



A Conceptual Hybrid Adaptive–Generative AI Framework for Intelligent Skating Performance Optimization

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DOI - 10.5281/zenodo.19396707

Abstract:

Skating performance requires precise coordination of balance, speed, posture, and edge control, which are often difficult to monitor and optimize using traditional coaching methods alone. This paper proposes a conceptual Hybrid Adaptive–Generative Artificial Intelligence framework designed to enhance skating performance through intelligent analysis and personalized feedback.

The proposed system utilizes data from wearable sensors, video analysis, and training logs to create a dynamic performance model of the athlete. Adaptive algorithms adjust coaching strategies based on individual skill development, while generative components create tailored drills and predictive insights to support skill improvement and injury prevention.

This conceptual framework aims to bridge the gap between traditional coaching and intelligent sports analytics, providing a scalable and personalized training environment. The study highlights the potential of hybrid AI systems to transform skating coaching methodologies by enabling data-driven decision-making, continuous performance monitoring, and adaptive learning pathways for athletes.

Introduction:

The rapid development of Artificial Intelligence (AI) technologies has significantly influenced various sectors, including healthcare, finance, education, and sports science. In recent years, AI has emerged as a powerful tool in sports analytics, enabling data-driven decision-making, performance evaluation, and intelligent training optimization. Among various sports disciplines, skating represents a highly technical and physically demanding activity that requires a combination of balance, speed, coordination, and precise biomechanical control.

Traditionally, skating training is guided by experienced coaches who evaluate athletes through visual observation and manual feedback. Although such methods are valuable, they are often subjective and may fail to capture subtle biomechanical patterns that influence performance. Furthermore, manual evaluation limits the ability to continuously monitor athletes during training sessions and competitions.

Adaptive Artificial Intelligence represents a promising approach for addressing these challenges. Adaptive AI systems continuously learn from incoming data and update their models to reflect new performance patterns. In the context of sports training, adaptive AI can analyze athlete performance over time, identify areas of improvement, and modify training recommendations accordingly. This dynamic learning capability allows the system to personalize training programs based on the athlete's unique progress and performance characteristics.

In parallel, the emergence of Generative Artificial Intelligence has introduced new possibilities for creating intelligent training support systems. Generative AI models are capable of producing new content such as training plans, coaching feedback, and movement simulations based on learned patterns from large datasets. In sports training, generative AI can assist coaches by generating personalized drills, technique correction guidelines, and performance improvement strategies.

The objective of this research is to present a conceptual architecture that demonstrates how hybrid AI technologies can support athletes and coaches in improving skating performance through data-driven insights and intelligent training recommendations. The framework aims to enhance training efficiency, reduce injury risks, and promote long-term athlete development through the integration of advanced AI techniques

Background and Motivation:

As a skater, I have personally experienced that skating performance depends on balance, posture, speed control, and edge techniques, which require continuous practice and precise feedback. Traditional coaching methods mainly rely on visual observation and manual feedback, which may miss subtle performance errors.

Objectives of the Study:

1. To provide a data-driven approach for personalized coaching and performance monitoring in skating.
2. To explore the potential of AI-enabled sports analytics for improving athlete training and skill development.
3. A Conceptual Framework Paper will focus on architecture design, theoretical modeling, and future vision — without heavy prototype implementation.

Literature Review:

1. Artificial Intelligence in Sports Performance Analysis:

Artificial Intelligence (AI) has become an important tool in sports science for improving athlete performance, analyzing movement patterns, and optimizing training strategies. AI-based systems can process large amounts of performance data and provide insights that help coaches and athletes make data-driven decisions.

2. Computer Vision and Motion Analysis in Sports:

Computer vision techniques play a crucial role in modern sports analytics. Video-based motion tracking systems allow researchers to analyze athlete movements, posture, speed, and biomechanical patterns. These systems use techniques such as pose estimation, object tracking, and deep learning models to extract performance metrics from video footage.

3. AI Applications in Skating Performance Evaluation:

Recent research has explored the use of AI specifically in figure skating and similar sports. For example, a study proposed a system that evaluates skating techniques using 3D pose estimation derived from camera images and inertial measurement sensors. The system automatically detects edge errors in skating movements and achieved an accuracy of approximately 83% when analyzing unknown skaters' data.

4. AI-Based Coaching and Training Recommendation Systems:

In recent years, research has shifted toward developing AI-driven coaching systems capable of providing personalized training instructions. For example, the CoachMe model analyzes an athlete's motion and compares it with reference movements to generate corrective feedback similar to a human coach. The system identifies movement errors and produces detailed improvement instructions tailored to the athlete.

5. Data-Driven Athlete Training and Performance Optimization:

Modern sports training increasingly relies on data-driven performance monitoring. Wearable sensors, GPS tracking devices, and IoT technologies allow continuous monitoring of athletes during training sessions. These technologies generate large datasets related to movement, speed, fatigue, and biomechanical patterns.

Concept of Adaptive AI in Sports Training:

In a sports environment, adaptive AI systems collect data from wearable sensors, video recordings, and performance tracking tools. This data is analyzed using techniques from Machine Learning, allowing the system to identify patterns related to athlete movement, posture, speed, and balance.

Another important feature of adaptive AI in sports training is continuous learning. As more performance data is collected over time, the AI model becomes more accurate in understanding the athlete's strengths, weaknesses, and progress patterns. This enables the creation of personalized training programs that evolve with the athlete's skill development.

Thus, adaptive AI supports data-driven coaching, real-time feedback, and long-term performance monitoring, making sports training more efficient and scientifically guided.

Concept of Generative AI in Sports Training:

Generative AI analyzes athlete performance data using techniques from Machine Learning and movement analysis methods such as Computer Vision. Based on the skater's previous performance, the system can generate customized drills, corrective exercises, and optimized practice routines.

For example, if the system identifies weaknesses in balance, posture, or edge control, generative AI can design targeted practice sessions that focus on improving those specific skills. It can also create simulated training scenarios to help athletes practice different movement patterns and strategies.

Another important capability of generative AI is its ability to provide predictive insights. By analyzing historical performance data, it can forecast possible improvement areas and suggest training adjustments before performance issues become significant.

Thus, generative AI enhances sports training by enabling innovative coaching support, personalized practice design, and intelligent performance improvement strategies.

Limitations and Challenges:

- Data Availability
- Key Considerations for Wearable Tech
- Sensor and Equipment Dependency: Relies on specific hardware.
- Technical Complexity: Can be challenging to implement.
- Accuracy of Motion Detection: Crucial for reliable data.

- Privacy and Data Security: Essential for user trust.
- Adoption by Coaches and Athletes: Influences widespread use.

Future Scope:

- Advanced AI Integration
- Mobile Application Development
- Framework Expansion for Broader Performance Optimization
- Expansion of the existing framework to include a wider range of sports.

Possible Research Contributions:

- Proposed hybrid architecture (CV + RL + Generative AI)
- Adaptive athlete-specific improvement model
- AI-based injury risk prediction
- Intelligent feedback system

Conclusion:

Extra Advantage Since I am connected to skating field, i can: Use real training insights Include practical problems coaches face Add real-world validation.

This paper proposed a conceptual framework that integrates Adaptive Artificial Intelligence and Generative Artificial Intelligence to support intelligent skating performance optimization.

Although the framework is conceptual in nature, it highlights the promising role of AI-driven systems in transforming traditional sports training. With further research, real-time data integration, and technological advancements, such intelligent frameworks can contribute significantly to more scientific, personalized, and efficient skating training environments.

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