Chapter 17
Gait Abnormality Detection Using Deep Convolution Network

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ABSTRACT

Human gait analysis plays a significant role in clinical domain for diagnosis of musculoskeletal disorders. It is an extremely challenging task for detecting abnormalities (unsteady gait, stiff gait, etc.) in human walking if the prior information is unknown about the gait pattern. A low-cost Kinect sensor is used to obtain promising results on human skeletal tracking in a convenient manner. A model is created on human skeletal joint positions extracted using Kinect v2 sensor in place using Kinect-based color and depth images. Normal gait and abnormal gait are collected from different persons on treadmill. Each trial of gait is decomposed into cycles. A convolutional neural network (CNN) model was developed on this experimental data for detection of abnormality in walking pattern and compared with state-of-the-art techniques.

DOI: 10.4018/978-1-7998-3053-5.ch017

INTRODUCTION

Automatic diagnostic systems for pathological gait based on machine learning (ML) techniques have become a popular approach in rehabilitation centers and clinics (Khokhlova et al., 2019; Rueangsirarak et al., 2018). ML-based automatic gait assessment techniques have surpassed all other classical approaches with its quantitative assessment, preciseness in prediction, and effectiveness to deal with high dimensional data (Figueiredo et al., 2018). Examination of the progress of gait treatment using such automated systems is vital for certain neuromusculoskeletal diseases (Papageorgiou et al., 2019).

Periodic assessment of gait pattern using these systems helps the clinicians to prescribe patient-specific intervention and plan future treatment (Figueiredo et al., 2018). Qualitative analysis of gait pattern is highly laborious and prone to the experience level of the doctors for precise assessment (Rueangsirarak et al., 2018). Quantitative analysis based on statistical methods or mathematical transform often fails to model complex nonlinear relationship of gait data (Figueiredo et al., 2018). Automatic diagnostic systems based on ML algorithms detect gait abnormality by classifying normal and pathological gait using some salient features. In literature, different supervised classification models have been used for gait diagnosis (De Laet et al., 2017; Zhang et al., 2009), out of which support vector machine (SVM) was reported to be the best (Figueiredo et al., 2018). Recently, Convolutional Neural Network (CNN) model has gained popularity due to its effectiveness to deal with high dimensional data (Castro et al., 2017; S. S. Lee et al., 2019). But, the investigation of the usability of this model to diagnose human gait is still in its infant state.

Most of the existing gait diagnosis systems contain highly expensive sensors which make them non-affordable for most of the clinics, especially in the developing countries. An affordable gait diagnosis system is an urgent need for the modern society. Low-cost Microsoft Kinect sensor, demonstrated to be worthy for gait diagnosis (Bei et al., 2018; Khokhlova et al., 2019) due to its portability, affordability, and unobtrusive sensing property, seems to be promising gait diagnosis.

The rest of this chapter is organized as follows. In section 2, relevant state-of-the-art literature is provided. In section 3, data processing, experimental setup and proposed CNN model for the classification of human gait as Normal and Abnormal is provided. In section 4, the results and comparison with other existing models are presented. Finally, this chapter concluded with future research directions in section 5.

Related Work

Considerable amount of works has been done to construct automatic diagnostic system. Vaughan et al. (2005) constructed a diagnostic system based on fuzzy clustering technique. Using spatio-temporal feature they have identified five different clusters which represent different walking pattern of Cerebral Palsy (CP) patients. Schmidt et al. (2006) established a fuzzy rule-based expert system using surface EMG signal and investigated its clinical applicability. Carriero et al. (2009) used principal component analysis (PCA) and fuzzy C-mean clustering to diagnose CP gait pattern. They found some overlapping clusters representing variable gait type of CP patients. Laet et al. (2017) combined expert knowledge with ML-based gait diagnosis techniques and reported a better performance than fully quantitative method. But, all of these diagnostic systems for CP patients associates high cost. Dolatabadi et al. (2017) proposed an automated gait diagnosis system for acquired brain injury (ABI) and stroke patients using two Kinect (v2) sensors. Two Kinect v2 sensors were placed at the opposite ends of walking track. The authors examined the ability of k-nearest neighbor (k-NN) and Gaussian Process Latent Variable Model