Infinite Science | Publishing

Is there a preferred foot side for IMU-based freezing of gait detection in Parkinson's disease?

A. Dvorani[1*], M. C. E. Jochner[3], C. Salchow-Hömmen[3], A. Kühn[3], N. Wenger[3], T. Schauer[1,2]

[1] *SensorStim Neurotechnology GmbH, Berlin, Germany*
[2] *Technische Universität Berlin, Control Systems Group, Berlin, Germany*
[3] *Charité Universitätklinik, Neurology Department, Berlin, Germany*
[*] *Corresponding author, email: advorani@sensorstim.com*

Abstract: Freezing of Gait (FoG) is one of the most severe symptoms of Parkinson's disease, which arises in the late stages of the disease and affects the human motoric system. Gait specific features derived from a foot-attached IMU can be used for online detection of FoG. In this article we raise the question whether both feet are equally affected by FoG or there exists a most affected foot that should be used for IMU-based FoG detection. Annotated walking data from six Parkinson patients with IMU data from both feet have been used to answer this question. The results show that a preferred side exists, and that the accuracy in FoG detection improves by 11% when choosing the more affected leg for the IMU placement.

I. Introduction

Parkinson's disease (PD) is one of the most common neurodegenerative disorders in the world. A deficiency of dopamine, as result of the degeneration of dopamine-producing cell in substantia nigra is the main cause of the disease. PD affects mainly the human motoric systems and is characterized by symptoms like rigidity, bradykinesia, tremor and Freezing of Gait (FoG). In 2016, an estimated number of 6.1 million people suffer from Parkinson's disease worldwide [1]. The increasing tendency of the disease over the past years (22 per 100,000 person-years for all age groups and up to 529 per 100,000 person-years in the older population over 65 years) poses a major issue for the modern society [2]. For the patients, the disease affects directly the quality of life and the social life. PD places also a burden on the health economics, due to cost treatment [3,4].

I.I. Freezing of Gait (FoG)

Freezing of Gait (FoG) is one of the most severe symptoms of PD, which arises in the later stages of the disease. FoG is defined as an episodic event, during which despite the intention to move, a mobility reduction or a complete blockage (Akinesia) takes place. Patients describe this event as "if the feet were glued to the ground" [5].

A notable aspect of the FoG is the increase of the fall-risk. Falls can cause physical injuries, fractures and in the worse-case-scenario death. Kalilani et al., (2016) [6] report that 10.6% of the falls could lead to death. Bradley et al (2014) [7] categorized the FoG episodes into three categories regarding the appearance of the motor activity: Festination (small forward movements using small and fast steps) shank trembling and akinesia.

In this article we introduce an Inertial Measurement Unit (IMU)-based wearable system for online gait monitoring and on-demand cueing for Parkinson patients. We also try to answer the question, if a preferred foot side exists for IMU-based FoG detection in Parkinson's disease.

II. Material and methods

The system consists of up to two inertial sensors, a stimulator for sensory or functional electrical stimulation (FES) and a smart device. The IMUs are used for monitoring the gait and detecting the gait phases in real-time. Both IMUs record 3D linear acceleration and 3D angular velocities at the instep of the both feet with a data rate of 200 Hz. The stimulator is used for electro-tactile on-demand cueing. In case of a FoG episode electrical pulses can be delivered, e.g. to the muscles lifting the foot, with the aim to unfreeze the blockade. The smart device is used for controlling and configuring the system components as well for data visualization and logging, and as an interface for cloud services. The communication between all system components is realized via Bluetooth Low Energy (BLE). Fig. 1 shows the system components and their position on human body.

Figure 2: Setup with stimulator (on belt), cuff with stimulation electrodes, and one IMU on each instep (foot) below the lashes (not visible).

In order to decide if one sensor on the most affected leg is be enough for FoG detection, we used FoG-labelled data from six Parkinson patients. In all data sets, IMU measurements are available from both feet at 200 Hz (MuscleLab, Ergotest, Norway). Patients performed 10-meter walking and FoG tests. The second test category is to provoke FoG and consists of standing up from sitting position, turning twice by 360° in each direction, leaving and entering the room and sitting down again. In [8], we introduced an algorithm for Parkinsonian gait phase and FoG detection. The proposed method detects three gait phases: rest phase, unrest phase and motion phase (as a subphase of unrest phase). A gait evaluation measurement, named "GaitScore", was introduced, that is based on the extremes of the pitch angle during a motion phase. A simple threshold separates motion phases into FoG- and non-FoG-related motion phases. In this contribution, for each IMU an or-combination of our FoG detection [8] the method proposed by Coste et al. [9] was performed. Coste et al. define a FoG criterion (FoGC) based on the IMU-estimated step length and cadence. The threshold values for GaitScore and FOGC are chosen as 0.4 and 0.008, respectively. We choose the accuracy as main performance measurement beside sensitivity and specificity.

