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# AUTOMATIC GAIT ANALYSIS: A REVIEW

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## ABSTRACT

*Human Gait disorders are considered as continuous nervous system dysfunction which shows abnormality in walking. Exact classification and identification of brain disease is vital for the primary analysis and proceed the treatment plan. But, the doctors find very difficult in diagnosis of cognitive level disorder and it needs accurate diagnosis and classification by machine intelligent based techniques.Hence for the effective identification of human motor diseases, machine learning based techniques are utilised. Thestudies which implements various machine intelligent techniques for the classification and identification of gait bound disorders were reviewed in this paper.*

**KEYWORDS:** *Gait Analysis, Gait Disorders, Machine Learning Techniques.*

## INTRODUCTION

Gait is mainly related with the way of walking. Every human has anexclusive gait pattern. The human gait pattern involves movement of arms, legs, hips, feet, lower limb, upper limb etc. Analysis of such gait pattern in pathological condition may help to the finding of cognitive level disorders [1]. Thus, to classify the type of neural disorders the human walk patterns need to be analysed.

Movement disorders are caused by spinal cord injury, Parkinson disease, multiple sclerosis, cerebral palsy, Huntington disease, Alzheimer's disease, hip and knee osteoarthritis, stroke and age-related gait impairment [2]. Early identification of such a disease by doctors in subjective analysis is difficult and hence some automatic gait recognition techniques were proposed in recent years.

The identification of human gait abnormality consists of phases such as data collection, feature extraction, classification and identification. Some of the studies related to the analysis of gait disorders is reviewed in this paper.

## LITERATURE SURVEY

Pushpa Rani[6] proposed a modified version of Extreme Learning Machine called Hybrid Extreme Learning Machine (HELM), which uses the Analytical Network Process (ANP) for choosing the input weights and hidden biases. Experimental results prove that the Hybrid Extreme Learning Machine (HELM) technique for gait classification results in better accuracy compared to the existing ELM and SVM techniques. HELM technique gives classification accuracy of 98.5% with the use of PCA and 99.2% with T-Test. The classification time is 0.51 seconds by using PCA and 0.38 seconds with T-test.

Djordje et al., [4] presents a method for classification of normal and impaired gait. Then classified four gait disorders associated with the hip, knee, ankle and calcaneus. The principal component analysis (PCA)

filter method is applied for preprocessing the gait data. The support vector machine(SVM) classier is used for the classification normal and four gait disorders shows best result. The classification of normal and gait disorder with linear SVM and RBF SVM gives an accuracy of 90.8% and 89.1%. The classification of normal and 4 gait disorders (Hip,Knee,Ankle,calcaneus) with linear SVM and RBF SVM gives an accuracy of 54.3% and 51.2%.

Wei Zeng et al., [7] proposed a method for the classification of parkinson's disease patients and healthy patients by using Radial Basis Function (RBF) neural networks. For training the dataset the gait dynamics of healthy controls and parkinson's diseases patients are approximated by RBF neural networks and stored in constant RBF networks. In the classification phase the constant RBF network is embeded in a bank of dynamical estimators. The classification is done with five-fold cross validation method and got 96.39% accuracy.

## GAIT RECOGNITION TECHNIQUES

### Gait Analysis Phases:

The human gait patterns can be recognized using various techniques to identify the human gait disorders. The figure 1 shows the phases for the identification of human gait disorders. Primary phase is to collect the human gait patterns, which can be gathered from the Public database or with the help of wearable inertial sensors or through video systems. The publicly available benchmark database such as PhysioBank[3]has gait measures of patientswhich is widely used in the most studies [1,7 ].

Preprocessing is the process of removing unwanted and redundant features and extracting the needed features to improve further classification process with lesser time. In feature extraction and selection phase the desired gait features are identified and extracted for further classification with the feature extraction techniques. In classification phase, the extracted gait features are classified into normal and abnormal gait patterns with the machine intelligent based techniques. Then the identification phase deals with particular diagnosis of the type of gait diseases based on the gait patterns.

