design Principles of the Electronic Scoring System

The selection of a scientific and effective indicator system is the basis and key to the establishment of an electronic scoring system for evaluation and scoring. This is because the validity of the indicators directly determines the quality and outcome of the construction of the electronic scoring system. Designing the electronic scoring system for gymnastics involves integrating various hardware and software components to accurately judge the performance of gymnasts in the competition with precision, colleges, and universities. The construction of the electronic scoring system for Artistic Gymnastics, as well as the design ideas, are mainly based on the international gymnastic scoring rules and electronic scoring characteristics attributes. The scoring structure of the gymnastics program is meticulous and rich in layers, and multiple scoring modules together form a Final Score. Therefore, based on the rules, combined with the actual Artistic Gymnastics competitions, combined with the characteristics of information technology, the following principles are proposed among a large number of indicators: practicality, accuracy, comprehensiveness, compatibility, training and support, data security and privacy protection of the indicator system (Stallings and Brown, 2020).

2.1. Principle of Practicality. A user-centered design that prioritizes the needs and expectations of the end-users (including arbitrators, referees, and athletes, as well as participants and spectators) should always be achieved in the system-building study. The electronic scoring system should be intuitive and user-friendly, firstly, with a clear and direct interface for inputting and viewing scores as the referees perform their judging work. Secondly, it should provide coaches and athletes, as well as participants and

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spectators, with clearly visible scoring data, so that coaches and athletes have a clear understanding of the scores of the competition. Thirdly, the audience should be able to fully understand the real-time status of the game to increase the audience's participation in the game.

2.2. Principle of Accuracy. In the context of a gymnastics rules-based approach to all aspects of running a competition in linked gymnastics, the system shall ensure that the system provides accurate and precise scoring. Minimize the risk of errors by preventing incorrect inputs through reasonable validation, checks, and safeguards. And have usability testing to gather feedback and identify areas for improvement. Iterate the design based on user input to enhance the user experience.

2.3. Principle of Comprehensiveness. Based on the four-year cycle of rule modification and improvement of the International Gymnastics Scoring Rules, the system should be constructed to adapt to the ever-changing needs of gymnastics development. Gymnastics rules, assessment standards, and competition formats may be updated and changed over time, and the scoring system should adapt to these changes. The build development should take into account that tools for analyzing and reporting scoring data are available. The system should benefit from detailed statistics and insights that can be continuously refined to improve the system's mode of operation (Westerman, 2022)

2.4. Compatibility Principle. We have to consider the compatibility of the system, the scoring system can be integrated with other technical components, for example, as the scoring system is continuously improved upgraded, and iterated, in the future, it should have the ability to be compatible with the registration system, timekeeping system, arbitration monitoring and video recording, video replay, screen display in the competition venues, and data analysis and other tools. So that users (arbitrators, referees, coaches, athletes, technical officials) as well as participants (TV media, broadcasters, sponsors, etc.) and spectators are kept informed throughout the entire tournament, seamless integration enhances the overall event experience.

2.5. Training and Support. Once the system is built and matured, the training and support resource function module should be improved to help users understand how to use the scoring system effectively. Reduce user errors with clear documentation and training materials. And planned, organized, and targeted pre-match referee pre-service training. At the same time, different competitions may have unique requirements, so the system should support customization to accommodate different situations and allow flexibility in scoring rules and criteria.

2.6. Data Security and Privacy Protection Principle. In the construction of a scoring system for the Artistic Gymnastics competition, whether the system is safe and reliable should be taken into consideration to guarantee the normal and smooth progress of the competition. The data security theme is reflected in several aspects: first, data security in the scoring process, standardizing the scoring work mode, scoring data protection, and preventing human tampering with data. Secondly, improve the relevant network construction, as well as data backup, to ensure that scoring can be carried out uninterruptedly even when there are technical failures or network problems. Also, improve scoring data security measures to protect scoring data from unauthorized access, manipulation, or destruction. Comply with relevant data privacy regulations, especially when handling personal information.

2.7. Main Functional Modules of the E-Scoring System. This study is based on many years of participation and organization of various competitions and activities in the process of the summed up experience, according to a variety of competition processes, scoring rules, and competition needs, and for the gymnastics competition mode of running competitions, competitions, competition items set up several items, the number of judges involved in the number of referees, refereeing positions more than one of the characteristics of the detailed and serious investigation and analysis, access to relevant information, planning and design of the system's overall framework, functional modules and the back-end support database (Schneiderman and Plaisant, 2010).

3. The Necessity of Constructing an Electronic Scoring System in Artistic Gymnastics Competition

Wang (2014) proposed that there are many disadvantages of relying on manual entry and processing of results due to the characteristics of gymnastics competitions with many events, complex processing of

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results, and real-time requirements for results processing. Xiong et al. (2023) believe that compared with traditional sports competitions, digitalization provides new kinetic energy for sports competitions, which can optimize the allocation of resources, promote the transformation of inputs and outputs, and broaden the industrial form, thus significantly improving the efficiency of the industry. Jiang (2022) suggests that with the rapid development of Internet technology, referee scoring makes extensive use of modern information technology to meet the development needs of social sports events. In traditional gymnastics competitions, the judges' scoring is judged mainly through the athletes' live competitions, based on the rules. Manual judging work mode, manual entry, and other means are used. Due to the manual scoring by the referee, forwarded to the scheduling team for entry, which means to enter the results, results, and results. In Artistic Gymnastics, there are many competitions, and the score composition module is meticulous because there are many manual entry links, and the operation process is prone to errors.

