Machine Learning Algorithms in Human Gait Analysis

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INTRODUCTION

Gait Analysis (GA) is the quantitative description of walking in terms of its mechanical aspects (Whittle, 2014). An illustration of various phases of the human gait can be seen in Figure 1. It is also defined as a synchronized movement of lower-limbs passing through various phases while maintaining a postural balance. If the coordinated movement of the human legs disturbs, the gait trajectory is considered as deviated one and called as abnormal gait. Therefore, the practical significance of the clinical gait analysis is known for the assessment of neurological, neuromuscular, and neurodegenerative disorders within different age groups. Moreover, the clinical data of abnormal gait helps medical professionals to understand the onset of any disease after neural impairment. Research into this topic has made steady progress over the past fifteen years through the proliferation of AI/ML-driven techniques into the field.

GA is carried out based on kinematics and kinetics, the former being concerned with the description of movement without considering forces that cause said movement and the latter doing the opposite. Kinematic approaches rely on joint angles, segment angles, and related angular velocities and accelerations. In contrast, kinetic approaches use ground reaction forces (GRFs), plantar forces, joint reaction forces, and torques. These are equally important to a comprehensive and valuable analysis of the pathological gait. Nowadays, exploiting healthy gait data, researchers have designed, developed, and controlled various lower-limb rehabilitation devices for motion assistance and gait rehabilitation of patients suffering from neural disorders (Kalita et al., 2021).

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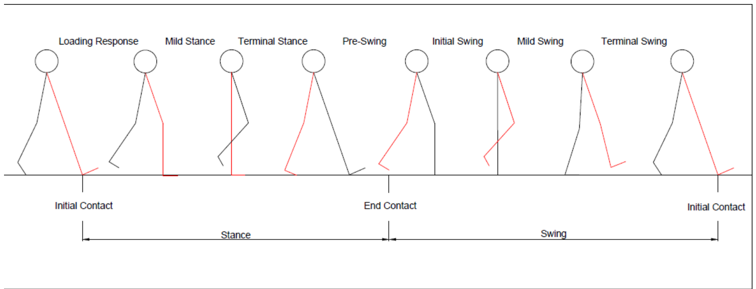
Figure 1. Human gait cycle



BACKGROUND

The gait data acquisition is often carried out through relational mapping of optometric and inertial sensor readings with supervised or unsupervised learning. Various approaches for tackling gait analysis through AI/ML methodologies have been documented over time. Choi et al. (2013) presented a 13-26-3 layered input-hidden-output ANN (Artificial Neural Network) used to estimate GRFs along three axes. Oh et al. (2013), through a different approach involving a smaller FFNN (Feed Forward Neural Network) of 14-3-6, managed to attain not only the reaction forces but moments along the three axes. Some of the said limitations of this approach were addressed by Ardestani et al. (2015) and successfully obtained the standard and rehabilitation gait patterns. A TDNN (Time Delay Neural Network) was utilized with genetic algorithms to get these results.

Further, it is essential to note that aside from the methodology used for the analysis, specifics of data collection methods can also strongly impact the efficacy. Positioning of the sensors can strongly affect the quality of data and results. The sensor position also affects data compatibility, making it challenging to address the potency of analysis methods that use different sensor positions. This was discussed by Mu et al. (2020) in their attempt to develop a supervised model that could transfer from sensors mounted in one position corresponding to a labeled phase space to another that does not have labels. The applications of these GA methods are vast and expansive, finding use in gender identification by Guffanti et al. (2020); Parkinson's Disease by Mu et al. (2017); Cerebral Palsy based on research by Choisne et al. (2020) and in simple gait event detection in several different studies. Recently, Narayan and Kumar Dwivedy (2021) proposed a low-cost gait rehabilitation device where clinical gait analysis is used as a reference trajectory for the gait correction of Cerebral Palsy subjects.

Although significant developments are being carried out in gait analysis using machine learning techniques, the comprehensive reviews on such techniques are very limited in the literature. The motivation behind this research lies in the possibility of quick, inexpensive, and accurate monitoring and analysis of pathological gait to understand root causes before the prescription of remedial treatments. Therefore, in this work, a mini yet systematic review is carried out to understand related technological contributions, which are as follows:

- Details of data acquisition methods and their classifications and types of data used in human gait analysis.
- In-depth exploration of four categories of relevant and effective ML techniques, i.e., Supervised, Unsupervised, Probabilistic, and Hybrid learning for gait analysis
- Discussions and future inferences for available gait data in the literature.

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