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Utilization of Wearable Sensors Based on Artificial Intelligence in Motion Monitoring

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ABSTRACT

Conventional sports monitoring methods are often hampered by inconvenient data collection and by accuracy issues. This paper explores the potential incorporation of artificial intelligence technology with wearable sensors to identify a low-cost, interpretable method of human motion monitoring. A single accelerometer is used to highlight applications of the rest of the method, which derives the vertical component and uses the pre-peak threshold, the pre-trough threshold, and the time lapse between the peak and trough of this component signal as feature values. The hardware components are simpler and fewer than in past applications, but better feature values are chosen to decrease the processing complexity for classification calculations and to enable the development of a decision tree algorithm to recognize and classify human motions. Together these approaches drastically reduce problems with inconvenience and reliability in comparison with conventional methods. The results show that the proposed method reaches a 93.89% recognition accuracy rate, which allows for accurate identification and classification of simple motion categories.

KEYWORDS

Acceleration Sensor, Artificial Intelligence, Decision Tree, Motion Monitoring, Human Motion Recognition

INTRODUCTION

At present, wearable sensor technology (Zhang et al., 2019) is rapidly emerging across multiple areas of research; this development has significantly advanced the field of sports monitoring (Su et al., 2022). Wearable sensors hold strong potential for applications such as sports science (Qiu et al., 2019), medical rehabilitation (Cen et al., 2023), and health monitoring when assessed against baseline physical activity. Despite the advancement of these technologies in various areas, traditional motion monitoring techniques still have considerable limitations, particularly related to complex movements and dynamic environments (Often affected by data latency and external interference, these limitations lead to insufficient real-time function and robustness).

Wearable sensor technology has developed from single-sensor (Lu et al., 2022) usage to multi-sensor fusion (Wang & Ping, 2021). Sensors have become miniaturized and are now capable of collecting and transmitting real-time data through advancements in microelectronics (Dieny et al., 2020) and wireless communication (Cao et al., 2023). Nonetheless, the limitations of single sensors with respect to gauge motion are still apparent, especially in applications involving complex motion and high levels of precision. The current technology often fails to capture the full range of the motion, leading to inadequate accuracy rates. For this reason, the focus of research has been shifting toward

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multi-sensor fusion and increased complexity of data analysis (Li et al., 2020), and these strategies will presumably help to improve the accuracy of monitoring. However, they also come with additional challenges, namely data synchronization, redundant processing, computational complexity, and demands for hardware and energy.

As for data processing technology (Xu et al., 2024), the technology of motion monitoring has evolved from simple signal processing to the more complex and powerful technology of pattern recognition. Early motion monitoring methods relied on simple threshold determination and frequency analysis. Although threshold methods are easily understood, they lack sufficient accuracy, especially in complex dynamic motion and across a variety of application domains. However, with the development of machine learning (Sindayigaya & Dey, 2022) and other artificial intelligence technology (Leng et al., 2022), the capabilities of data processing technology significantly expanded. Methods of statistical pattern recognition, (Zaman & Hassan, 2019) such as support vector machines (SVMs; Chandra & Bedi, 2021), neural networks (Li et al., 2021), decision trees (Charbuty & Abdulazeez, 2021), etc., have significant transfer potential for sports data research. These types of methods can automatically extract and select key features in sports actions and thus can significantly increase action recognition. However, methods based on machine learning have limitations as well; especially in situations with high noise, high dynamic range, and complex backgrounds, they show reduced efficiency and robustness. In practice, these technologies still struggle with issues like reliance on a vast amount of annotated data, excessive computational load with real-time requirements, and lack of adaptability in real-world settings. AI technology can adaptively learn motion variation in dynamic environments and is thus able to improve the flexibility and accuracy of monitoring. So, while wearable sensor technology and data methods for monitoring motion have advanced significantly, traditional motion monitoring methods still have several limitations when dealing with complex environments, changing motion models, and real-time monitoring. Improving the accuracy, real-time function, and robustness of these methods will be the focus of future research.

This paper presents a human action recognition method based on a single acceleration sensor (Chen et al., 2021). Unlike traditional complex systems that rely on the fusion of multiple sensors, this research presents a straightforward, efficient recognition method based on a single accelerometer and a decision tree algorithm. Specifically, this paper estimates the vertical signal component measured with an accelerometer to extract characteristic values such as the threshold before and after the peak, as well as the time difference between peak and trough. In comparison with traditional methods that analyze many redundant features, the use of fewer and more representative feature values significantly reduces computational complexity while also improving real-time performance and system efficiency. Moreover, the decision tree classification algorithm can handle these features effectively and is capable of accurately classifying common human movements, such as running, jumping, and squatting (Geng et al., 2020) while minimizing system burden.

This study introduces the following innovations compared to existing motion monitoring methods based on multi-sensor fusion: First, efficient identification can be achieved using a single sensor, which reduces the hardware requirements and makes it simpler for users to wear the devices, avoiding the need for multiple sensors with their typical disadvantages (reduced comfort, increased energy consumption, and data synchronization problems). Second, in real-time and embedded environments, computational resources and hardware costs are often limited. The method presented in this paper reduces computational complexity and hardware requirements by using a single sensor and simple feature extraction, enabling real-time activity recognition on resource-constrained devices. This method can solve the problems of inconvenient data collection and low accuracy in traditional sports monitoring technology, thereby improving the efficiency and accuracy of sports monitoring and providing users with more accurate sports data support.

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