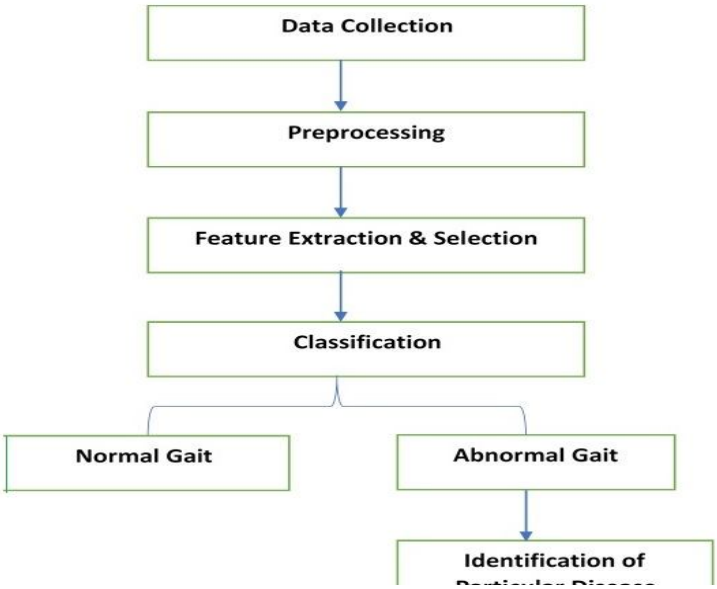


Fig 1: Phases of Gait Analysis

### Abnormal Gait Classification with HELM:

Pushpa Rani et al.,[6] presents classification of gait patterns with Hybrid Extreme Learning Machine(HELM). This system consists of several digital or analog cameras for acquiring gait video data. The

gait videos are segmented into many frames. Finally, background elimination method is done and silhouette images are collected for further processing. This video-based data can be collected from the publicly available CGA Normative gait database [5].

In preprocessingthe morphological operations like erosion, dilation and outermost contour technique are applied in each silhouette image to extract features and distance signals. Then the ranking of extracted features is done with T-Test algorithm to avoid redundant features.

The classification of normal and abnormal gait is done with HELM technique which is the modified version of Extreme Learning Machine (ELM). First, the input weight and hidden biases are chosen randomly with the help of Analytical Network Process (ANP) technique. Then corresponding output weights are fixed with the ELM algorithm and the output hidden biases are randomly generated. Finally, training is done with the HELM and the trained data is classified into normal and abnormal gait using the CGA Normative Gait database.

### Classification of Gait Disorders with SVM:

Djordje et al., [4] first classified normal and impaired gait. Then classified four gait disorders associated with the hip, knee, ankle and calcaneus.The dataset used is collected from the clinical gait database maintained by rehabilitation centre of the Austrian workers Compensation Board(AUVA). This database contains GRF measurement including center of pressure (COP) signals from 279 patients with gait disorders (GD) and 161 healthy controls which are gathered with force plates under the ground. The patients were classified with the four classes as calcaneus, ankle, knee and hip by physical therapist.

For preprocessing the principal component analysis (PCA) filter method is applied to reduce the dimension of a dataset by transforming the data into a set of uncorrected principal components (PCs) variables. The discrete GRF parameters in combination with time distance parameters (TDP) and the global PCA parameters is investigated by Linear Discriminant Analysis (LDA) to access the discriminative power of individual parameters. Hence additional modelling and data transformation is not needed.The SVM classifier applied in this study for the classification of normal and abnormal gait and also multi-class classification between normal and four gait disorders (calcaneus, ankle, hip and knee)

The SVM employed for the classification with linear and radial basis function (RBF) kernels. The DPs and TDP parameters were normalized by min-max normalization and PCA representations were Z-standardized. The linear SVM shows best performance by applying PCA to all five GRF signals.

### Parkinson's Disease Classification with RBF Neural Network:

Wei Zeng et al., [7] proposed a method for the classification of Parkinson's disease patients and healthy patients by using Radial Basis Function (RBF) neural networks. The Ground Reaction Force (GRF) gait data provided by Physio Bank public database [3] was used in this study.

This database contains measures of gait from 93 patients with idiopathic PD and 73 healthy controls. In this database 8 different sensors were placed in each foot of the subjects and measured the vertical ground reaction force [3]. From the time series of the left and right foot various gait features are collected as the Variants of gait dynamic feature vectors.