In Xu, (2021) discussion on the construction of electronic scoring systems for gymnastics competitions, the focus is placed on creating a system that is efficient, accurate, and stable. The system is carefully aligned with the specific requirements of gymnastics competitions and their established rules. A key principle in the system's design is the user-first approach, ensuring that the system is intuitive and user-friendly. Xu emphasizes the use of a modular design to allow various components of the system to function cohesively, which aligns with the goals of the software life cycle process. This ensures that the system is not only functional but also enhances user experience, optimizing both performance and usability during gymnastics events.

The development process of the electronic scoring system, as outlined by Xu et al. (2019), follows a structured software development life cycle to ensure reliability and functionality in gymnastics competitions. This process includes stages such as feasibility study, planning, requirements analysis, design (both outline and detailed), implementation, testing, validation, and maintenance. Each phase aims to improve the system's reliability, ensuring it operates effectively during events. By adhering to this approach, the system achieves high-quality development, minimizing errors and biases in scoring while supporting its long-term use in competitions. The system's focus on reliability and user satisfaction helps streamline the judging process, providing a more efficient and accurate evaluation method.

Heiniger and Mercier (2018) found that, although under the current judging system, referees cannot judge athletes of the same nationality in apparatus finals, ethnic bias favors neighboring, political, ethical, or politically identical or similar countries. Religious structures may still exist. Leskošek et al. (2012) argued that one of the biggest factors influencing individual preferences is national bias, which tends to be present in the judging process, especially in large international competitions.

In Artistic Gymnastics, the referees judge the athletes through the live competition, according to the rules. In recent years, with the popularization and development of Artistic Gymnastics, the number of participants in gymnastics competitions has been steadily increasing, showing a growing trend. This also puts higher and higher demands on the accuracy and efficiency of the judging of gymnastics competition organizing. In the context of the new era, with the continuous integration of sports informatization and sports competitions, the use of electronic scoring systems in sports competitions has gradually become the norm. Recall that the emergence of a series of problems in the traditional gymnastics scoring method has made the traditional gymnastics scoring method has been difficult to provide the best quality service for the development of gymnastics competitions, out of touch with the development of the new era, seriously affecting the construction of a strong sports country, the high quality of Artistic Gymnastics competitions run. In the gymnastics competition, the referee scoring is based on the athletes' on-site performance, and the athletes are given fair, just, and open scoring based on the difficulty score of the sets of movements of each event, the choreography score, the connecting bonus or error deduction and the completion of the scoring, and so on. Artistic Gymnastics competition is necessary with the integration of digitalization, information technology development, big data computing technology, regional networks, 5G technology, etc. applied to competitive gymnastics competitions, based on the rules of gymnastics scoring logic, scoring path, from the scientific and efficient, practical and convenient, and accurate and open point of view,

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electronic scoring of gymnastics competitions for the construction of a systematic study for the gymnastic "basic sports "The study is based on the scoring logic and scoring path of gymnastic rules (Tu, 2021).

Summary of Review Literature

Artistic gymnastics in China has experienced remarkable growth, marked by significant achievements and challenges. Since Huang Yubin's 1980 world championship in the Rings event, milestones such as the 2008 Olympic team victories and individual successes at the 2020 Tokyo Olympics reflect the sport's evolution. The competition system, governed by the Fédération International de Gymnastic (FIG), includes stages such as qualifications, team finals, individual all-around, and apparatus finals. Scoring emphasizes technical difficulty, execution, and artistry, rewarding gymnasts for seamless, creative routines. As the international competition system evolves, it presents opportunities for China to innovate and refine its approach, leveraging a deep understanding of rules to gain a competitive edge.

Scoring in artistic gymnastics integrates components like the Difficulty Score (D-score), Execution Score (E-score), and deductions for violations to ensure fairness and transparency. The D-score highlights the technical complexity of routines, while the E-score evaluates execution quality and aesthetics. Neutral deductions ensure adherence to competition regulations, creating a balanced system that values creativity and precision. Advancements in electronic scoring systems have further enhanced accuracy and fairness. These developments underscore the necessity of aligning with modern scoring standards, paving the way for a technologically integrated future in gymnastics competition management.

