

Article | Received 4 July, 2026; Accepted 24 September, 2026; Published 10 October, 2026
<https://doi.org/10.55092/pe20260024>

Intelligent chess venue model design driven by technological revolution



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Abstract: Guided by the practical needs of refereeing, this paper constructs a framework for an intelligent arena system for board game competitions, with a core focus on officials' work and deeply empowered by technology. The system integrates technologies such as the Internet of Things (IoT), artificial intelligence (AI), and edge computing to automate and intellectualize processes including arena setup, game recording, behavior monitoring, and result statistics. Key technological breakthroughs have been achieved in automatic piece setup before each round, real-time data synchronization, and AI-assisted adjudication. Practical deployment demonstrates that this system can reduce the overall competition workflow time by over 30%, decrease the referees' workload by 80%, and achieve an accuracy rate exceeding 95% in providing early warnings for complex situational judgments. This research not only provides a feasible path for the intellectualization of Xiangqi (Chinese chess) competitions, but its system architecture and technical solutions are also applicable to the development of intelligent arenas for other board sports.

Keywords: intelligent arena; IoT; AI; board game competition; system architecture

1. Introduction

1.1. Research background and significance

The rapid development of Xiangqi (Chinese Chess) tournaments, driven by national fitness initiatives and the AI wave, has exposed significant limitations in traditional, human-reliant arena management models, particularly concerning efficiency and fairness [1]. Key challenges include: strained referee resources leading to error-prone arena setup and time-consuming processes; manual game recording and result statistics prolonging tournament cycles; limited anti-cheating measures; and the failure to effectively digitize vast amounts of game record data for utilization.

The maturation of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Edge Computing provides a solution for constructing an intelligent arena. A three-layer technical architecture—comprising a perception layer (intelligent boards enabling millisecond-level piece recognition), an analysis layer (AI rule engines parsing complex game situations), and a platform layer (cloud platforms integrating the entire tournament workflow)—forms a “perception-analysis-decision” closed loop, effectively enhancing tournament efficiency and fairness.



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The intelligent arena system developed in this study offers multi-dimensional value. In practice, it can reduce officials' transactional workload by 80%, shorten the tournament cycle by 40%, and improve player focus and perceived fairness. Theoretically, it proposes a "Technology-Rules-Experience" tripartite coupling framework. From an industry perspective, it promotes the standardization and commercialization of tournament organization [2].

1.2. Related work

Internationally, chess and Go have pioneered technology systems centered on intelligent hardware and algorithms, such as DGT electronic boards and Chess.com's AI arbiter system. However, these technologies still face limitations when dealing with the unique complex adjudication scenarios inherent to Xiangqi [3].

Domestic research has made progress in tournament management software and live broadcasting systems, but a significant gap remains regarding a holistic architecture for intelligent arenas. Current Xiangqi tournaments continue to struggle with issues like delayed information updates, error-prone manual operations, and resource wastage.

This paper proposes an intelligent arena system based on IoT and computer technology. By integrating information display screens with a central management system, it enables real-time updates of match information, automated recording of game processes, and cloud synchronization of data. The system features standardization, intellectualization, and eco-friendliness, providing a feasible path for the digital transformation of board game competitions.

Recent advancements in multimodal data fusion and analysis, such as those seen in Federated Learning with Domain Adversarial Attention Mechanisms (FedDAAM) [4] and large-scale multimodal dataset construction (LMVD) [5], underscore the potential for sophisticated, privacy-aware data handling in complex systems, which inspires our approach to multi-sensor data integration and behavioral analysis.

1.3. Research objectives and contents

(a) Core objective

Design and verify a chess intelligence game model meet the following characteristics:

Efficiency: the event process compressed by more than 30% (compared to manual mode).

Authority: complicated situation case warning accuracy 95% or greater (by the referee group review).

Extensibility: support from provincial trials to the serie a multistage event deployment in the country.

(b) Research Content (See Table 1 for details)

Table 1. Research content.

Content Module	Key Scientific Question	Output Achievement
Requirements Modeling	Extraction of core pain points of referees/chess players/organizers	Smart Arena Functional-Non-functional Requirement Matrix
Architecture Design	Loosely coupled interaction mechanism of four-layer modules	Microservice-based System Blueprint
Rule Engine	Formal representation and reasoning strategy of chess rules	Configurable Example Knowledge Base
Workflow Reconstruction	Definition of authority and responsibility boundaries for human-machine collaborative refereeing	Smart Arena SOP (Standard Operating Procedure)
Empirical Analysis	Performance verification of the model in real competitions	Pilot Competition Evaluation Report

2.The overall architecture design of the intelligent chess competition venue

2.1. Design principles

To meet the demand of the core of intelligent field, architecture design to follow the following principles:

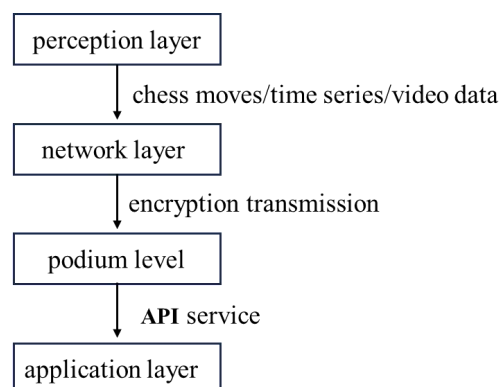
The centralized: all technical modules in the service of the referee decisions, AI no alternative decisions.

