

Research on risk prediction and management of outdoor sports based on artificial intelligence

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Abstract: With the increasing popularity of outdoor sports, participants are increasingly facing risks and safety issues. The application of Artificial Intelligence (AI) technology in risk prediction and management offers a novel approach to addressing these concerns. This paper explores the application of AI technology in the risk prediction and management of outdoor sports, analyzing its advantages, challenges, and future development directions.

1. Research Background

With the advancement of socio-economic development and the improvement of living standards, outdoor sports have gradually become an important means of daily leisure and recreation [1]. Activities such as mountaineering, rock climbing, hiking, skiing, trail running, and paragliding attract numerous participants due to their challenging, adventurous, and unpredictable nature, but they also pose potential risks [2]. The complexity, variability, and unpredictability of natural environments are among the primary risk factors in outdoor sports [3]. Adverse weather conditions, complex terrain, and threats from wildlife can lead to situations such as getting lost, hypothermia, falls, and drowning, which poses significant threats to the safety and property of participants [4]. Additionally, the lack of knowledge, skills, experience, preparation, and proper equipment among participants, as well as their unfamiliarity with the environment, can further increase the likelihood of accidents. Traditional risk prediction and management methods largely rely on human experience and intuition, which are insufficient for comprehensively, timely, and accurately predicting and responding to various risk factors in outdoor sports [5]. On-site monitoring and manual interventions often fall short when dealing with the complex and dynamic outdoor environment. Therefore, effectively identifying and managing the risks associated with outdoor sports has become a pressing issue. AI technology, with its powerful data processing and analysis capabilities, offers new possibilities for risk prediction and management in outdoor sports [6].

2. Application of AI Technology in Risk Prediction and Management of Outdoor Sports

In recent years, the development of artificial intelligence has driven the upgrade of risk management technologies. AI has achieved significant success in the field of risk prediction and

management, especially in data collection and processing, risk identification and assessment, risk monitoring and strategy formulation, and emergency response. It has enabled the automation of risk monitoring and the use of machine learning for customized solutions, greatly enhancing the accuracy of risk analysis and decision-making efficiency. The AI risk management process flowchart is shown in Figure 1.

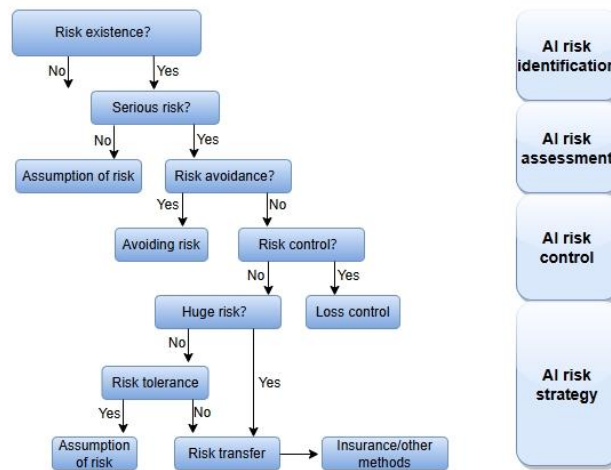


Figure 1: AI Risk Management Implementation Process Flowchart

2.1. AI Technology in Risk Prediction for Outdoor Sports

1) Data Collection and Processing

AI technology relies on a large volume of diverse and high-quality data as the foundation for its models. A diverse dataset can better capture the complexity of problems and prevent models from overfitting to specific scenarios. Accurate, complete, and consistent data help models establish accurate associations and patterns, enhancing their ability to solve real-world problems. AI can collect physiological data such as heart rate, body temperature, and blood oxygen saturation of outdoor sports participants in real-time through wearable devices like smartwatches, smart glasses, and heart rate bands. Environmental data such as weather, terrain, altitude, temperature, and humidity can be collected through sensors and GPS systems. Behavioral data, including athletes' activity trajectories, exercise intensity, and speed, can be recorded via activity trackers and mobile applications. These data are then processed to identify and handle duplicates, missing values, and anomalies, and converted into a uniform format for transmission to a central database for comprehensive analysis, providing a robust and precise data foundation.

