Posture Detection with waist-worn Accelerometer: An application to improve Freezing of Gait detection in Parkinson’s disease patients

D. Rodríguez-Martín¹, A. Samà¹, C. Pérez-López¹, A. Català¹, J. Cabestany¹, A. Rodríguez-Molinero²

¹Technical Research Centre for Dependency Care and Autonomous Living (CETpD), Universitat Politècnica de Catalunya – BarcelonaTech (UPC), Spain
{daniel.rodriguez-martin, albert.sama, carlos.perez-lopez, andreu.catala, joan.cabestany}@upc.edu
²Electrical & Electronic Engineering Department, NUI Galway (NUIG), Ireland
alejandro.rodriguez@nuigalway.ie

Abstract. Freezing of Gait (FoG) is one of the most disturbing symptoms in Parkinson’s disease (PD). Current algorithms that detect this symptom depend on frequency features extracted from wearable systems. These algorithms have only been evaluated under laboratory conditions and, in real life, they might present false positives, reducing the reliability of the algorithm. This paper presents the evaluation of 20 PD patients in their homes and the inclusion of a posture algorithm to contextualize FoG detection. This algorithm, in average, improves specificity a 5% while preserves the sensitivity. In some patients, specificity increases by 11.9% maintaining the sensitivity.

Keywords: Accelerometers, Parkinson’s disease, Postures, Freezing of Gait, Contextualization

1 Introduction

Parkinson’s disease (PD) is a neurodegenerative disease that mainly affects the motor system. Within PD symptoms, Freezing of Gait (FoG) affects almost 50% of patients with advanced PD. FoG avoids effective stepping when walking [1] being a main cause of falls. Patients feel their feet “glued to the floor”, and consequently, loose their balance and falls [2].

FoG assessment is problematic since, on the one hand, significant percentage of PD patients affirm they do not to experience FoG episodes at the doctor’s office [3]. On the other hand, evaluation methods trust in questionnaires filled by patients, caregivers and neurologists providing a subjective assessment.

Consequently, objective assessment of FoG has been explored, mainly based on wearable movement sensors such as accelerometers and gyroscopes [4], which could
provide a precise evaluation since the symptoms could be detected at patients’ home in daily live and not only in the doctor’s office.

Another issue is the lack of reliability on the current algorithms to detect FoG giving results of sensitivity below 70% in some cases [5, 6]. For this reason, the algorithm should be enhanced by means of other techniques or contextualized in order to know the activity the patient is currently performing.

This paper presents the results of evaluating inertial signals from with 20 PD patients in their homes on detecting FoG based on current state-of-the-art method. Furthermore, a posture algorithm has been included within the evaluation in order to improve the results by means of contextualizing FoG detection (i.e., removing all those false positive episodes detected when the patient is sit). It is well-known that FoG mainly occur when the patient is stand or walking [7] and, although it have been shown that Freezing can occur when a patient is sit, the patient cannot fall in this posture or in a prone position [2]. Results show how posture contextualization significantly increases specificity up to a 5% in all the patients while sensitivity slightly decreases.

2 Evaluation methods

In this section, the main hypothesis is described and methods used to contextualize posture and perform enhanced FoG detection are presented.

The Posture Algorithm employed in this paper has been previously evaluated with PD patients achieving relevant results on posture identification [8]. This algorithm detected the following postures transitions / activities: Stand, Sit, Stand-to-Sit, Sit-to-Stand and Walking. Participants carried an inertial system called 9x2 on the left side of the waist [9] as shown on Figure 1.

![Fig. 1. The 9x2, location of the system and neoprene belt](image)

Results obtained showed sensitivities and specificities over 81% in all postures and activities after training a total of 31 healthy users and 2884 postures and evaluating over 8 PD patients in different PD motor states.