Conceptual Framework

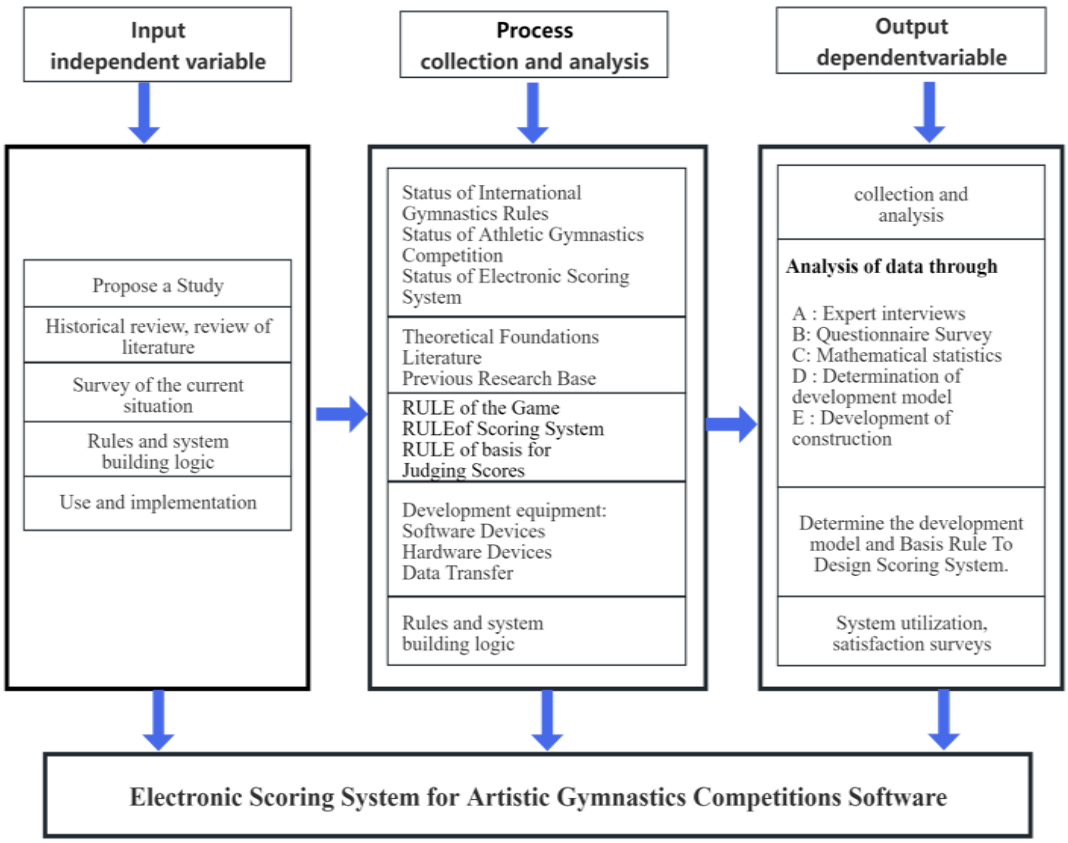

Figure 1 Conceptual Framework

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Methodology

1. Research Tools: The research in this study is as follows: (1) An in-depth interview form was used to collect expert opinions and suggestions from 5 experts on the current situation of the artistic gymnastics scoring system and the indicators for developing the electronic scoring system for artistic gymnastics competitions. (2) Questionnaires for Delphi were used to collect expert consensus on developing the electronic scoring system for artistic gymnastics competitions. (3) A connoisseurship expert's interview form was used to collect stakeholders' opinions to confirm the developed electronic scoring system for artistic gymnastics competitions.

2. Participants: The research participants were divided into four groups as follows: (1) Five experts were invited to evaluate the in-depth interview form and the questionnaires for Delphi using the Index of Item Objective Congruence (IOC), to evaluate the consistency of the question list with the objectives. (2) Five experts, consisting of international referees, national gymnastics coaches, computer specialists, and directors of university gymnastics faculty, were invited to participate in in-depth interviews to build a draft model of an electronic scoring system for competitive gymnastics competitions and provide valuable insight into the current state of gymnastics scoring. (3) Twenty experts, including seven international and national referees, five university experts with extensive gymnastics experience, three gymnastics competition experts, three competition schedulers, and two computer experts, were invited to conduct a Delphi consensus to screen the core indicators for the construction of an electronic scoring system for artistic gymnastics competitions. (4) Nine experts, including international referees, professional experts from the University of Physical Education and Sport, and experts in the organization of competitions, were invited to confirm and improve the developed electronic scoring system for artistic gymnastics competitions through the connoisseurship method.

3. Data Collection; (1) Studied the literature and research related to the international gymnastics rules and the electronic scoring system for artistic gymnastics competitions to gather foundational information for drafting questions for expert interviews. (2) In- depth interviews with five experts to investigate the current situation of the artistic gymnastics scoring system and the key indicators for developing the electronic scoring system for artistic gymnastics competitions. (3) 20 experts were invited to conduct two rounds of Delphi consensus to develop the electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations. (4) Nine experts were invited to confirm and improve the developed electronic scoring system for artistic gymnastics competitions using the connoisseurship method.

4. Data Analysis: The collected data were mainly analyzed using a software package. (1) The expert interview was analyzed using content analysis. (2) Delphi consensus was analyzed using median and interquartile range. The criteria specified are as follows: Median ≥ 3.50 and IQR ≤ 1.50. (3) Connoisseurship was analyzed by content analysis. (4) The evaluation criteria were in the form of a rating scale with 5 levels according to the Likert method, the evaluation criteria being interpreted as follows:

Table 1 Likert 5-level rating scale evaluation criteria

Average Score	Interpretation
5	Strongly agree
4	Quite agree
3	Neutral/fair
2	Disagree
1	Strongly disagree

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Results

The researcher followed these steps and presented the research results as follows:

Part 1: Five experts were invited to conduct in-depth interviews to collect feedback on the open construction of the international gymnastics rules combined with the electronic scoring system.

Part 2: The Delphi consensus collected feedback results from 20 experts in two rounds.

Part 3: Nine experts in connoisseurship confirm the results of the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations.

Part 1: Five experts were invited to conduct in-depth interviews to collect feedback on the open construction of the international gymnastics rules combined with the electronic scoring system.