Consistent rules: all the parameters will be from the 2020 edition of the Chinese chess association authorized “chess competition rules” regulation shall prevail.

Localization of adaptation: the core engine (AI) hardware and software support domestic chip/OS ecology.

2.2. System architecture

The “perception-network-latfomr-application” hierarchical architecture is adopted, and each layer is decoupled through standardized interfaces (Figure 1).

**Figure 1.** System architecture diagram.

Perception Layer: Deploy an intelligent chessboard (integrating RFID/ pressure sensing/visual recognition technology to solve the problem of high-precision recognition of chess pieces), networked chess clocks, environmental sensors and audio and video equipment to collect core data of the competition venue in real time [6]. For specific technical solution design and performance index description, please refer to Table 2.

Table 2. Scene adaptation design for the perception layer.

Equipment Type	Technical Solution	Chess Scene Adaptation Design	Performance Indicators
Smart chessboard	Three-mode integration: RFID chip (chess piece identity); Pressure sensing matrix (coordinate positioning); Top wide-angle camera (visual verification).	Pressure sensor positions the main target; Visual auxiliary recognition.	Recognition delay $\leq 80\text{ms}$; Error rate $\leq 0.05\%$.
Internet-connected clock	Beidou/GPS dual-mode timing; Bidirectional communication protocol.	Supports “second - adding system” (such as precise execution with + 3 seconds per move); Automatically triggers chessboard locking when timed out.	Clock error $< \pm 10\text{ms}/24\text{h}$.
Behavior analysis camera	Edge computing node runs lightweight CNN model.	Focuses on typical rule violations: Number of leaving seats > 2 times/minute; -Hand lingering outside the chessboard area $> 10\text{s}$. Automatically lift the chess pieces when illumination is insufficient;	Recognition accuracy rate $\geq 92\%$.
Environmental sensor	Temperature/humidity/illumination/noise monitoring.	Disk fill light brightness; Reminds referees to intervene when noise exceeds the standard.	Data sampling rate 1Hz.

Network layer: high speed, reliability and safety of the private network, guarantee low latency and high concurrent data transmission to improve real-time response ability and introducing edge to compute node (this layer can choose according to need to increase the intelligent board). The topology and protocol stack are shown in Figure 2. If an intelligent chessboard is introduced, the entire process from placing a piece to the referee's alarm can be executed in the sequence shown in Figure 3.

The platform layer: as a “wisdom mind”, core data integration platform and key AI engine. The key innovation lies in the construction of a deeply integrated AI rule engine, role recognition engine, behavior analysis engine and event management engine, achieving the monitoring of abnormal behaviors and efficient management throughout the entire process (dynamic orchestration algorithm Based on the improved Hopcroft-Karp algorithm, it achieves $O(n \log n)$ complexity and supports generating matches within 3 seconds for events with a scale of 2 to 1000 participants [7]. Score pipeline: Game ends $\rightarrow$ Automatic verification $\rightarrow$ Relevant calculations $\rightarrow$ API release, the entire process takes less than 10 seconds.

Application layer: Targeting different user groups, it provides an intelligent workbench for referees, receiving real-time data information, AI case law early warning and reference information, chess player terminals, event management backends, public information display systems, and data service portals (for example, the arrangement data can be set to be visible to all or some groups of people before each round based on permissions, *etc.*)

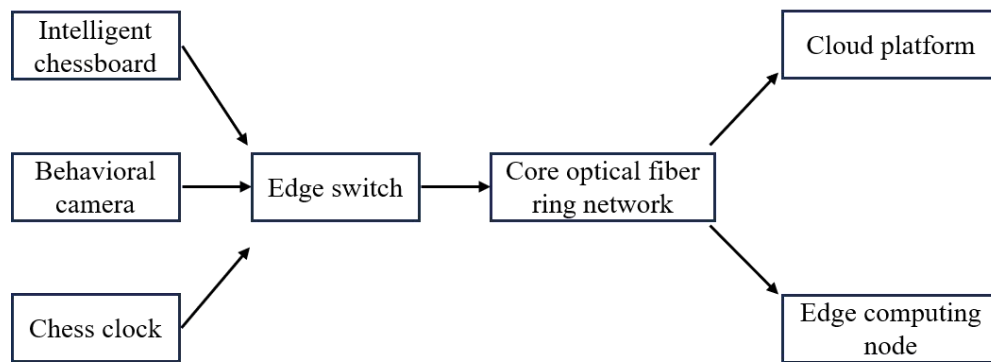


Figure 2. Topological structure and protocol stack of the network layer.