III. Results

The Table 1 shows the results of the FoG detection for each patient, trial, and foot. It can be observed that for each patient one of the feet provides better performance in the detection of FoG episodes than the other foot. Our hypothesis is that this foot corresponds to the most affected leg by a Parkinson patient. By selecting the more severely affected foot, an average improvement in accuracy, sensitivity and specificity of 11%, 10% and 14% respectively could be achieved. The average accuracy, sensitivity and specificity over all patients are 0.86, 1.00, and 0.80 respectively when using the preferred foot. These numbers outperform the averages of each foot side given in Table 1.

IV. Conclusions and discussion

In this article we investigated the question, whether there exists a foot mostly affected by FoG in Parkinson patients. The obtained performance numbers of an IMU-based FoG detection, introduced in [8,9], for six patients from different trials show that FoG detection usually outperforms for one foot side that probably corresponds to the most affected foot. This is only a first indication, and a statistical analysis involving more patients should follow to verify this hypothesis. In summary, one IMU on the mostly affected foot should be sufficient for FoG detection in an on-demand cueing system.

AUTHOR'S STATEMENT

Research funding: This work was funded by the German Federal Ministry of Education and Research (BMBF) within the project Mobil4Park (FKZ 16SV81 68). Conflict of interest: AD is employee and TS is scientific adviser/ co-founder of the SensorStim Neurotechnology GmbH, which is startup developing FES stimulation devices. All other authors declare that they have no competing interests. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: Ethics Approval was given by the ethics committee of the Charité.

Table 1: Result of FoG detection for both feet. The preferred side of each patient for FoG detection is highlighted in grey.

		Left Foot			Right Foot		
Patient	Trial	Acc.	Sens.	Spec.	Acc.	Sens.	Spec.
P1	T_1	0.86	1.00	0.81	0.83	0.50	0.86
	T_2	0.71	1.00	0.67	0.87	1.00	0.85
	T_3	0.58	1.00	0.55	0.91	1.00	0.90
P2	T_1	0.90	1.00	0.89	0.76	1.00	0.74
	T_2	0.76	1.00	0.72	0.75	0.67	0.76
	T_3	0.83	1.00	0.78	0.77	0.50	0.80
P3	T_1	0.90	1.00	0.85	0.97	1.00	0.96
	T_2	0.86	1.00	0.71	0.97	1.00	0.95
P4	T_1	0.59	1.00	0.42	0.52	1.00	0.48
	T_2	0.88	1.00	0.74	0.82	1.00	0.69
P5	T_1	0.70	1.00	0.67	0.88	1.00	0.87
	T_2	0.71	1.00	0.70	0.89	1.00	0.86
P6	T_1	0.84	1.00	0.57	0.89	1.00	0.75
	T_2	0.81	1.00	0.52	0.86	1.00	0.71
	Mean	0.86	1.00	0.69	0.84	0.91	0.80
	Std	0.11	0.00	0.13	0.11	0.19	0.12

REFERENCES

[1] E. Ray Dorsey, A. Elbaz, E. Nichols, and et. al. Global, regional, and national burden of Parkinson's disease, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Neurology, 17(11): 939-953, November 2018. ISSN 1474-4422, 1474-4465

[2] C. M. Lill and C. Klein. Epidemiologie und Ursachen der Parkinson-Erkrankung. Nervenarzt, 88(4):345-355. April 2017. ISSN 1444-0407

[3] O. Moore, Ch. Perez, and N. Giladi. Freezing of gait affects quality of life of peoples with Parkinson's disease beyond its relationship with mobility and gait. Movement Disorders, 22(15):2192-2195, 2007. ISSN 1531-8257

[4] J. M. Hausdorf, Y. Balash, and N. Giladi. Time series analysis of leg movements during freezing of gait in Parkinson's disease: akinesia, rhyme or reason? Physica A: Statistical Mechanics and its application, 321(3):565-570, April 2003. ISSN 0378-4371.

[5] C. Punin, B. Bazallo, R. Clotet, and et al. A Non-Invasive Medical Device for Parkinson's Patients with Episodes of Freezing of Gait. Sensors, 19(3):737, Jan. 2019

[6] L. Kalilani, M. Asgharnejad, T. Palokangas, and T. Durgin. Comparing the Incidence of Falls/Fractures in Parkinson's Disease Patients in the US Population. PLoS ONE, 11(9):e0161689, 2016. ISSN 1932-6203

[7] W. G. Bradley, R. B. Daroff, G. M. Fenichel, and J. Jankovic. Neurology in Clinical Practice: Principles of diagnosis and management. Neurology in Clinical Practice. Butterworth Heinemann, 2004. ISBN 978-99976-25-88-5

[8] A. Dvorani, M. C: E. Jochner, T. Seel, C.Salchow-Hömmen, J. Meyer-Ohle, C.Wiesener, H. Voigt, A. Kühn, N. Wenger, T. Schauer, Inertial Sensor Based Detection of Freezing of Gait for On-Demand Cueing in Parkinson's Disease, submitted to "IFAC World Congress 2020", Berlin, 2020

[9] C. A. Coste, B. Sijobert, R. Pissard-Gibollet, and et al. Detection of Freezing of Gait in Parkinson Disease: Preliminary Results. Sensors, 14(4):6819-6827, April 2014.

.