Expert Systems With Applications 56 (2016) 156–163

Contents lists available at ScienceDirect

Expert Systems With Applications

journal homepage: www.elsevier.com/locate/eswa

Detection of Parkinson's disease by Shifted One Dimensional Local Binary Patterns from gait

Ömer Faruk Ertuğrul[a,*], Yılmaz Kaya[b], Ramazan Tekin[c], Mehmet Nuri Almalı[d]

[a] Department Electrical and Electronic Engineering, Batman University, 72060 Batman, Turkey
[b] Department Computer Engineering, Siirt University, 56100 Siirt, Turkey
[c] Department Computer Engineering, Batman University, 72060 Batman, Turkey
[d] Department Electrical and Electronic Engineering, 100. Yıl University, 65080 Van, Turkey

ARTICLE INFO

Article history:
Received 14 January 2015
Revised 6 March 2016
Accepted 7 March 2016
Available online 15 March 2016

Keywords:
Parkinson's disease
Shifted one-dimensional local binary pattern
Automatic diagnosis
Expert systems
Biomedical
Gait

ABSTRACT

The Parkinson's disease (PD) is one of the most common diseases, especially in elderly people. Although the previous studies showed that the PD can be diagnosed by expert systems through its cardinal symptoms such as the tremor, muscular rigidity, disorders of movements and voice, it was reported that the presented approaches, which utilize simple motor tasks, were limited and lack of standardization. To achieve a standard approach in PD detection, an approach, which is built on shifted one-dimensional local binary patterns (Shifted 1D-LBP) and machine learning methods, was proposed. Shifted 1D-LBP is built on 1D-LBP, which is sensitive to local changes in a signal. In 1D-LBP the positions of neighbors around center data are constant and therefore, the number of patterns that can be exacted by it is limited. This drawback was solved by Shifted 1D-LBP by changeable positions of neighbors. In evaluation and validation stages, the Gait in Parkinson's Disease (gaitpdb) dataset, which consists of three gait datasets that were recorded in different tasks or experiment protocols, were employed. Statistical features were exacted from formed histograms of gait signals transformed by Shifted 1D-LBP. Whole features and selected features were classified by machine learning methods. Obtained results were compared with statistical features exacted from signals in both time and frequency domains and results reported in the literature. Achieved results showed that the proposed approach can be successfully employed in PD detection from gait. This work is not only an attempt to develop a PD detection method, but also a general-purpose approach that is based on detecting local changes in time ordered signals.

1. Introduction

Parkinson's disease (PD), which was described in detail by Bisaglia, Filograna, Beltramini, and Bubacco (2014), is a progressive neurodegenerative disease that causes progressive motor control, cognitive and visual deficits (Stuart, Alcock, Galna, Lord, & Rochester, 2014; Yuvaraj et al., 2014a). It was pointed out that the PD, which is the second most common neurodegenerative disorder after Alzheimer disease and influence a large part of a worldwide population of elderly people (Das, 2010; Hariharana, Polat, & Sindhu, 2014). Pan, Iplikci, Warwick, and Aziz (2012) reported that the ratio of PD affected people was around 180/1,000,000 in 2012 and the prevalence of PD has been in an increasing trend because of the prolongation of mean human life. The cardinal symptoms of PD are the tremor, muscular rigidity, bradykinesia (i.e., slowness of movement), akinesia (impaired movement) and dysphonia (disorders of voice). Also, emotional processes are often accompanied by these symptoms such as depression, executive dysfunctions, sleep disturbances, autonomic impairments (Yuvaraj et al., 2014b).

Numerous intelligent PD detection methods, which depended on the identification of one or more physiological and psychological symptoms of PD, were presented as an alternative or as a diagnostic support system for clinical studies. For example, higher accuracy was reported by employing an expert system that was based on a motion sensor attached to the index finger with compared to conventional clinical ratings for measuring bradykinesia, hypokinesia, and dysrhythmia in PD patients (Heldman, Espay, LeWitt, & Giuffrida, 2014). Due to the larger ratio of PD affected people, there is a lot of study in the literature about PD detection and some of them are summarized in Table 1.

Since, PD patients prone to fall and may lose their functional independence with severe gait disturbances, gait disorders are one of the major debilitating symptoms in detecting PD patients. Also,

---

[*] Corresponding author. Tel.: +90 488 2173719; fax: +90 488 2153601.
E-mail addresses: omerfarukertugrul@gmail.com, omerfaruk.ertugrul@batman.edu.tr (Ö.F. Ertuğrul), yilmazkaya1977@gmail.com (Y. Kaya), ramazan.tekin@batman.edu.tr (R. Tekin), mna1@yyu.edu.tr (M.N. Almalı).

http://dx.doi.org/10.1016/j.eswa.2016.03.018
0957-4174/

Table 1
Some PD detection studies presented in the literature.