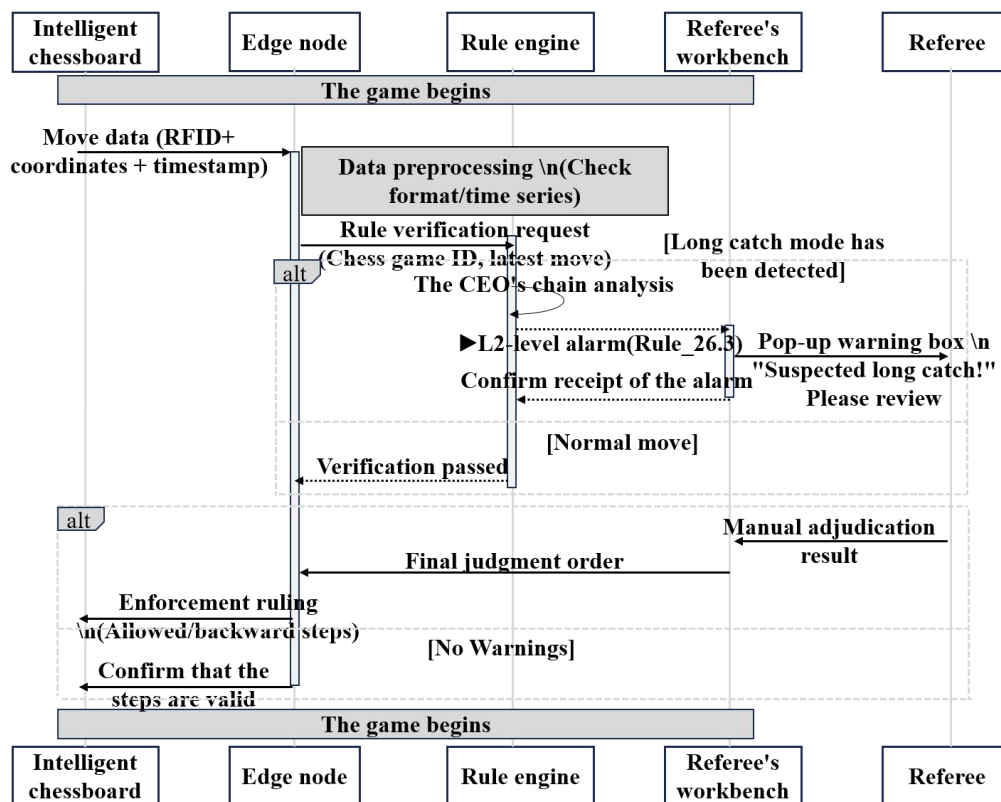


Figure 3. Shows the processing sequence after introducing the intelligent chessboard.

3. Key technologies and functional realization

The key technologies of this system mainly consist of two parts: information placement technology and the implementation of intelligent competition venue business logic.

3.1. Information delivery technology

It is mainly realized through the display screen of chess competition information. It includes a microprocessor module and a power supply module, as well as a data storage circuit module and a

wireless communication module connected to the microprocessor module. The input end of the microprocessor module is connected to a key operation circuit module, a timing circuit module and a video acquisition circuit module. The interaction among the modules is shown in Figure 4. The input terminal of the video capture circuit module is connected to a camera for recording the game board, and the output terminal of the microprocessor module is connected to a display screen (see Figure 5). The competition management computer of the intelligent chess competition venue system and the chess competition information display screens installed on each player's seat in the venue are wirelessly connected and communicate with the competition management computer through a wireless network. The connection situation is shown in Figure 6.

Through the above links can send data real-time in athletes the information on the screen, where the seat so as to realize the facilitation of events organization and management, run competitions, low cost, intelligent data management, greening process run competitions and promoting the commercialization of the game.