2) Risk Prediction Models

Various risk prediction models are constructed based on AI technologies such as machine learning and deep learning. By integrating and analyzing vast amounts of historical and real-time data, these models can identify high-risk behaviors, environments, and sudden incidents, issuing early warnings to participants and helping them take preventive measures. For example, neural network models trained on historical data can predict the probability of accidents and risk factors under different conditions, alerting outdoor sports participants to take necessary precautions. Common risk prediction models include:

a) Neural Network Models

Neural network models have powerful nonlinear processing capabilities. They can learn and capture complex patterns and relationships in data through extensive training. These models automatically extract useful features from raw data, enabling high-precision and real-time predictions,

making them suitable for personalized risk assessments in the dynamic context of outdoor sports.

b) Random Forest Models

Random forest models excel at handling high-dimensional data, have strong resistance to overfitting, and offer interpretability. They can comprehensively analyze multidimensional data to provide holistic risk assessments. Additionally, by combining outputs from multiple decision trees, they enhance prediction accuracy and robustness.

c) Support Vector Machines (SVMs)

SVMs are adept at handling small sample sizes, providing high-precision classification, and processing nonlinear data. They are well-suited for high-dimensional data classification and regression problems, achieving precise predictions through hyperplane construction, making them ideal for risk classification and anomaly detection in outdoor sports.

3) *Real-time Monitoring and Early Warning*

AI systems can continuously monitor the status of outdoor sports participants and environmental changes, analyzing data through algorithms to predict potential risks. Upon detecting abnormal physiological indicators, behaviors, or environmental factors, the system can instantly issue alerts, advising participants to cease activities or alter their routes. It can also preemptively notify medical rescue teams, significantly enhancing the safety of outdoor sports. For instance, if the AI system detects a sudden rise in an athlete's heart rate or a sharp change in environmental temperature, it will immediately issue a warning, suggesting appropriate measures.

2.2. Application of AI Technology in Risk Management

1) *Risk Identification, Assessment, and Decision Support*

AI technology can comprehensively identify and assess risks in outdoor sports projects by analyzing various internal and external risk factors (including human, material, and environmental factors), providing scientific bases for decision-makers. By simulating and predicting the outcomes of different decision scenarios, AI systems assist outdoor sports participants in selecting optimal solutions, thereby reducing accident rates. For example, AI can assess the risk of a hiking trail by considering weather changes, equipment carried, and individual health conditions, helping participants take preemptive safety measures.

2) *Emergency Response and Rescue*

AI technology can optimize emergency response and rescue processes in the event of outdoor sports accidents. Utilizing technologies such as Geographic Information Systems (GIS), drone technology, and intelligent command and dispatch systems, AI systems can quickly locate accident sites, analyze casualties, efficiently coordinate various resources, optimize rescue plans, and guide rescuers in conducting efficient rescue operations. Typically, most outdoor sports accidents occur in remote wilderness areas. Drones equipped with AI recognition algorithms can autonomously identify and analyze various targets, scenes, or objects during flight, quickly reaching accident sites to provide real-time video and environmental data, aiding rescue teams in saving time and formulating the best rescue strategies.

3) *Training and Education*

AI technology can also be utilized in risk management training and education for outdoor sports. Firstly, virtual reality (VR) technology can simulate various risk scenarios, allowing athletes to learn coping methods and techniques in a safe environment, thereby enhancing their risk awareness and emergency response capabilities. Secondly, AI technology can analyze athletes' training data to assess their risk-handling abilities and provide detailed training feedback and improvement suggestions. Thirdly, AI technology can develop and offer a wealth of educational resources and courses. By creating online learning platforms, interactive teaching modules, and intelligent assistants, it helps

outdoor sports participants and managers systematically learn risk management knowledge and skills, fostering a culture of risk management in outdoor sports.

By leveraging these AI capabilities, the safety and efficiency of outdoor sports can be significantly improved, ensuring a better experience for participants and more effective management by organizers.

