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AI Approaches in Gait and Posture Analysis: A Review

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Abstract

This review synthesizes current research on the application of artificial intelligence (AI) in gait and posture analysis, focusing on methodologies, algorithms, and clinical applications. It examines the use of machine learning (ML) and deep learning (DL) techniques to extract relevant features from sensor-derived data, offering objective, and automated assessments that surpass traditional methods. A systematic literature review was conducted, analyzing studies that utilized AI for gait and posture analysis with quantitative data from wearable sensors, motion capture systems, or depth cameras. The review highlights the strengths of AI, including its high accuracy and capacity to process large datasets, while acknowledging limitations such as data heterogeneity, interpretability challenges, and generalization issues. Results indicate that ML algorithms, like SVM, RF, and KNN, and DL models like CNN and RNN, are effectively employed for gait and posture classification, parameter estimation, and clinical applications such as Parkinson's disease monitoring, scoliosis screening, and fall risk assessment. Future research directions emphasize addressing data heterogeneity, developing real-time analysis capabilities, enhancing explainable AI, and integrating personalized analysis into clinical workflows. The integration of AI into clinical practice holds the potential to revolutionize the diagnosis and management of musculoskeletal and neurological disorders, improving patient outcomes and quality of life.

Keywords: Gait, posture, AI, Machine Learning, Deep Learning, wearable devices, sensor, cameras

INTRODUCTION

Human posture and gait are intricate biomechanical processes serving as significant indicators of neurological and musculoskeletal well-being. Deviations from typical posture and gait patterns can signal various orthopedic injuries, Parkinson's disease, stroke, cerebral palsy, and other underlying medical conditions. Traditionally, the evaluation of posture and gait has relied heavily on time-consuming kinematic measurements and subjective visual assessments [1].

However, the increasing availability of wearable sensors, depth cameras, and sophisticated motion capture systems has generated a substantial amount of quantitative data, paving the way for artificial intelligence-driven analysis [2]. Machine learning (ML) and deep learning (DL) algorithms can now automatically identify complex features and trends within this data, enabling more efficient and objective evaluations [3]. This review seeks to thoroughly investigate the application of AI methodologies in gait and posture analysis, with a focus on the specific algorithms employed, their clinical applications, and potential avenues for future research [4].

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MATERIALS AND METHODOLOGY

Literature Search Strategy

A systematic literature search was conducted using electronic databases including PubMed, IEEE Xplore, ScienceDirect, ACM Digital Library, and Google Scholar. The search terms included:

"gait analysis," "posture analysis," "artificial intelligence," "machine learning," "deep learning," "wearable sensors," "motion capture," "kinematic analysis," "clinical application," and related keywords. The search was limited to peer-reviewed articles published in English between 2010 and 2025.

Inclusion and Exclusion Criteria

Inclusion

- AI techniques for gait or posture analysis.
- Quantitative information from depth cameras, motion capture devices, or wearable sensors was used.
- Report on the performance of the AI algorithms.
- Addressed clinical applications or diagnostic outcomes.

Exclusion

- Focused solely on traditional gait or posture analysis without AI.
- Employed qualitative or subjective assessments.
- Were review articles, conference abstracts, or book chapters (except for significant reviews used as secondary sources).

Data Extraction and Synthesis

This review synthesized data extracted from selected articles, encompassing data types (kinematic, kinetic, inertial), sensor types (accelerometers, gyroscopes, motion capture systems, depth cameras), AI algorithms (SVM, RF, KNN, CNN, RNN), extracted features (gait parameters, joint angles, postural sway), performance metrics (accuracy, sensitivity, specificity), and clinical applications (Parkinson's disease, stroke, scoliosis, fall risk), to identify trends, patterns, and key findings regarding the application of AI in gait and posture analysis.

RESULTS AND DISCUSSION

AI Techniques in Gait Analysis

Machine Learning (ML) algorithms, including Support Vector Machines (SVM), Random Forests (RF), and k-Nearest Neighbors (KNN), are commonly utilized for gait classification and parameter estimation, effectively processing structured data from kinematic and inertial sensors [5, 6]. Deep Learning (DL) models, particularly Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), demonstrate enhanced capabilities in analyzing complex gait patterns from raw sensor data and video sequences, with CNNs excelling in image-based data and RNNs in sequential data [7–9]. AI facilitates automated feature extraction of essential gait parameters like stride length, cadence, and swing phase duration. Consequently, AI-driven gait analysis finds applications in the diagnosis and monitoring of clinical conditions such as Parkinson's disease, stroke, multiple sclerosis, and orthopedic injuries [8, 10].

AI Techniques in Posture Analysis

Machine Learning (ML) algorithms are employed to classify postural abnormalities, such as scoliosis and kyphosis, by utilizing features derived from depth camera data and wearable sensors. Deep Learning (DL), specifically Convolutional Neural Networks (CNNs), exhibits promising outcomes in analyzing postural images and identifying subtle deviations from normal posture [11, 12]. AI facilitates the extraction of features related to joint angles, body sway, and spinal curvature. Consequently, AI-based posture analysis is utilized in clinical applications including scoliosis screening, fall risk assessment, and rehabilitation monitoring [11, 12].

Strengths and Limitations

AI's strengths lie in its capacity for automated and objective analysis, high accuracy, and efficient processing of large datasets, enabling the identification of subtle patterns beyond traditional methods.

However, limitations include the requirement for substantial labeled datasets for training, challenges in interpreting Deep Learning (DL) models, and concerns regarding generalization across diverse populations and environments.

Challenges and Future Directions

Moving forward, key areas requiring focus include tackling data heterogeneity stemming from varied sensors and patient demographics and developing AI capable of real-time gait and posture monitoring for immediate clinical application. Enhancing Explainable AI (XAI) to improve model interpretability is vital for building trust and facilitating clinical adoption, while personalized analysis, tailoring algorithms to individual patient needs, presents a promising avenue for research. Finally, seamless integration of AI tools into existing clinical workflows is crucial for ensuring widespread and effective use.

CONCLUSIONS

AI has emerged as a powerful tool for gait and posture analysis, offering significant advantages over traditional methods. ML and DL algorithms demonstrate high accuracy and efficiency in extracting meaningful features from complex data. Future research should focus on addressing data heterogeneity, real-time analysis, explainability, and personalized analysis. The integration of AI into clinical workflows has the potential to revolutionize the diagnosis, monitoring, and rehabilitation of various musculoskeletal and neurological disorders, improving patient outcomes and quality of life.

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