References	Dataset type	Method	Obtained accuracy
Prashanth, Roy, Mandal, and Ghosh (2014)	Dopaminergic imaging using single photon emission computed tomography with ^{123}I-Ioflupane	Support vector machine and logistic regression method	96% classification accuracy
Camara et al. (2015)	Local field potentials that were recorded in the subthalamic nucleus	Discrete wavelet transform and artificial neural network	89.5% classification accuracy
Khan, Westin, and Dougherty (2014)	3 and 2 levels of the Unified Parkinson's Disease Rating Scale	Support vector machines	85% and 92% classification accuracies for 3 and 2 levels, respectively
Yuvaraj et al. (2014a)	EEG signals under six emotional states (happiness, sadness, fear, anger, surprise and disgust)	ICA method	76.90% ± 1.08% and 86.78% ± 2.08% classification accuracies, for PD patients and healthy controls, respectively
Yuvaraj et al. (2014b)	EEG signals under six emotional states (happiness, sadness, fear, Anger, surprise and disgust)	Higher order spectral features and k Nearest Neighbor and Support Vector machine	The highest obtained accuracy was 93.16% for Surprise emotion
Mazilu et al. (2012)	Gait signals (DAPHNet dataset)	Naïve Bayes, Random Forests, C4.5, MLP, AdaBoost with C4.5 and Bagging with C4.5	Average sensitivity and specificity were 0.95
Tripoliti et al. (2013)	Gait signals	Naïve Bayes, Random Forests, Decision - Random Tree methods	Obtained accuracies were in the range of 96.11% - 91.2%
Kim et al. (2015)	Gait signals	AdaBoost.M1 classifier	Obtained highest sensitivities were 0.86, 0.84 and 0.81 when sensor was at waist, trouser pocket and ankle, respectively
Mazilu et al. (2016)	Gait signals recorded from upper and lower limb motion (the CuPiD dataset)	FFT-based + statistical features and machine learning methods	90% classification accuracy
Chen et al. (2013)	Speech signals	Fuzzy k-nearest neighbor	The highesr classification accuracy was 96.07%
Hariharana et al. (2014)	Speech signals	A hybrid method of Gaussian mixture model, principal component analysis, linear discriminant analysis, sequential forward selection and sequential backward selection and least square support vector machine, probabilistic neural network and general regression neural network	The highest obtained accuracy was 100%
Peker, Şen, and Delen (2015)	Speech signals	Minimum redundancy maximum relevance attribute selection and complex-valued artificial neural network	98.12% classification accuracy
Chakraborty, Chakraborty, and Mukherjee (2016)	Speech signals	Sugeno–Takagi Fuzzy Inference System based on Fuzzy C-Means clustering	96.4% classification accuracy
Gürüler (2016)	Speech signals	k-means clustering-based feature weighting method and a complex-valued artificial neural network	The highest obtained accuracy was 99.52%

recording gait signals is easy in a consultation and it does not decrease the comfort of patients. Taken into account these facts, gait signals are generally employed for this purpose. For instance, Bronstein, Hood, Gresty, and Panagi (1990) employed moving room test to detect the PD patients. But, via this method, high classification accuracy was achieved while the room was moving, on the other hand, the PD patients and healthy controls did not distinguish, when the room was stationary. Halliday, Winter, Frank, Patla, and Prince (1998) presented a method to detect the freezing of gait events (FoG), which is an extreme form of gait dysrhythimicity, by utilizing the EMG signals. Wearable sensors were employed for long-term monitoring of gait in PD instead of EMG signals (Moore, MacDougall, Gracies, Cohen, & Ondo, 2007).

Tripoliti et al. (2013) used wearable sensors (six accelerometers and two gyroscopes) to detect FoG events. The entropies of sensor signals recorded from healthy subjects, patients with FoG symptoms and patients without FoG symptoms were classified by Naïve Bayes, Random Forests, Decision Trees and Random Tree. Reported FoG detection accuracy, sensitivity, and specificity of the Random Forests were 96.11%, 81.94%, and 98.74%, respectively. Moreover, Grimpampi, Bonnet, Taviani, and Mazza (2013) presented a method for classifying hemiplegia and PD based on lower trunk angles during pathological over ground level walking from the angular velocities recorded by a wearable inertial sensor. Furthermore, Woods, Nowostawski, Franz, and Purvis (2014) achieved 96% accuracy in discriminating Parkinson's and Essential postural tremors via digital acceleration sensors integrated on a smartphone by discrete wavelet transform and support vector machines. Although extensive researches have been carried out on PD detection, Stuart et al. (2014) reported that the methods, which utilize simple motor tasks for detecting PD, were limited and lack of standardization that can also be seen from Table 1.

The aim of this study is to evaluate and validate a general expert and intelligent system in order to detect PD from any gait signal. However, analyzing signals with different circumstances (for example, to compare the patterns of rhythmic auditory stimulation and walking for complex tasks) decreases the accuracy of employed machine learning, in order to develop a general scheme to detect PD by gait, the Gait in Parkinson's Disease (gaitpdb) dataset, which consists three gait datasets that were recorded in different tasks or experiment protocols, were employed in tests as a reference dataset in this study (Frenkel-Toledo et al., 2005a, 2005b; Yogev et al., 2005; Hausdorff et al., 2007). In order to achieve higher detection accuracy and also lower computational cost and