To understand the current status of the electronic scoring system for gymnastics competitions in Guangdong Province. Five experts were invited to interviews and addressed key modules, metrics, and frameworks in the development of electronic scoring systems for artistic gymnastics competitions. The following questions were put to the experts for an interview:

1. How do you think we use an electronic device in a gymnastics judge?
2. Components of Judge D's decision in electronic scoring: What details should be included?
3. Components of Judge E's decision in electronic scoring: What details should be included?
4. What components should be put in the software application of gymnastic judgment?
5. What are the main judging modes currently used in competitive gymnastics competitions?
6. What do you think are the advantages and disadvantages of the current traditional, manual judging mode for competitive gymnastics competitions?
7. How to improve the judging efficiency of judges in competitive gymnastics competitions, and what aspects should be prioritized?
8. What are the main standard structures and indicators for constructing an electronic scoring system for competitive gymnastics?
9. What are the main factors affecting the scoring efficiency of competitive gymnastics competitions?
10. How to choose the operation mode of the electronic scoring system in competitive gymnastics competitions?

The expert's interview results found that the current rule-based judging model for artistic gymnastics competitions uses a D-score and E-score-based scoring model. The use of an electronic scoring system in gymnastics competitions could realize the synergy between sports and technology, help referees score more accurately, reduce human errors, improve the efficiency and quality of competitions, and make competitions fairer and more equitable. When it comes to judging by human referees, subjective factors can influence their decisions. Referees might allow their personal preferences or interests to affect their evaluations, making it challenging to achieve a fully standardized and consistent judgment across all participants. There is also the phenomenon of exchanging opinions, artificially changing scores, and altering rankings, which indirectly affects the rankings of matches. At the same time, the process of counting grades involves a large number of people, and speed and accuracy are affected by the potential for human error. Despite significant advancements, the manual judging system has been developed and standardized over many years, particularly in handling tasks such as organizing match schedules and editing the order of appearances, which electronic systems cannot yet fully replace. Additionally, manual judging offers flexibility, allowing referees to make timely adjustments in response to unforeseen circumstances, a characteristic that remains challenging for automated systems to replicate.

The development of an artistic gymnastics electronic scoring system should include software, hardware, and a network. The software package includes a competition scoring system (a) input scores; (b) calculating scores; (c) displaying scores; (d) competition results processing system, (post-competition compilation of results, statistical data), competition video processing, (viewing and playback functions), and judges' terminals (editing competition modes). The hardware package includes a scoring tablet, a computer, and an LED display. The transmission connection includes network connection, data

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transmission, and sharing. Therefore, to improve the judging efficiency of the referees in the game, fairness, impartiality, and openness are the primary conditions while guaranteeing the efficiency of the game, the development of the system should be attention to the clear division of labor in each module, simple, intuitive and easy to operate and realize the openness of information, and through the standardized judging workflow and judging standards, it is clear that the duties and responsibilities of each referee are divided, to improve the efficiency of judging.

The main factors affecting the efficiency of electronic scoring are the organization of the competition, the venue, the competence of the referee in business law, the stability of the system network, the working mode of the scoring process, and how the scores are displayed. The standard structure of the system construction should be in line with the competition rules, including rules, referee operations, athlete information, competition information, and performance data, to ensure the science, fairness, and practicality of the electronic scoring system. The standard indicators should be accurate, reliable, real-time, fair, and easy to use. People-oriented, electronic scoring is an aid to ensure the quality of the competition. It should ensure the smooth operation of the system, stability, clear composition of each score, and guarantee the accuracy of the data of the competition. For large-scale international competitions of the Olympic Games, a fully functional, reliable, and safe mode of operation should be selected. For large domestic competitions, a combination of centralized and distributed operation modes can be used to guarantee efficient and accurate scoring. Smaller competitions may use an operating mode that completes all scoring operations on a single computer and focuses on display effects.

Part 2: The Delphi Consensus collected feedback results from 20 experts in two rounds.

In this research, 20 experts participated in the survey, fulfilling the basic requirements of the modified Delphi method. The researcher used questionnaires for data collection. To ensure the validity and reliability of the data collected in the Delphi method, the questionnaire was evaluated by 5 experts, with an IOC value of 0.96. After the first and second rounds of the Modified Delphi consensus, the results were as follows:

Table 2 The results of the first and second rounds of the Delphi consensus (N=20)

First-level indicator	Second level indicators	First round		Second round		Result
		Mdn.	IQR	Mdn.	IQR	
Electronic scoring system user interface	1. The standard structure of the electronic scoring system should be built according to the International Gymnastics Rules.	5.00	0.00	5.00	0.00	Retain
	2. The standard structure of the electronic scoring system should be established by the Gymnastics Competition.	5.00	0.00	5.00	0.00	
	3. The technicians who develop and build the system should be familiar with the international rules of gymnastics.	5.00	0.00	5.00	0.00	Retain
	4. Security of the Electronic Scoring System?	5.00	0.00	5.00	0.00	
	5. Stability of the Electronic-Scoring System?	5.00	0.00	5.00	0.00	Retain
	6. Accuracy of the Electronic-Scoring System?	5.00	0.00	5.00	0.00	
	7. The simplicity of the Electronic Scoring System?	5.00	1.00	5.00	1.00	Retain