In preprocessing and selection phase, the stride-to-stride time series data of footfall contact times such as left and right swing intervals, the left and right stance intervals are derived from GRF signals. The standard deviation (SD), the mean and coefficient of variation (CV) are calculated as technical tools to assess the gait dynamics and analyse the difference of gait between PD patients and healthy control gait between PD patients and healthy control subjects and useful for further classification.

For training the dataset the gait dynamics of healthy controls and neurodegenerative diseases patients are approximated by Radial Basis Function (RBF) neural networks and stored in constant RBF networks. In the classification phase the constant RBF network is embeded in a bank of dynamical estimators. The set of estimators and test gait patterns of the patients are compared and classified with five-fold cross validation method.

## RESULT AND DISCUSSION

According to the survey it is found that PCA is a widely usedpreprocessingor feature Selection technique for dimensional reduction of gait dynamics. The dimensional reduction does not imply on recognition performance but it reduces the complexity of data features and computational cost of the recognition process.The classification of disease is evaluated with cross-validation scheme with different k-folds (5-fold [4,7]) in the reviewed studies. The Hybrid ELM classifier with PCA applied for the classification of abnormal gait[5] gives the highest accuracy of 99.2% compared with other classifiers. The review shows the human gait pattern classification and recognition made easier with the implementation of machine learning techniques which has the ability to work with nonlinear and multidimensional gait data. The table.1 shows the study goal, techniques used in preprocessing and classification phase and results of the reviewed literatures. The figure.1 shows the graphical representation of classification accuracy of the reviewed literatures.

**Table 1: Studies that applied Machine learning approach for gait pattern classification**

| Author | Study Goal | Preprocessing/Feature Extraction Techniques | Classification/Recognition Techniques | Results |
|---|---|---|---|---|
| Pushpa Rani et al.,[6] | Classification of normal and abnormal gait | PCA & T-Test | Hybrid ELM | Accuracy of 99.2% with T-Test |
| Djordje et al., [4] | Classification of orthopaedic gait impairments at hip, knee, ankle & calcaneus | PCA & LDA | Support Vector Machine | Accuracy of 91% with LinearSVM(N/GD classification) |
| Wei Zeng et al., [7] | classification of Parkinson's disease | Mean,SD,CV | RBF Neural Networks | Accuracy of 96.39% |

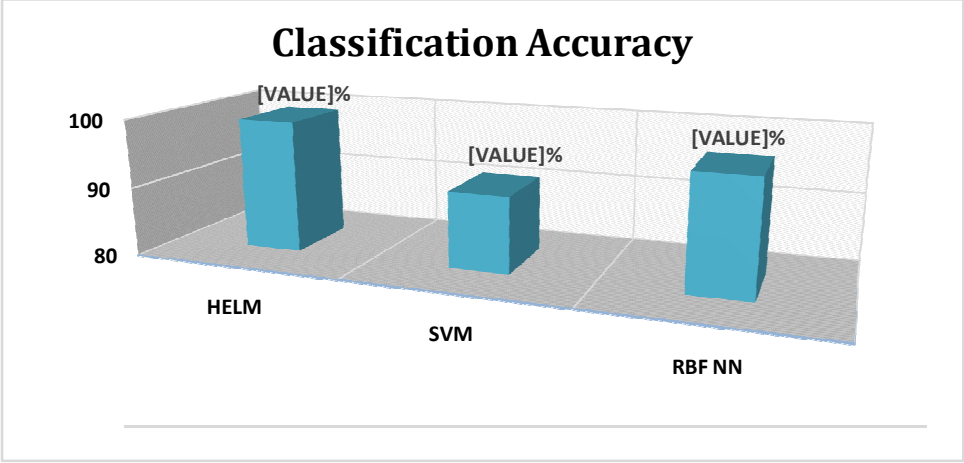


**Figure1: Graphical Representation of Classification Accuracy**

## CONCLUSION

This paper considersreview on automatic gait analysis techniques proposed in various literaturesas a means to deduce if an observed walking pattern appears to be normal or not. The majority of gait analysis techniques known from literature which implements machine learning algorithms for the classification of

gait disorders and got good results. Hence the machine intelligence-based technique will be proposed in future for the effective classification and identification of gait bound diseases with minimum time and accuracy.

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