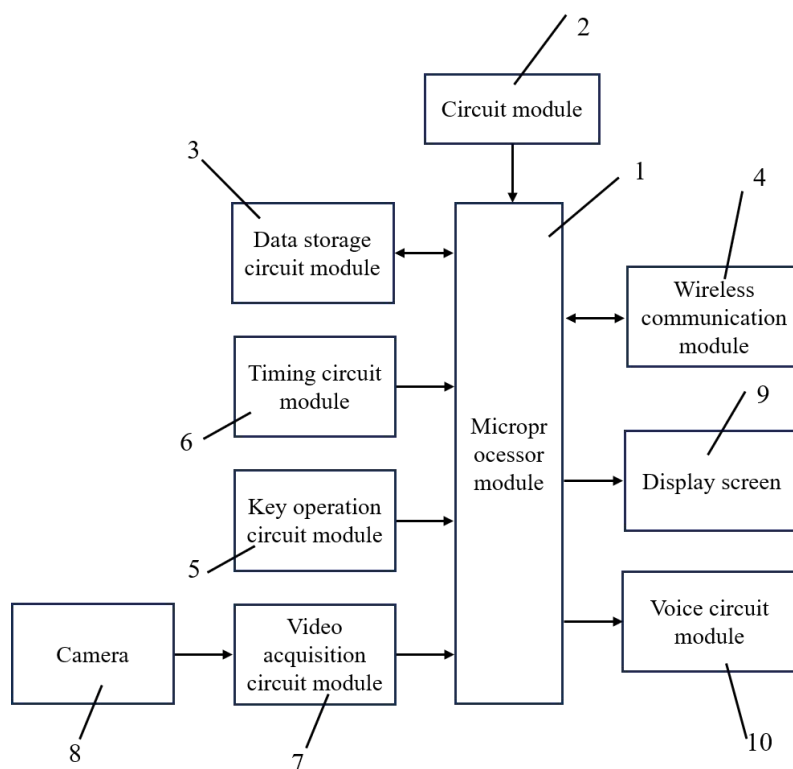


Figure 4. Interaction of the information display screen module.

The information display screen module includes a microprocessor module (1) and a power supply module (2) that supplies power to each power-consuming module in the chess competition information display screen, as well as a data storage circuit module (3) and a wireless communication module (4) connected to the microprocessor module (1). The input terminal of the microprocessor module (1) is connected to the key operation circuit module (5), the timing circuit module (6), and the video capture circuit module (7). The input terminal of the video capture circuit module (7) is connected to the camera (8) used for recording the game board, and the output terminal of the microprocessor module (1) is connected to the display screen (9).

Sponsor LOGO		o Camera		
Name of the competition				
Name of the red team player	Photo of the red team player	Repetition	Name of the black team player	Photo of the black team player
Number of the red team player			Number of the black team player	

Figure 5. Appearance of the information display screen (electronic name tag).

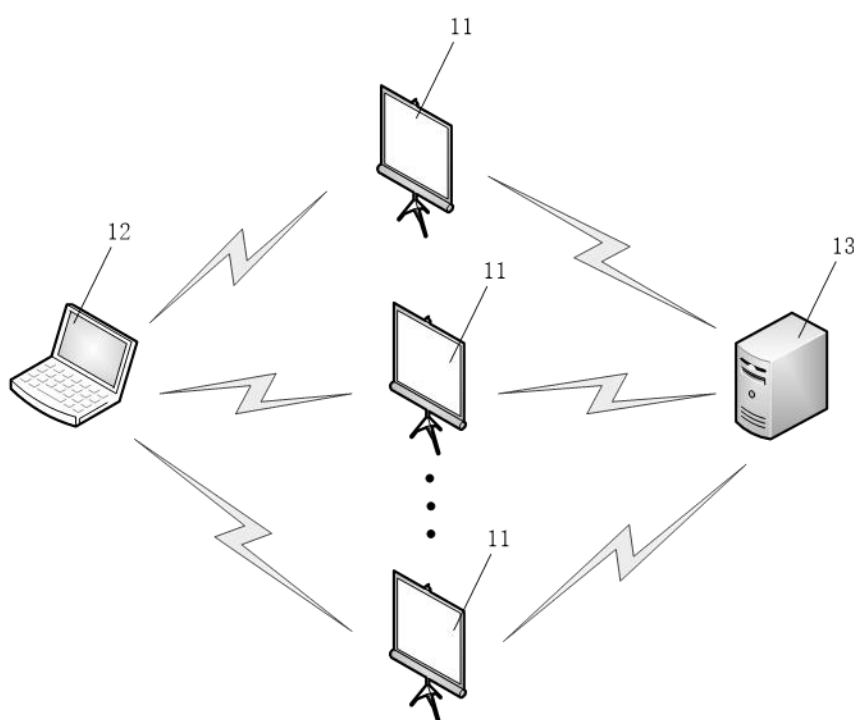


Figure 6. Network topology and connection conditions.

3.2. The implementation of business logic for the intelligent competition venue

The methods for conducting chess competitions and completing various business operations by using the intelligent chess competition venue system mainly include the following steps:

Step 1: Place a competition management computer (12) for the use of the chief referee or the chief arranger at the competition venue. Place a board game information display screen (11) on each player's seat at the venue, and wirelessly connect the board game information display screen (11) to the competition management computer (12) via a wireless network.