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First-level indicator	Second level indicators	First round		Second round		Result
		Mdn.	IQR	Mdn.	IQR	
	8. Clear operating guidelines for the user interface?	5.00	1.00	5.00	1.00	
Scoring modules and data processing	9. The scoring module of the user interface shall have the function of entering scores and displaying scores.	5.00	0.00	5.00	0.00	Retain
	10. The scoring module of the user interface should have the function of calculating scores automatically.	5.00	0.00	5.00	0.00	
	11. The software should have video post-editing and downloading functions.	5.00	1.00	5.00	1.00	Retain
	12. The software should have statistical data in terms of data processing.	5.00	0.00	5.00	0.00	
	13. The software shall have the ranking of the competition results in terms of data processing.	5.00	0.00	5.00	0.00	Retain
	14. Uploading of documents such as rules of the game, competition arrangements, appearance bye-bye, etc., at the data terminal?	5.00	0.25	5.00	0.25	
	15. Upload the result book in the data terminal.	5.00	1.00	5.00	1.00	Retain
	16. Set up the function of competition mode in the data terminal.	5.00	1.00	5.00	1.00	
Data transmission	17. Information data transmission, able to connect to the IPAD function?	5.00	0.25	5.00	0.25	Retain
	18. Information data transmission can be connected to a computer.	5.00	0.00	5.00	0.00	
	19. For information data transmission, can it connect with an LED display to show the final score?	5.00	0.00	5.00	0.00	Retain
	20. Can information data transmission achieve IPAD, computer, display, multiple device connection, and data synchronization?	5.00	0.00	5.00	0.00	

From the two rounds of the Delphi consensus in Table 2, it was found that the indicators met the criteria that set of Median ≥ 3.50 and IQR ≤ 1.50. Therefore, the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations was drafted as follows:

Table 3 Electronic scoring system user interface, the indicators that passed the criteria were as follows:

Level 1 Components	Level 2 Factors	Level 3 Indicators
Electronic scoring	1. The electronic scoring system shall be constructed	The construction of international gymnastics rules is an important guarantee to ensure objective and fair scoring, promote the

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Level 1 Components	Level 2 Factors	Level 3 Indicators
System User interface	according to the International Rules of Gymnastics.	standardized development of gymnastics technology, improve scoring efficiency and accuracy, and adapt to the development needs of gymnastics competitions. It must be ensured that the system can comply with international rules and competition standards, and provide a fairer, more accurate, and efficient scoring service for gymnastics competitions.
	2. The construction standard of the electronic scoring system should be in line with the needs of the gymnastics competition application.	Conforming to the actual needs of the use of gymnastics competitions is the key to ensuring the smooth running of the competition, fair and accurate scoring, as well as enhancing the overall competition experience. By continuously optimizing and improving the functions and performance of the electronic scoring system, the standardization and modernization of gymnastics competitions can be further promoted.
	3. The technicians who develop it should be familiar with the International Gymnastics Rules.	As the rules of gymnastics are constantly updated and changed, the scoring system needs to be optimized and upgraded accordingly. Technicians need to familiarize themselves with the changes in the rules so that they can update and adjust the system promptly to ensure that it always meets the requirements of international gymnastics competitions. After the technicians are familiar with the rules, they can ensure that the scoring system maintains consistent scoring standards and results when dealing with competitions in different countries and regions. At the same time, if there are various malfunctions and problems. The technicians' familiarity with the rules allows them to locate the problem faster and quickly troubleshoot and fix it, thus ensuring the reliability and stability of the system.
	4. The electronic scoring system shall have security.	Gymnastics electronic scoring systems need to be secure to ensure the integrity and accuracy of competition data, protect the privacy of participants and spectators, prevent malicious attacks and interference, safeguard system stability and reliability, and comply with laws, regulations, and industry requirements. These security requirements are important to ensure the fairness, accuracy, and smooth running of the competition.
	5. The electronic scoring system shall have stability.	Stability is required to ensure the continuity of the competition process, to guarantee the accuracy and reliability of the scoring results, and to adapt to the complex and changing competition environment. These stability requirements are important to ensure the smooth running and fairness of the competition.
	6. The electronic scoring system should be accurate.	Gymnastics electronic scoring systems need to be accurate to ensure the fairness of the results and enhance the credibility and recognition of the competition. If the scoring system has errors or inaccuracies, it may lead to the misjudgment of athletes' scores, which in turn affects the fairness of the competition results. Accuracy is important for maintaining the fairness of gymnastics competitions, enhancing the quality of competitions, and promoting the development of gymnastics.
	7. The electronic scoring system should be easy to use.	The gymnastics electronic scoring system needs to be easy to use to improve the efficiency of use, reduce the operation error rate, enhance the user experience, promote the popularization and promotion of the system, and better integrate into the gymnastics competition.

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Level 1 Components	Level 2 Factors	Level 3 Indicators
	8. The user interface should have clear instructions.	The user interface has clear instructions that reduce learning costs, and the clear instructions act as a wizard, guiding them step-by-step through the grading process. This not only improves efficiency but also reduces the number of errors caused by improper operation.

