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Exploring the Advantages of Digital Sports Using Multi-Domain Integration of the Internet of Things

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ABSTRACT

The convergence of IoT-enabled cross-domain integration has emerged as a transformative approach for advancing digital sports ecosystems. This study proposes an enhanced Markov clustering algorithm to address data heterogeneity across physical, informational, and social domains in sports digitization. Experimental validation on 30,000 datasets demonstrates a 0.44% improvement in recall rate compared to conventional Markov clustering (p<0.05), while maintaining computational efficiency through optimized iteration termination conditions. The framework provides actionable insights for constructing intelligent sports management systems, significantly enhancing real-time athlete monitoring and multi-domain resource coordination.

KEYWORDS

Digital Sports Ecosystem, Cross-Domain IoT Integration, Markov Clustering Optimization, Heterogeneous Data Fusion, Athlete Performance Analytics

INTRODUCTION

Digital sports training ecosystems are inherently collaborative: training planning, load management, performance analysis, and injury prevention require coordinated work across roles (e.g., coach, athlete, analyst, and medical staff). Despite rapid growth in sports Internet of Things (IoT) and analytics, collaboration often remains fragmented across devices and systems, leading to inconsistent interpretations, delayed decisions, and limited accountability. In the 21st century, with the rapid development of computer technology and the Internet, global data has shown a considerable growth trend, and the world has entered the big data era. Therefore, digital has become a core strategic resource for many countries worldwide, and digitalization has become a hot topic. In addition, digital systems are widely used across all walks of life (H. Zhang & Li, 2023). With the development of society and the times, improving the training quality of reserve talents and the sports performance of young athletes requires the development of a sports digital training system. Only in this way can it adapt to the times and keep pace with the trend in international sports development.

The IoT reflects the dissemination of advanced technologies in training as a foundation, and digital technologies can enhance the understanding of sports management information (W. J. Zhang & Shen, 2022). The construction of a sports digital training system is a long-term, complex, and systematic project (Zhou, 2023). Due to the apparent differences in individual data indicators across athletes,

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digital software is used to analyze these data. Moreover, providing support for the formulation of subsequent training would positively improve athletes' training levels.

This study conducted an in-depth investigation into the current state of the sports digital athlete training system, focusing on the selection of sports digital materials and digital training, to understand the current state of sports digital construction. Through comparison and analysis, the weak points in the development of digital athlete training are identified, and the theoretical basis for optimizing and constructing the sports digital athlete training system is provided, thereby improving the training quality of sports reserve talents and enhancing athletes' performance. Putting forward strategies and suggestions for developing the future digital sports training system would lay a theoretical foundation for the digital research and development of these sports.

To address these challenges, we studied how multi-domain IoT integration can support shared situational awareness and coordinated decision-making in digital sports. The study focused on integrating physical, information, and social domains into a unified collaboration context model. Contributions of this work include:

- a collaboration-oriented multi-domain model for integrating physical signals, information artifacts, and social context in digital sports
- a Markov clustering (MCL) fusion mechanism with an improved termination condition to reduce computational cost in large-scale graphs
- a prototype microservice architecture that operationalizes the proposed integration for collaboration services (e.g., monitoring, annotation, and service discovery)
- an evaluation of scalability and service discovery performance under sports-platform-like workloads, with discussion of implications for practice

The remainder of this article is organized as follows. It first reviews related work on e-collaboration, digital sports, and multi-domain IoT integration. It then introduces the proposed multi-domain collaboration model and context representation, followed by a description of the prototype implementation. Next, it presents the performance evaluation and resulting findings, before discussing the implications and limitations of the proposed approach. The article concludes by outlining directions for future work.

BACKGROUND AND RELATED WORK

This section reviews e-collaboration and shared situational awareness concepts relevant to distributed sports training teams; digital sports and IoT sports platforms; and multi-domain data fusion methods that enable context-aware collaboration. Research on e-collaboration examines how geographically dispersed stakeholders organize their activities, exchange knowledge, and stay in touch using digital technologies. The philosophy of shared situational awareness is a fundamental notion that denotes the consistent understanding of system condition, task progress, and situational elements among team members (Draisbach et al., 2019). The literature notes that successful collaboration requires timely information sharing, role awareness, and shared artifacts to minimize coordination breakdowns and delays in the decision-making process (Chen et al., 2019; Duan & Wang, 2022). Sports training settings are multi-role by nature and involve the coach, athletes, analysts, and medical personnel, each of whom requires a diverse perspective on the same underlying information. The decentralized and time-stamped nature of training and competition further underscores the need for systems that facilitate shared awareness of role-based responsibilities and access controls (Bentaleb et al., 2025). These lessons encourage the incorporation of the social context and role information on digital sports collaboration platforms.

Digital sports systems are increasingly grounded in IoT technologies to gather, store, and analyze extensive data from wearable sensors, smart equipment, and training conditions. Previously available