3. Advantages and challenges of AI technology in risk prediction and management of outdoor sports

3.1. Advantages

1) Accurate Prediction

Risk factors in outdoor sports typically exhibit complex non-linear relationships that traditional linear models struggle to effectively capture. AI technology can simultaneously process and analyze various types of data, including physiological indicators, environmental factors, and behavioral data. This multidimensional data processing capability provides comprehensive risk assessments, resulting in more thorough and accurate predictions. Particularly, deep learning-based neural network models can handle complex non-linear data relationships. Neural networks learn deep patterns and relationships within the data through the connection and adjustment of multiple neurons. For instance, by training on historical data, neural networks can identify complex relationships between heart rate and body temperature changes, predicting health risks under specific outdoor conditions.

2) Real-time Warning

AI systems can provide real-time monitoring and early warnings, responding promptly to sudden situations. On the one hand, AI technology can process video data from sports parks, outdoor sports bases, trails, and other outdoor venues. Deep learning models, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), extract various visual features from the video (e.g., color, edges, texture). Target detection algorithms then analyze these features to identify and assess objects (e.g., people, plants, animals). If the system detects potential threats, such as participants lying down or staying still for extended periods, it immediately triggers the warning mechanism, sending alerts to managers via mobile apps, emails, text messages, or office alarms, and transmitting relevant video clips to management for further analysis and action.

3) Efficient Management

AI technology optimizes emergency response and risk management processes, enhancing management efficiency. For outdoor sports managers, AI provides scientifically effective management tools that significantly improve operational efficiency. By monitoring and analyzing large volumes of real-time data, AI systems can conduct comprehensive risk assessments of sports activities, identifying high-risk areas and periods, and providing scientific bases for managers to formulate more reasonable management strategies. In large outdoor sports events, AI systems can monitor the health data of all participants in real-time, quickly identifying and warning of potential health issues to ensure the safety of the event. Additionally, by analyzing environmental data and movement trajectories, AI systems can optimize route planning and activity arrangements, reducing unnecessary risk exposure and enhancing the safety and participation in activities.

4) Dynamic Adaptation

AI models possess self-learning and updating capabilities, enabling them to dynamically adapt to different environments and conditions, continually optimizing risk prediction and management. By constantly receiving and processing new data, AI systems can adjust their algorithms and model parameters, maintaining efficient risk prediction and management capabilities. For instance, in skiing, AI can dynamically adapt to risks such as avalanches, hypothermia, and injuries; in hiking, it can adjust to fatigue, dehydration, and getting lost; in mountaineering, it can adapt to risks like hypoxia, falls, and high-altitude pulmonary or cerebral edema. AI's dynamic adaptability, through self-learning

and adjustment, can maintain efficient risk prediction and management in complex and changing outdoor environments, providing more precise and personalized safety assurances.

3.2. Challenges

1) *Data Quality*

High-quality data, characterized by accuracy, completeness, and consistency, is fundamental for the effective operation of AI systems. However, acquiring and processing data in outdoor environments poses significant challenges, making it difficult to ensure data quality. Data providers or collection devices may be affected by weather, altitude, terrain, and other factors, leading to incomplete or inaccurate data collection. For example, sensors may be unstable in high-altitude extreme temperatures. Additionally, outdoor sports such as mountaineering, skiing, paddleboarding, and trail running involve diverse data types with varying sources and formats, making unified processing challenging. Ensuring data quality through unified collection, filtering, deduplication, and validation is a current issue.

2) *Technical Complexity*

AI technology has entered a practical phase, continuously evolving towards higher precision, tackling more complex tasks, and expanding capability boundaries, requiring advanced technical support and expertise. Building high-precision risk prediction models for outdoor sports necessitates extensive work in data collection and analysis, hyperparameter tuning, cross-validation, and model integration. These processes are time-consuming and complex. Additionally, real-time monitoring and warning in outdoor sports risk management demand high-performance computing technology and optimized algorithms, requiring efficient data processing capabilities to quickly complete data collection, processing, and analysis, and promptly issue warnings.

3) *Privacy and Security*

Despite governmental measures in many countries to protect personal privacy in AI applications, requiring developers to adopt stringent data encryption and access control measures to ensure user information security, issues such as data leaks, tampering, and authenticity verification remain concerns. For example, personal activity data collected by pedometers, smartphones, or watches, even when anonymized, can be re-identified and linked to demographic data using machine learning techniques. On the other hand, the safety of AI systems is still debatable, with potential severe, widespread, and complex consequences. Existing AI algorithms often exhibit the "black box" problem, where the results are not explainable, leading to user distrust. In outdoor sports risk prediction, identification, and assessment, erroneous analyses by AI systems can result in significant harm to participants' lives and property.