Table 4 scoring modules and data processing, the indicators that passed the criteria were as follows:

Level 1 Components	Level 2 Factors	Level 3 Indicators
Scoring modules and data processing	9. The scoring module shall have the ability to enter scores and display scores, including D-scores, E-scores, and Final Score.	In the process of constructing the gymnastics electronic scoring system, the design of the scoring module incorporating the elements of input scores, display scores, difficulty scores (D scores), completion scores (E scores), and final scores is based on the comprehensive considerations of the professionalism, transparency, accuracy, and user experience of gymnastics scoring. Together, these design elements form the core framework of the gymnastics electronic scoring system, providing a strong guarantee for the smooth running and results of the competition.
	10. The scoring module shall have the function of automatically calculating scores.	The scoring module has the function of automatic score calculation, which can significantly improve the scoring efficiency, ensure the accuracy of scoring, enhance the transparency of the game, facilitate data management and analysis, as well as adapt to different scales of the game. It enables referees, athletes, and spectators to quickly understand the progress of the game and enhances the real-time and interactive nature of the game.
	11. The software shall have a viewing function.	The software should have a viewing function, which enhances the transparency and fairness of the scoring and ensures that all participants can monitor the scoring process in real time. The view function should cover the real-time scores, historical scores, scoring details (including D and E scores), rankings, and scoring rules and criteria of each athlete. The ability to monitor the scoring process in real-time and to obtain and verify match data promptly to meet the needs of different users.
	12. The software shall have the function of statistical data.	It has the function of statistical data, which can efficiently collect, organize, and analyze the competition data, provide an accurate scoring basis for the referees, and generate rankings and results. At the same time, it provides valuable feedback information for athletes, coaches, and event organizers, which can help optimize training strategies, improve the quality of competitions, and promote the sustainable development of gymnastics.
	13. The software shall have the function of ranking scores.	It should have a ranking function, which can instantly reflect the athletes' performance and sports level, and provide an intuitive competition situation for athletes, coaches, and spectators. At the same time, it is convenient for the event organizers to manage the results and award subsequent prizes, and enhance the spectacle and participation of the competition.
	14. The software shall have the function of uploading competition rules and arrangements.	With the function of uploading rules and competition schedule, it can ensure that all participants (including referees, athletes, coaches, and spectators) can obtain the latest rules, competition schedule, and related information, which guarantees the smooth running of the

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Level 1 Components	Level 2 Factors	Level 3 Indicators
		competition, improves the transparency of the competition and allows more people to participate in the competition.
	15. The software shall have the function of uploading the result book.	With the function of uploading the scorebook, it is convenient for all parties, such as tournament organizers, referees, coaches, athletes, etc., to be able to quickly and accurately record and access the results of the tournament, improve the efficiency and accuracy of the management of the tournament, and also provide convenience for the subsequent analysis of the data and the preservation of historical records.
	16. The software shall have the function of uploading the competition mode settings.	It is equipped with the function of setting up the competition mode and can flexibly configure the framework of competition personnel and the number of personnel according to different types, scales, and demands of the competition. Interface layout and operation flow to ensure that the system adapts to diverse competition scenarios to meet the usage habits and needs of different user groups.

Table 5 data transmission, the indicators that passed the criteria were as follows:

Level 1 Components	Level 2 Factors	Level 3 Indicators
Data transmission	17. The electronic scoring system should be able to connect to an IPAD.	The electronic scoring system uses the network to connect to the iPad for scoring, which guarantees the independence of scoring, and the real-time transmission and synchronization of scoring data and The referee uses the iPad for scoring, with an intuitive operation interface, which can enhance the scoring efficiency.
	18. The electronic scoring system should be able to connect to a computer.	Ability to use computers for scoring as they provide more stable and powerful computing and data processing capabilities to support complex scoring algorithms and interface operations to ensure an efficient, accurate, and reliable scoring process.
	19. The e-scoring system should be able to connect to an LED display to show the final score.	With the ability to connect to an LED monitor to display the final score, it can instantly and clearly show the results of the game to the on-site audience, contestants, and the referee team, enhancing the public transparency of the game and improving the spectator's viewing experience.
	20. The e-scoring system should be able to synchronize data from the IPAD, computer, and monitor.	The system's ability to simultaneously connect data to an iPad, computer, and LED display guarantees the independence of scoring for referees in different positions. It ensures real-time synchronization and multi-terminal display of scoring data, enhances the transparency of the scoring process, and facilitates different roles, such as referees, coaches, and spectators, to obtain accurate information at any time.

The diagram for the electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations was summarized as follows:

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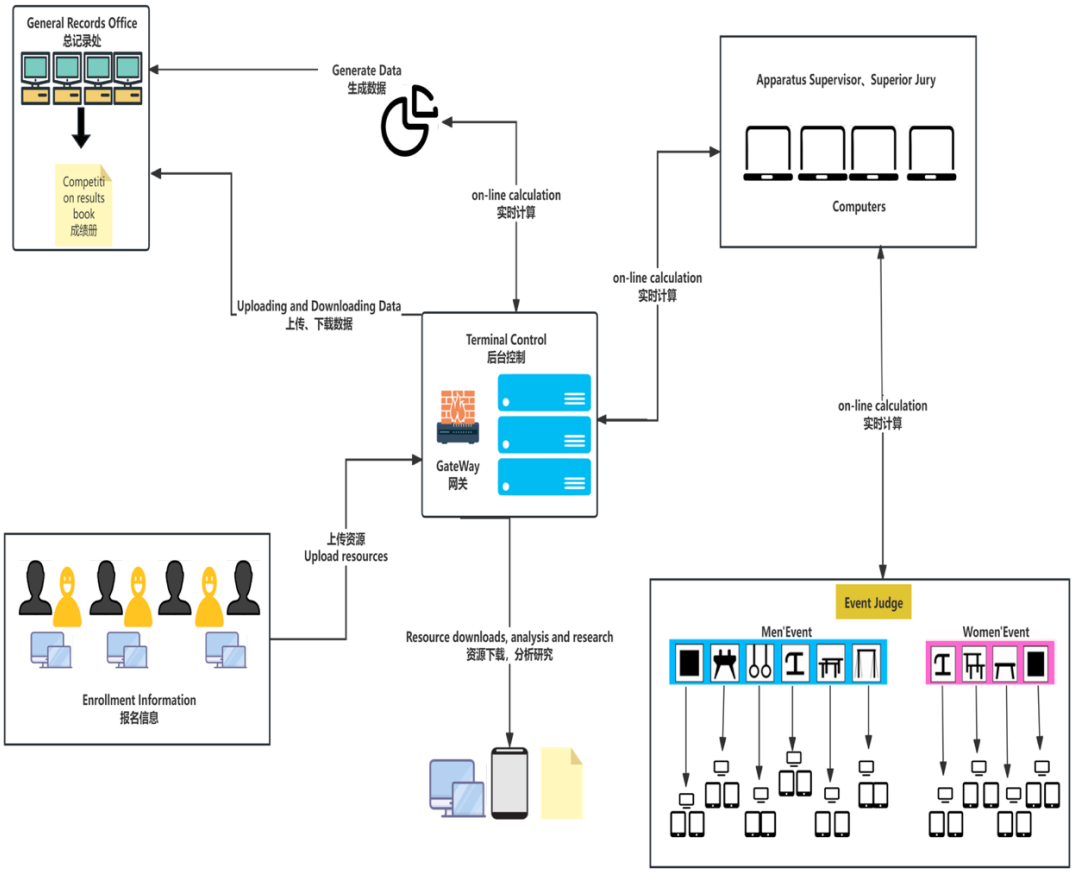

Figure 2 Conclusion of the electronic scoring system for artistic gymnastics competitions

Part 3: Nine experts in connoisseurship discussion to confirm the results of the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations.

In the third part of this research, the researcher invited nine experts to conduct a connoisseurship panel to confirm the developed electronic scoring system for artistic gymnastics competitions based on international gymnastics rules and regulations. The questions for use in the connoisseurship discussion were as follows:

1. How well does this electronic scoring system for artistic gymnastics competitions work in competitions?
2. This electronic scoring system for artistic gymnastics competitions, what is the design idea?
3. What impact does an electronic scoring system for artistic gymnastics competitions have on the operation of the competition, whether in line with the use of gymnastics rules?
4. Is the electronic scoring system of artistic gymnastics competition, whether it is conducive to the practical use of the combination of transport gymnastics competition?
5. Is the electronic scoring system compatible with the current needs and development of artistic gymnastics competitions?

Based on the insights of the nine experts' discussions using the connoisseurship method, the nine experts agreed that the construction of the electronic scoring system for artistic gymnastics competitions was innovative and beneficial, especially in terms of the integration of gymnastics competitions with the electronic scoring system. They recognized the potential of this electronic scoring system to improve the efficiency of gymnastics competition running and judging. Although the electronic scoring system brings many advantages, there are some potential challenges, such as system stability and data security. The e-scoring system was found to be feasible and in line with the future trends of gymnastics competitions, although it still needs careful refinement, continuous improvement, and constant refinement during

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competitions. Despite the challenges, experts believe that the e-scoring system provides a comprehensive framework that, if implemented carefully and adapted to different competition scenarios, could significantly improve the efficiency of gymnastics competitions.

In summary, electronic scoring systems will work positively in competitions and can significantly improve the accuracy and efficiency of scoring, enhance the transparency and fairness of competitions, and improve the viewing experience of spectators. However, to ensure the normal operation and accurate scoring of the system, it is also necessary to carry out proper maintenance and management of the system, guarantee the maturity of the technology and stable performance of the electronic scoring system, and strengthen the data security management measures.

The final electronic scoring system for artistic gymnastics competitions included the user interface, registration module, uploading of competition rules, scoring interface, score display, data transmission, and general end control. The details of the developed electronic scoring as shown in the following flow chart.

