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A new hybrid intelligent system for accurate detection of Parkinson's disease

M. Hariharan[a,*], Kemal Polat[b], R. Sindhu[c]

[a] School of Mechatronic Engineering, Universiti Malaysia Perlis (UniMAP), 02600, Campus Pauh Putra, Perlis, Malaysia
[b] Department of Electrical and Electronics Engineering, Faculty of Engineering and Architecture, Abant Izzet Baysal University, 14280 Bolu, Turkey
[c] School of Microelectronic Engineering, Universiti Malaysia Perlis (UniMAP), 02600, Campus Pauh Putra, Perlis, Malaysia

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ABSTRACT

Elderly people are commonly affected by Parkinson's disease (PD) which is one of the most common neurodegenerative disorders due to the loss of dopamine-producing brain cells. People with PD's (PWP) may have difficulty in walking, talking or completing other simple tasks. Variety of medications is available to treat PD. Recently, researchers have found that voice signals recorded from the PWP is becoming a useful tool to differentiate them from healthy controls. Several dysphonia features, feature reduction/selection techniques and classification algorithms were proposed by researchers in the literature to detect PD. In this paper, hybrid intelligent system is proposed which includes feature pre-processing using Model-based clustering (Gaussian mixture model), feature reduction/selection using principal component analysis (PCA), linear discriminant analysis (LDA), sequential forward selection (SFS) and sequential backward selection (SBS), and classification using three supervised classifiers such as least-square support vector machine (LS-SVM), probabilistic neural network (PNN) and general regression neural network (GRNN). PD dataset was used from University of California-Irvine (UCI) machine learning database. The strength of the proposed method has been evaluated through several performance measures. The experimental results show that the combination of feature pre-processing, feature reduction/selection methods and classification gives a maximum classification accuracy of 100% for the Parkinson's dataset.

1. Introduction

Parkinson's disease is a progressive neurodegenerative disorder which can be characterized by several indications like tremor, rigidity and slowness of movements. PWP may have difficulty in walking, talking or completing other simple tasks [1–3]. According to the statistics by Parkinson's disease foundation, it is estimated that seven to 10 million people are living with PD worldwide [4]. In next 25 years, the number of PWP is expected to increase due to the raise in proportion of elderly people [1–3]. Age is the most important risk factor for the onset of PD as the incidence of PD increases with age. With the new and effective medications of PD, several improvements are possible to enhance PWP's quality of life. Researchers have proposed various non-invasive methods to

* *Corresponding author*. Tel.: +60 134622469; fax: +60 49885167.
E-mail addresses: hari@unimap.edu.my, wavelet.hari@gmail.com (M. Hariharan).
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detect the severity of PD using acoustic analysis of voice signal, physiological signals, wearable sensors and gait analysis etc. Among them, detecting PD progression using acoustic analysis of voice signal has drawn significant attention [5–11].

Little and his co-researchers have proposed different non-linear features using non-linear dynamics for the objective analysis of voice signals of PWP and healthy controls [9–11]. These methods could help to improve the existing methods through better representation of voice signals. Little et al. have conducted substantial research using the non-linear and several conventional pitch/amplitude perturbation based features for the discrimination of the voice signals of PWP and healthy controls. The success rate was 99% using the best selected features through support vector machine based classifier. Several studies have been conducted using Little's PD dataset in the past three years and they have achieved the accuracy from 75.03% to 100% using various feature selection, feature pre-processing and classification algorithms [12–21]. For instance, Kemal Polat has applied a feature pre-processing method based on fuzzy *c*-means clustering for the classification of PD's and obtained a maximum accuracy of 96% [22] with *k*-nearest neighbor classifier.