Step 2: The director or choreography long in game management computer (12) set up after the game content, sent to various chess game information on the screen (11), chess game information on the information shown on the screen (11) chess game, The information of the chess competition

mentioned includes the competition name, round, player's unit, player's name, player's photo, table number, and timing time (in specific implementation, the time can also be reminded to the players by setting up a voice circuit module 10 as needed).

Step 3: Players according to the information displayed in the chess game on the screen (11) on the right information accordingly, began to race; During the competition, the camera (8) records the game board. The microprocessor module (1) collects the game board recorded by the camera (8) through the video capture circuit module (7) and stores it in the data storage circuit module (3) for the chief referee to view. Players compete according to the time displayed on the chess competition information display screen (11).

Step 4: After the match, the director of a sentence, gives the result of the match and sent to each chess game information on the screen (11), for players to look at it.

Step 5: Beginning to collect (such as join smart board, can be in accordance with the following steps to generate chip).

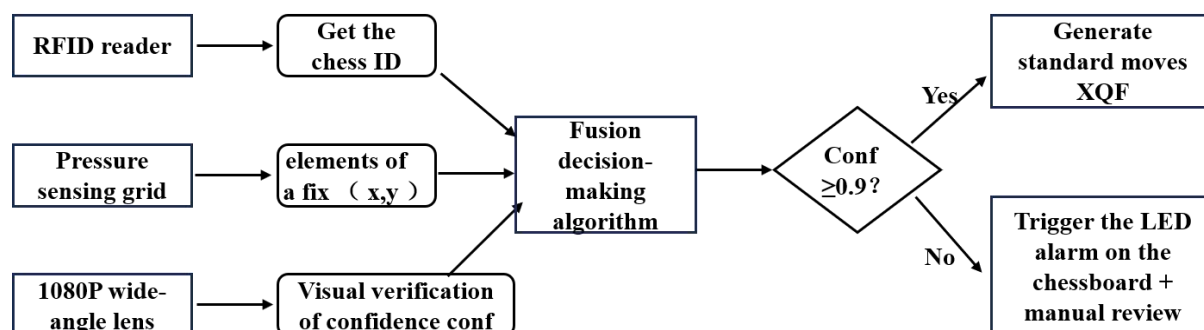


Figure 7. Shows the logic diagram of the intelligent chessboard generating game records.

Note: smart board key parameters:

the pressure sensor layout: 45 * 45 mm checkerboard embedded 8 x 8 dot matrix (accuracy + / - 0.5 mm);

RFID anti-interference design: pieces at the bottom of the ceramic substrate label (10 kg under pressure, misreading rate < 0.01%);

visual check optimization: Fine-tuning of the YOLOv5s model for chess pieces (mAP@0.5 = 98.2%).

4. Intelligent sports field application

4.1. Full-process intelligent workflow

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

(a) Before each round of the chess game

Referees familiar with the organization of Chinese chess competitions are well aware that the final pre-match inspection in traditional Chinese chess competitions is of great significance. It is necessary to verify whether the competition equipment is complete and meets the requirements, mainly including the competition table, competition chairs, chess pieces, chessboard, chess clock and various tables and cards-record paper, score report cards, draw cards, name tags, table numbers are all complete. It is

particularly necessary to check and confirm whether the placement of the table name tags and athlete name tags on each table is consistent with the arrangement of the match schedule. Take the preliminary round of the mass competition of Chinese chess at the 15th National Games as an example (Figure 8). For such a large-scale event, if even the slightest mistake or error occurs, the consequences would be unimaginable.

After using this system, the table signs and player name signs on each chess table in every round will be automatically displayed in the form of electronic projection screens. All that is needed is for the chief referee or the chief arranger to “project” the arrangement data information on the management machine, and it can be “one-click completed” to be displayed on the projection screens of the chess tables. The timing clock and the camera will automatically activate the recording function. If an intelligent chessboard is used, the game records will also be automatically recorded. All the contestants only need to follow the process shown in Figure 10 to participate in each round of the competition. This greatly reduces the workload of referees in setting up tables and tags as well as repeated proofreading. It not only shortens the entire event process but also improves the efficiency of table setting (estimated time reduction by 80%).

