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Research on the Application of Computer Vision Technology in Sports Mechanics Analysis

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ABSTRACT

With the continuous development of computer vision technology and related hardware devices, motion mechanics analysis is gradually being applied in sports training. However, due to the complex characteristics of motion mechanics and irregular movements, motion mechanics analysis still has limitations in practical application scenarios. This article constructs a multi convolutional 3D CNN model that combines BN algorithm, dropout technique, and spatial pyramid pooling technique. Different features are used as inputs for 3D CNN models tested on video datasets. The experimental results show that combining the “BM+OFM+three FDF” features as model inputs can achieve high recognition accuracy. Therefore, the 3D CNN model constructed in this article can effectively improve the accuracy of motion mechanics recognition and has good application value.

KEYWORDS

Computer Vision, Movement Mechanics Analysis, 3D CNN, Feature Combination

INTRODUCTION

Computer vision, an interdisciplinary research field with a long-standing history, continues to grow and evolve. Initially, its applications were predominantly centered on fundamental tasks such as object recognition, tracking, and measurement (Suo et al., 2024). However, with the integration of multiple disciplines, including image processing and pattern recognition, the scope of computer vision research has expanded significantly, accompanied by numerous challenges. Early advancements in the field were constrained by inadequate hardware and limited computational power, particularly when processing large-scale data and complex image information(Ghosh et al., 2023). These limitations in computing resources posed significant barriers to progress.

The advent of enhanced computational capabilities and the rapid growth of big data technology have created new opportunities for the field. Advances in image processing techniques now enable the efficient conversion of image data into formats conducive to deeper analysis and understanding by both humans and machines(Zhang, 2024). This development mimics the visual perception processes of the human eye and brain, effectively substituting human involvement in visual information processing. Consequently, the application boundaries of computer vision have expanded considerably. Furthermore, the introduction of deep learning technology has facilitated substantial breakthroughs in computer vision research(Wang et al., 2024). Leveraging robust feature extraction capabilities, deep learning enables automated learning and extraction of critical information from extensive datasets. This

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has significantly accelerated the progress of computer vision, particularly in advanced applications such as object detection, image segmentation, and action recognition.

Recently, the rapid advancement of sports and exercise science has brought increasing attention to the application of computer vision in sports mechanics analysis. This field has demonstrated significant potential in video analysis by enabling the automatic extraction and evaluation of human motion and its associated features. A central research focus in computer vision and artificial intelligence (AI) is developing methods for computers to autonomously analyze and comprehend human motion and mechanical characteristics from video data. Sports mechanics analysis not only enhances the understanding of athletic performance but also provides a scientific foundation for optimizing athlete training, monitoring health, and preventing sports-related injuries. However, the diversity of motion postures, the complexity of mechanical properties during movement, and the variability of video backgrounds present substantial challenges in motion mechanics recognition. Traditional manual feature extraction methods often depend on extensive domain expertise and involve labor-intensive processes, which undermine robustness and efficiency. Consequently, designing automated, robust, and efficient algorithms for motion mechanics recognition has emerged as a critical issue within the realm of computer vision. Such advancements are pivotal for overcoming the limitations of manual methods and advancing the precision and scalability of motion analysis systems.

To address these challenges, this study proposes a 3D convolutional neural network (CNN) model leveraging multiple convolution operations to extract detailed motion features, thereby enhancing recognition accuracy and algorithm robustness. The model comprises five convolutional layers, three downsampling layers, and two fully connected layers, maximizing the advantages of convolution operations in deep learning to effectively capture spatial and temporal features in videos. Recognition testing experiments on video datasets were conducted to evaluate the model's performance, exploring various network parameter initialization methods, including optimal batch size and packet loss zeroing rates. The study also compared and analyzed the impact of different feature combinations. Experimental results indicated that when “binary maps (BMs) + optical flow maps (OFMs) + three-frame difference maps (FDFs)” are used as model inputs, the recognition accuracy reaches 94.4%. This high performance is particularly notable when applied to video datasets with complex backgrounds and diverse motion mechanics, highlighting the model's significant potential in motion mechanics analysis. This study not only offers a novel solution for the automated analysis of motion mechanics but also establishes a foundation for extending computer vision technology to other domains. By advancing research in this area, the application of computer vision in complex scenarios will expand further, particularly in sectors such as sports, healthcare, and robotics, fostering innovation and driving technological development.

LITERATURE REVIEW

Computer vision technology has been widely applied across various industries, including sports mechanics analysis. Qiu et al.(2023) emphasized its use in transport vehicle analysis, industrial product testing, agricultural pest control, and medical diagnosis. Schulc et al. (2024) introduced a wearable sensing system for monitoring basketball players utilizing multiple inertial measurement units. Zhang (2024) proposed a method for measuring the 3D motion posture of athletes, addressing the limitations of traditional identification methods in analyzing subtle movement parameters. Sharma (2024) examined the evolution of vision-based motion analysis in sports biomechanics and rehabilitation, highlighting the shift from manual approaches to marker-based systems. Li (2023) detailed the CoachAI project, which leverages machine-learning techniques for microscopic data collection and tactical analysis in badminton matches. Ghosh et al. (2023) presented an Internet of things-based posture detection system for sports and medical science applications, emphasizing the critical role of sensor technology selection.