In this paper, a new feature weighting method using Model-based clustering (Gaussian mixture model) was suggested to enrich the discriminative ability of the features (dysphonia features). In order to reduce/select the best dysphonia features, two projection based feature reduction techniques (PCA and LDA) and two step-wise feature subset selection techniques (SBS and SFS) were used. Two validation schemes were used such as 10-fold cross validation and conventional validation to demonstrate the efficacy of the proposed method. LS-SVM, PNN and GRNN were used as classifiers to discriminate the voice signals of PWP and healthy controls. From the experimental results, it can be concluded that the proposed hybrid intelligent system gives excellent classification accuracy of 100% using weighted dysphonia features.

The organization of the paper is as follows: Section 2 presents the dataset description, fundamentals of feature weighting and feature reduction/selection methods. Section 3 describes the review of LS-SVM PNN and GRNN. Experimental results are presented in Section 4 and the results are discussed in Section 5. Section 6 concludes the paper.

2. Materials and methods

To evaluate the effectiveness of the proposed method, PD dataset has been taken from UCI machine learning database, which consists of both conventional and non-linear dysphonia features (22 raw features – RF) [9–11,23]. This dataset was created by Little and his colleagues in collaboration with 10 medical centers in US [9–11,23]. The dataset consists of features extracted from the speech samples of 31 people (23 with Parkinson's disease + 8 normal). An average of six sustained phonations was recorded from each subject, ranging between 1 s and 36 s in length. 48 sustained phonations from 8 normal people and 147 sustained phonations from 23 PD patients were used to extract the RF and prepare the PD dataset. Table 1 shows the list of dysphonia features used in this study.

Table 1 – List of dysphonia features [8–11].

MDVP: Fo(Hz), Fhi(Hz), and Flo(Hz)	Average, maximum and minimum vocal fundamental frequencies (3 features)
MDVP: Jitter (%), Jitter (Abs), RAP, PPQ and DDP	Measures of variation in fundamental frequency (5 features)
MDVP: Shimmer, Shimmer (dB), APQ3, APQ5, APQ and DDA	Measures of variation in amplitude (6 features)
NHR and HNR	Measures of ratio of noise to tonal components in the voice (2 features)
RPDE and D2	Non-linear dynamical complexity measures (2 features)
DFA	Signal fractal scaling exponent (1 feature)
Spread 1, Spread2, and PPE	Non-linear measures of fundamental frequency variation (3 features)

2.1. *Proposed method*

Classification of PWP and healthy controls is a typical pattern classification problem. The proposed hybrid intelligent system include feature pre-processing using Gaussian mixture model based feature weighting, feature reduction/selection using PCA, LDA, SFS and SBS and feature classification using LS-SVM, PNN and GRNN. Fig. 1 illustrates the block diagram of the proposed hybrid intelligent system. In this present work, several experiments were performed using 22 original raw features and weighted features.

2.2. *Feature weighting using Model-based clustering (Gaussian mixture model)*

Feature weighting is one of the pre-processing techniques in any pattern classification problem. These techniques have been applied by the researchers either to discard the irrelevant features or to improve the discrimination ability of the features. The performance of any classifier always depends on the relevant and robust features. Several clustering based algorithms have been proposed for feature weighting. In this work, Model-based clustering (Gaussian mixture model) approach was proposed to improve the robustness of the dysphonia features. Generally, Gaussian mixture model (GMM) was used as classification model in different pattern recognition

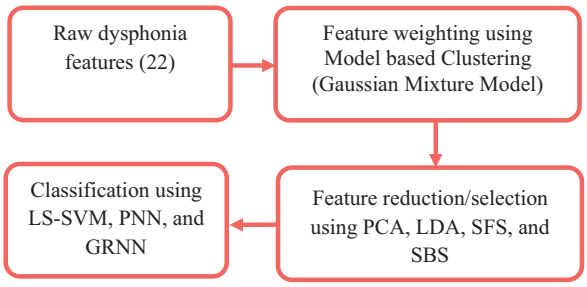

Fig. 1 – Block diagram of the proposed hybrid intelligent system (feature weighting, feature reduction/selection and classification).