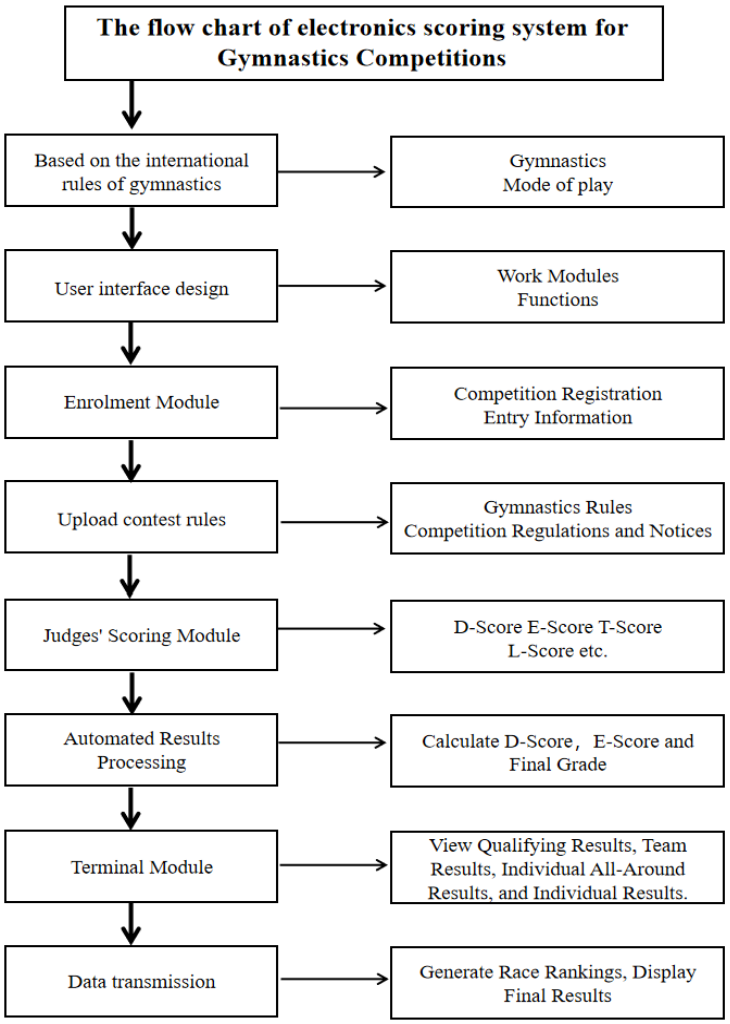

Figure 3 The confirmation of the developed electronic scoring system for artistic gymnastics competition Based on international gymnastics rules and regulations.

Conclusion

The result found that the developed electronic scoring system for artistic gymnastics competitions, aligned with international gymnastics rules and regulations, was both innovative and highly beneficial. The system comprises three first-level indicators: (1) Electronic Scoring System User Interface; (2) Scoring Modules and Data Processing; and (3) Data Transmission. Furthermore, the system integrates 20 second-level indicators supporting these key elements. By combining sports, science, and technology, the system

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promotes the synergistic development of gymnastics and information technology. Its scientifically constructed framework enhances the efficiency of judging in gymnastics competitions while ensuring fairness and accuracy. This innovative approach improves the overall credibility and effectiveness of scoring in artistic gymnastics.

Discussion

1. Reliability of electronic scanning systems

1) The electronic scoring system construction for gymnastics competitions, as discussed by Xu (2021), is designed with an emphasis on ensuring efficiency, accuracy, and stability within the system. This includes aligning the system with the specific needs of gymnastics competitions and their established rules. A key aspect of the system's development is the user-first principle, which prioritizes user experience in the design and operational processes. The system is built through a modular approach, ensuring that its various components can work cohesively, in line with software life cycle goals. Xu's (2021) approach to structuring the system is guided by the classification of design goals, ensuring that both the functionality and usability of the electronic scoring system are optimized for gymnastics competitions.

2) The development process of the system follows a structured life cycle, as outlined by Xu et al. (2019). This process includes a feasibility study, planning, requirements analysis, outline, detailed design, system implementation, integration testing, validation, and maintenance. The purpose of these stages is to improve the system's reliability, ensuring that it can function effectively during competitions. This structured approach guarantees the high-quality development of the e-scoring system, supporting its long-term use in gymnastics events. By focusing on these principles, the system can maintain a high standard of performance and user satisfaction, helping to streamline the scoring and judging process while minimizing errors and biases.

2. Based on gymnastics competition characteristics:

The use of electronic scoring systems in gymnastics and other competitive sports offers several advantages over traditional manual scoring methods, particularly in enhancing the accuracy and efficiency of results processing. According to Zhang and Zhong (2017), electronic scoring systems help streamline the competition process by automating the data entry and result tabulation. This minimizes human error, which is especially critical during multi-event or simultaneous competitions, where manual entry can lead to omissions or inaccuracies in scoring. By utilizing electronic systems, the process of verifying scores becomes faster and more accurate, as data is directly processed and immediately reflected in the results. This not only prevents potential biases in manual scoring but also ensures that results are published quickly and reliably, which is crucial for athletes, organizers, and audiences. Additionally, the automation reduces the risk of subjective interference that can occur with manual scoring, promoting fairness and transparency in the evaluation process.

Recommendation

Recommendation for this research

1. This electronic scoring system was developed and confirmed according to the current gymnastics rules of the International Gymnastics Federation. Therefore, before using this electronic score system, we must consider the current rules and regulations of that time, it is constantly being upgraded and improved as the rules change.

2. For the effectiveness of the use of this electronic score system, the referees need to be trained. The plan is to use the electronic scoring system for gymnastics competitions and continue to refine the system after 30 to 50 competitions.

3. The results of this study can lay the foundation for further research into the construction of the "All Gymnastics" (ACRO, AER, TRA, PK, RG) electronic scoring system model.

Recommendation for further research

1. Trial run the electronic scoring system on a large scale through 30 to 50 gymnastics competitions to ensure the efficiency and effectiveness of the system.

2. When the rules and regulations of international gymnastics change, the electronic scoring system shall be readjusted and improved according to the developments in international gymnastics.

3. The knowledge and practice of Artificial Intelligence (AI) have improved rapidly, and the system should be actively built in conjunction with AI, making the electronic scoring system more intelligent and diversified.

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