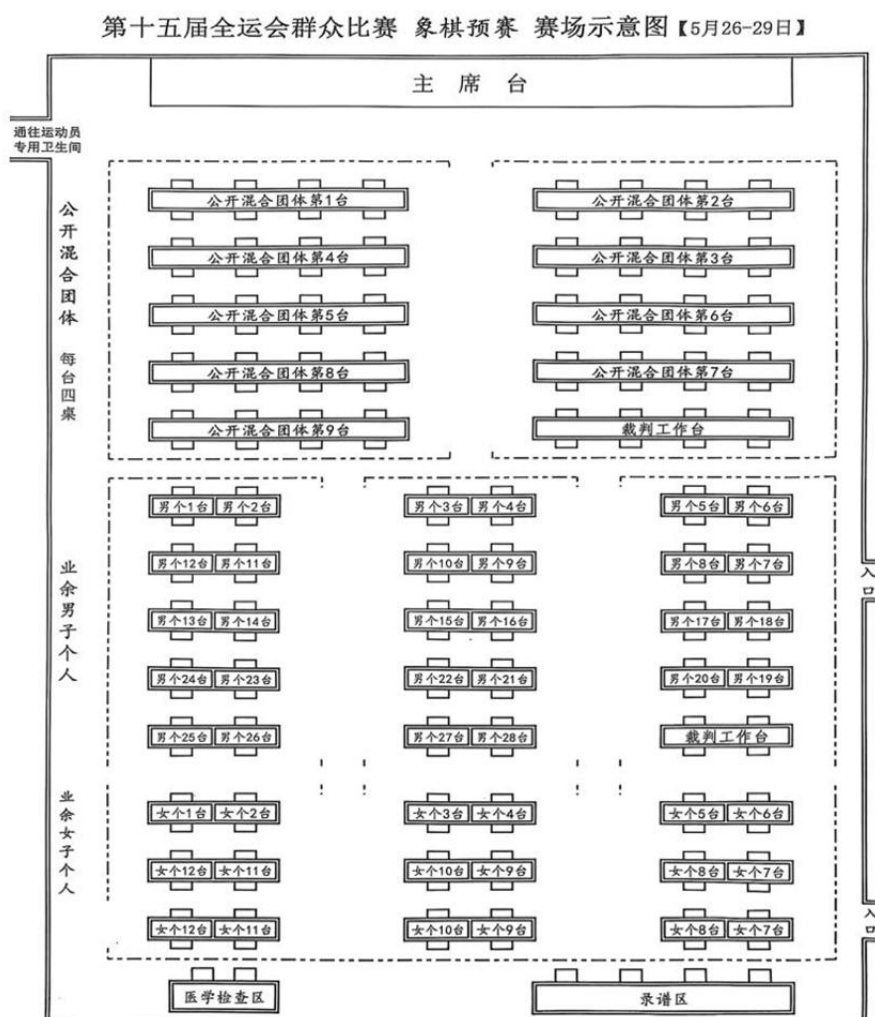


Figure 8. Schematic diagram of the Chinese chess venue of the national games.



Figure 9. Table setting positions at the national games venue (referee's perspective).

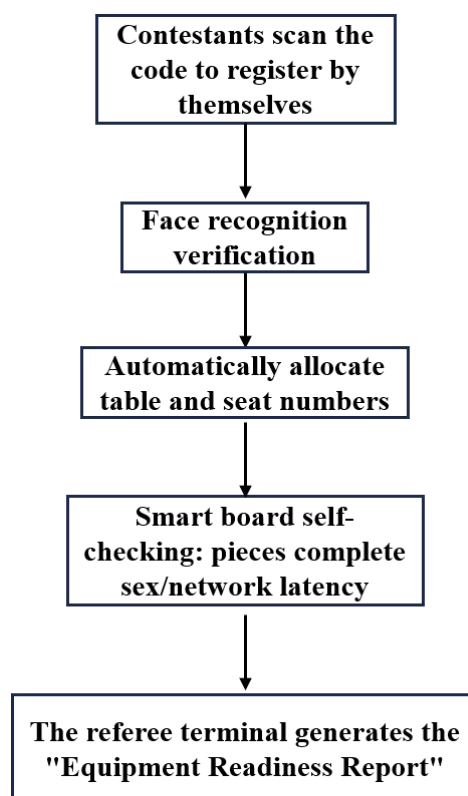


Figure 10. The competition process of athletes in the intelligent system.

(b) Core scenarios during the competition

After each round of the game starts normally, the scene during the game is not much different from that in a traditional competition venue. The only difference is that there are fewer referees on the table. In a traditional competition venue, the number of referees on the table is generally around 1:8, meaning one referee is approximately in charge of eight games. Usually, the entire competition venue may require 10 to 20 referees (with slight variations depending on the scale of the event). However, after using this system, what is needed more is “human-machine collaborative officiating”, so only 1 to 2 referees in the entire competition venue are required to observe whether the equipment is operating normally.