4. The future development direction of AI technology in outdoor sports risk prediction and management

4.1. For Technicians: Enhanced Risk Prediction Capabilities

In the future, with the continuous development of AI technology, its application in outdoor sports risk prediction and management will become more accurate, refined, and intelligent. By integrating with advanced technologies such as 5G, VR, AR, IoT, and edge computing, the stability and reliability of AI can be further improved, leading to more accurate predictions of outdoor sports risks. For example, the high speed and low latency characteristics of 5G technology will significantly enhance data transmission efficiency, IoT's extensive connectivity will increase device interoperability, and edge computing will help reduce data transmission delays, enabling real-time responses.

4.2. For Participants: Enhanced Safety and Sports Experience

AI technology provides participants with various innovative solutions in outdoor sports risk management. Through personalized health monitoring, dynamic safety navigation, and augmented reality (AR) assisted training, AI can identify potential risks and provide specific recommendations to participants. This helps outdoor sports enthusiasts systematically acquire safety knowledge and skills, significantly enhancing their safety and overall sports experience.

4.3. For Managers: Improved Emergency and Response Efficiency

AI technology offers managers numerous advanced tools and methods for outdoor sports risk management. Future development directions include comprehensive environmental monitoring, intelligent incident response systems, and data-driven decision support. These advancements enable managers to better ensure the safety of outdoor sports participants, improve the efficiency and effectiveness of facility management, and provide more scientific, precise, and efficient management tools.

5. Conclusion and Recommendations

5.1. Conclusion

Artificial intelligence technology provides multi-source data and technical support for outdoor sports risk management, enabling intelligent risk prediction and assessment, monitoring and early warning, and timely rescue and response. This offers an innovative approach to managing outdoor sports risks. Its advantages in accurate prediction, real-time warnings, and efficient management will greatly enhance the safety of outdoor sports. However, challenges such as data quality, technical complexity, and privacy security still need to be addressed. In the future, AI technology will play an even greater role in outdoor sports risk management for participants, managers, and technicians, providing comprehensive safety assurances for outdoor sports enthusiasts.

5.2. Recommendations

1) Improve Data Quality and Management

Organizations should collect high-quality data comprehensively, establish strict data cleaning and preprocessing procedures, and integrate data from various sensors and devices to ensure accuracy and reliability, especially in outdoor environments. Additionally, they should establish real-time data collection and updating mechanisms to facilitate timely outdoor sports risk assessment and prediction.

2) Technological Optimization and Innovation

Research teams should explore advanced technologies such as deep learning, reinforcement learning, automated machine learning, edge computing, cloud computing, 5G, VR, AR, and IoT. They should continuously optimize AI algorithms to enhance the accuracy and processing efficiency of outdoor sports risk prediction models.

3) Promote Standardization

Regulatory bodies and industry organizations should establish unified data formats and processing standards, develop standardized communication protocols, set unified system interface and API standards, and implement strict data privacy protection and security standards.

4) Increase Popularization and Personalization

Through media publicity, promote online learning platforms and interactive teaching tools. There is a need to use AI to provide risk management knowledge and skills training, and continuously

optimize AI models to offer customized risk assessments and management plans based on each outdoor sports participant's specific situation.

5) *Enhance Interdisciplinary Collaboration and Research*

There is a need to encourage co-operation between the fields of information technology, data science, sports science, environmental science and medicine. Establish shared platforms to share research results and data to provide a more comprehensive understanding of risk factors in outdoor sports and provide multifaceted solutions to develop more comprehensive and in-depth risk management strategies.

6) *Enhance User Participation and Education*

On the one hand, outdoor sports participants and managers can be more involved in the design and implementation of the AI system. By collecting their feedback and suggestions, the AI system can better meet their specific needs. On the other hand, user education and training can be conducted regularly to teach outdoor sports participants and managers how to effectively use AI technology for risk management.

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