On the other hand, FoG detection algorithm was performed by Moore et al.[5] and extended by Bächlin et al.[6]. The main condition to estimate that a FoG episode has occurred in these works is presented in the following equation:
where the Freezing Index $F_I$ is power of the freeze band (3-8Hz) divided by the power of the locomotion band (0.5-3Hz) between 3 Hz and 8 Hz. Power Index ($P_I$) is the amount of movement between 0.5 to 8 Hz. According to Bächlin et al. Freezing Threshold ($F_{th}$) and Power Threshold ($P_{th}$) classifies whether a FoG episode is positive or negative [6].

FoG episodes detected by the algorithm described in Equation (1) are processed according to the current posture provided by posture detection algorithm and the following conditions:

- In case the FoG algorithm detects a Positive, but the label reveals it is not a FoG episode (False positive), the Posture Algorithm is then considered, if the Posture Algorithm detects sit posture, this False Positive episode is then removed.
- In case the FoG algorithm detects a Positive, and the label reveals this is a real FoG episode (True Positive), the Posture Algorithm is also considered, if the Posture Algorithm detects sit posture, this True Positive episode is then removed.

### Experiments

20 PD patients (7 women and 13 men) took part in the study. PD patients were diagnosed according the Brain Bank (London) criteria and all of them have given their informed consent to perform the datasets[10]. Main inclusion criteria to participate in the study were Hoehn & Yahr stage above 2 [11] and not having dementia according to DSM IV criteria [12]. The mean age of the patients is 69.3 years-old with a standard deviation of 7.05 years old. The average Hoehn and Yahr stage is 2.74 with a standard deviation of 0.41.

All patients performed tests during 20 minutes in different motor states with the 9x2 system worn at their waist on the left side. All the tests were carried out at patients’ home, which eases FoG episodes presence [3]. Among the different activities patients executed, a False Positive (FP) protocol test was performed. This protocol test relies on performing different activities in which the patient executes a movement repeatedly and, in consequence, similar to a FoG episode. Some examples of these activities are brushing their teeth, painting in a sheet of paper or cleaning windows. Some patients performed these activities while sitting.

All data were video-recorded in order to establish a gold-standard to label the activities performed by patients.
4 Results

In this section, results of the evaluation of FoG detection combined with the Posture Algorithm and only FoG detection are shown.

Since the FoG detection algorithm does not provide an accurate value for all patients, sensitivity and specificity for different Power Threshold \((P_{th})\) and \((F_{th})\) values have been obtained. Moreover, the previously described posture detection algorithm [8] has been executed and sensitivities and specificities have been obtained according to the 2 conditions explained in Section 2. Average results show a sensitivity and specificity of 71.5\% and 74.7\% respectively with the FoG algorithm. With the inclusion of the Posture algorithm, results of sensitivity and specificity are 70.1\% and 79\%.

Figure 2 shows the results after employing the Posture Algorithm to FoG detection algorithm.

As shown, sensitivities keep the results (only decrease a 1.4\%) while specificities increases up to a 15\% with some Power Indexes and Freezing Indexes. On average, specificities are increased up to a 4.7\%.

![Sensitivity and Specificity differential results for different parameter values](Fig. 2)

5 Conclusions

This paper complements current FoG detection methods with a postural assessment of the patient in order to reduce false positives when the patient is not in a standing position. In 20 PD patients with 2.74 on average at Hoehn & Yahr scale, the specificity increases up to a 5\% adding the postural context at the FoG detection algorithm by a slightly descend on specificity of 1.5\% on average.

Moreover, an improvement of 11.9\% on specificity has been achieved in a patient which performed many activities while sit without decreasing sensitivity. These results show that current FoG detection methods still require to be improved but, by means of context algorithms, enhancement on FoG detection is possible.
Acknowledgements

This work has been performed within the framework of the FP7 project REMPARK ICT-287677, which is funded by the European Community. The authors would like to acknowledge the contributions of their colleagues from REMPARK Consortium (http://www.rempark.eu).

This work is partially funded by Instituto de Salud Carlos III (MoMoPa2 PI12/03028) with FEDER funds.

References