(c) Post-match data closure

In traditional competitions, at the end of each game in every round, it is often the “busiest” time for referees. They need to accurately record the results of the players' matches, the duration of the game, whether there were any fouls, and other information. Therefore, it may also be the time when mistakes are most likely to occur. After using this system, all the above tasks are automatically recorded and completed by the system, and everything becomes a piece of cake. After the system backend has collected all the competition data for each stage, the chief choreographer can start the next round of choreography without proofreading and continue until the entire competition is over. After the competition, all the data related to this competition will be automatically recorded in the background (if an intelligent chessboard is used, all the game records will also be recorded), thus forming a data closed loop.

4.2. Emergency response plan: handling of technical failure scenarios

(a) Fault response

After using this system, it is necessary to consider the unexpected occurrence of equipment and network failures. For instance, possible unexpected situations may include: sudden power outages at the competition venue, malfunctions of a certain display screen that prevent normal display, or network disruptions, *etc.* The main job of the 1-2 referees in the aforementioned stadium is to patrol the entire stadium and identify these problems.

(b) Disposal plan

Power supply guarantee is a matter that all competitions need to consider, so this system does not need to take it into account. In the event that a certain display screen malfunctions, simply replace it with the spare screen (a plug-and-play device) (the data will not be affected). There are two solutions for network outages. One is to prepare another network connection in advance for switching at any time. The second is to switch to a manual competition mode and operate in accordance with traditional events (only in extreme circumstances).

5. Experimental testing and data analysis

5.1. Testing environment and deployment

The system was deployed during a 2024 Xiangqi Championship in Shaanxi Province, involving 200 participants across 11 rounds of Swiss-system matches. The deployment included 20 intelligent chessboards, 200 information display screens, 5 edge nodes, and one cloud platform suite.

5.2. System performance testing

Table 3. System performance test indicators.

Test Item	Target Requirement	Measured Result
Piece Recognition Latency	≤ 80 ms	72 ms
Pairing Generation Time	≤ 3 s	2.4 s
Full Result Processing Time	≤ 10 s	8.5 s
AI Adjudication Alert Accuracy	$\geq 95\%$	96.7%
System Availability	$\geq 99.5\%$	99.8%

5.3. Comparative experiment analysis

A traditional tournament of similar scale held concurrently was selected as the control group. Comparative results are as follows:

- Official workload: the intelligent arena reduced the number of required officials by 75%, and decreased administrative task time by 82%.
- Tournament cycle time: the interval between rounds was reduced from 35 minutes to 22 minutes, shortening the overall schedule by 32%.
- Error rate: the error rate in piece setup and result entry dropped from 4.1% in the traditional model to 0.2%.
- Player satisfaction: based on questionnaire surveys, player satisfaction in the intelligent arena reached 94.2%, significantly higher than the 78.5% reported in the traditional format.

5.4. Data value mining

The system accumulated 1850 complete game records, 32,000 behavioral data points, and 56,000 environmental data points. Data analysis revealed:

A negative correlation ($r = -0.63$) was found between the frequency of a player leaving their seat and their positional advantage during the game.

Player focus was highest under ambient lighting intensities between 500 and 800 lux.

The player skill model constructed based on game record data showed an 89.4% consistency rate with official ratings.

5.5. User feedback and optimization suggestions

Officials reported that the system performed excellently in adjudication alerts and result processing, suggesting further enhancements to network redundancy and interface design. Players widely

acknowledged the system's convenience and fairness, with some suggesting the addition of personalized information display features.

6. Challenges and countermeasures, development and prospects

6.1. Challenge and countermeasure

(a) Challenges and countermeasures at the equipment and technical levels

Challenge: The current information display screens adopt technologies such as RFID, pressure sensing, and visual recognition, which result in high hardware costs. Moreover, the deployment of high-resolution display screens leads to the cost of a single device reaching several thousand yuan, making it difficult to popularize in small and medium-sized events.

Countermeasures: with the domestic LCD manufacturers and sensing module, dedicated chip manufacturers develop chess will target a single smart board cost down more than 40%.

(b) Challenges and countermeasures at the management and operation levels

Challenge: Some grassroots event organizers are too greatly influenced by the inertial thinking of the traditional event organization model. The acceptance of the intelligent competition venue system is relatively low. The traditional manual drawing and manual recording mode has strong inertia. It is believed that the introduction of the intelligent system requires additional learning costs, and there are concerns that equipment failures will affect the progress of the event. Take provincial amateur events as an example. It is estimated that about 60% of the organizers still use paper schedules and manual table setting, while only 30% have tried electronic tools.

Countermeasures: Introduce a "lightweight intelligent competition venue" solution, retaining the compatible interfaces between traditional processes and intelligent systems. For instance, while manually setting up the tables, the arrangement data can be synchronously entered through a mobile APP to achieve dual-track operation of "manual + intelligent" and lower the threshold for transformation. Launch a national training program for referees and organizers, and jointly hold an intelligent competition venue technology certification course with the Chinese Chess Association to enable them to master system operation and basic fault handling. We offer a "zero-cost" pilot service. For events that use the intelligent competition venue system for the first time, the technical team will provide on-site support throughout the process, covering the costs of equipment rental and technical maintenance, to allay the concerns of the organizers with actual results.

(c) Data security and privacy protection risks

Challenge: The sensitive information collected by the intelligent competition venue system, such as players' game records, biometric information (such as facial recognition verification data), and competition results, may lead to data leakage if there are loopholes in the storage or transmission process. Although blockchain evidence storage technology can keep the incidence of controversial events within 0.3%, cloud platform servers are at risk of hacker attacks. In historical cases, there have been instances where event data was tampered with.

Countermeasures: Build a three-level data security system of "end-edge-cloud". Terminal devices (intelligent chessboards, information display screens) use the national encryption SM4 algorithm to

encrypt data. Deploy firewalls and intrusion detection systems at edge nodes. The cloud platform realizes trusted evidence storage for key operations through blockchain technology. Data transmission uses a VPN encrypted channel. Establish a data classification management mechanism, mark the biometric information of the players as the highest classification level, and only authorize the core management personnel of the event to access it. The chess game data and score information will be partially opened to the public according to the permission Settings (for example, the arrangement data can be set to be visible to all or some groups of people before each round according to the permission Settings). Regularly conduct cybersecurity drills, carry out at least two penetration tests each year, simulate hacker attack scenarios, and promptly fix system vulnerabilities.

6.2. Development and outlook

(a) Direction of technological evolution

In the future, intelligent chessboards will develop towards “chip-level integration”, achieving breakthroughs in hardware integration and low power consumption. Focus on addressing the defect that once this system is deployed in a fixed site, it is not convenient to move. After the successful development of integrated chips in the future, it is expected to meet the demands of outdoor events and mobile scenarios.

(b) Deep integration and application of AI and big data

By accumulating a large amount of competition field data, a dual-driven model of “event knowledge graph + referee ability portrait” is constructed. The model is trained with artificial intelligence data to achieve “autonomous learning” and “self-improvement” of system functions, thereby reducing the pressure on referees in dealing with emergencies.

This aligns with trends in deep learning for complex pattern recognition from multimodal data [8].

(c) Industry application expansion

Build a global intelligent chess event ecosystem. In collaboration with international chess organizations, we will promote the standards of Chinese chess intelligent competition venues to the international stage, create the brand of “Global Chinese Chess Intelligent Competition Venues”, establish a global standard system for intelligent competition venues, provide technical support for the inclusion of Chinese chess in international event systems such as the World Mind Sports Games, activate commercial and industrial value, and facilitate the global dissemination of Chinese chess culture. Promote the popularization and recognition of Chinese chess culture overseas.

7. Conclusion

In conclusion, this paper proposes an intelligent chess competition venue system and method based on computer technology and Internet of Things technology, and establishes a new type of intelligent competition venue that combines the traditional competition mode with information technology. It can be set up with various competition modes such as 30 or fewer people, 60 or fewer people, 100 or fewer people, and over 100 people according to user needs. It can be applied in all environments including chess associations, chess sports schools, training institutions, and government sports departments.

around the world and across the country. The promotion and application of the intelligent chess competition venue system and method designed in this paper can significantly reduce the workload of referees, lower costs by reducing the number of referees, and thereby minimize unnecessary waste of labor resources.

Those skilled in the art should understand that the embodiments of this document may be provided as methods, systems, or computer program products. Therefore, this model can take the form of a complete hardware embodiment, a complete software embodiment, or an embodiment combining both software and hardware aspects. Moreover, this work may take the form of a computer program product implemented on one or more computer-available storage media (including but not limited to disk storage, CD-ROM, optical memory, *etc.*) which contain computer-available program codes.

These computer program instructions can also be loaded onto a computer or other programmable data processing devices, enabling a series of operation steps to be executed on the computer or other programmable devices to generate computer-implemented processing, thereby being carried out on the computer or other programmable devices. This enables those skilled in the art to implement and utilize various exemplary implementation schemes of this technology.

Declaration of generative AI and AI-assisted technologies

The authors did not use generative AI or AI-assisted technologies in the writing of this manuscript. During the preparation of this manuscript, the authors used generative AI tools only to improve language and readability. The authors take full responsibility for the content of the manuscript.

Acknowledgment

This work is supported by the Science and Technology Plan Project of Yulin City (2024-CXY-101).

Authors' contribution

X.W. designed and wrote this manuscript.

Conflicts of interests

The authors declare no conflict of interest.

Ethical statement

The authors confirm that all ethical standards relevant to this research have been strictly followed. No human subjects or animal models were involved in the present study. There are no potential conflicts of interest.

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