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INTERNSHIP REPORT

Analysis of Anticipatory Postural Adjustments of Parkinson's Patients using Inertial Sensors

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Preface

This report presents my practical work within the Project "Analysis of Anticipatory Postural Adjustments of Parkinson's Patients using Inertial Sensors" at the Research Centre for Information and Communications Technologies of the University of Granada (CITIC-UGR). The Muenster University of Applied Sciences required an internship of at least 10 weeks prior to the final bachelor's thesis.

This is a conjoint project of the University of Granada and the Department of Neurology of the Klinikum Grosshadern of Munich, which is part of the Ludwig-Maximilians University. The goal of the project was to carry out the so called Anticipatory Postural Analysis, which are the movements by a human subject between the moment he initiates gait and the first step. The medical community is interested in this procedure, as it can be used for the diagnosis of neurodegenerative diseases such as Parkinson's.

Contents

Abbreviations

APAs Anticipatory Postural Adjustments

COM Centre of Mass

COP Centre of Pressure

GRF Ground Reaction Force

HY Hoehn and Yahr scale

IMU Inertial Measurement Unit

MIMU Magnetic Inertial Measurement Unit

~~MIMU Magnetic Intertial Measurement Unit~~

PD Parkinson's disease

UPDRS Unified Parkinsons Disease Rating Scale

List of Figures

List of Tables

Chapter 1

Introduction

1.1 General

1.1.1 Parkinson's Disease

According to Patients Medical [3],

> "Parkinson's disease is a progressive, neurodegenerative disease that occurs when the neurons within the brain responsible for producing the chemical dopamine become impaired or die. Dopamine is essential for the smooth control and co-ordination of the movement of voluntary muscle groups. Once approximately 80% of the brain's dopamine producing cells no longer function, the symptoms of Parkinson's disease begin to appear. Parkinson's disease may be termed as a progressive movement disorder that is distinguished by marked slow movements, tremors, and unstable posture."

Especially in advanced stages of the Parkinson's disease (PD) many patients exhibit an episodic, brief inability to step that delays gait initiation or interrupts ongoing gait. This phenomenon is called freezing of gait and is often associated with an alternating shaking of the knees, called knee trembling. However, these clinical signs of balance or gait problems are not evident in early stages of the disease [4][5].

1.1.2 Anticipatory Postural Adjustments

A major challange to the human ballance control system is the fact that we are bipeds having only one foot in contact with the ground while walking and that two-thirds of our body

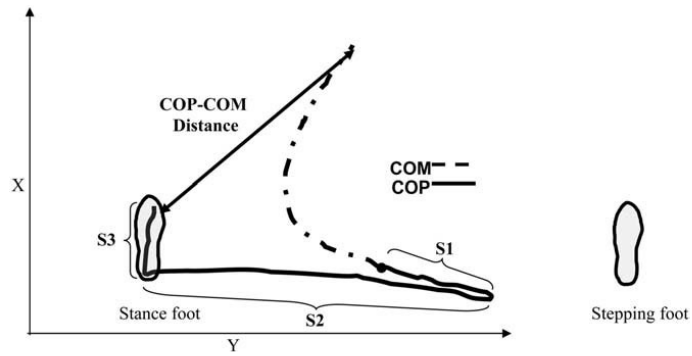

Figure 1.1: Anticipatory Postural Adjustments during forward-oriented gait initiation when stepping with the right foot [1]

mass is located two-thirds of body height above the ground [6]. Thus, to induce stable gait anticipatory postural adjustments (APAs) are necessary. The Encyclopedia of Neuroscience [7, p.133] defines APAs as "A predictive motor response that acts to counter, in a preemptive manner, the postural destabilization associated with a forthcoming movement." As seen in Figure 1.1 the centre of body mass (COM) is accelerated forward and laterally over the stance foot to make sure that the body does not fall laterally toward the stepping foot during the swing phase [7]. The curve of the centre of pressure (COP) is divided in three periods. Period S1 indicates the uncoupling of the COP and COM as the COP moves posteriorly and toward the intended stepping limb. Then, in the S2 period, the COP displaces mediolaterally toward the stance foot. Finally, during the S3 period the COP moves anteriorly under the stance foot [1].

1.2 Goals

The goal of the project was to analyse anticipatory postural adjustments and subsequently build a classifier using MATLAB, which is fed with data from both a force plate and a magnetic inertial measurement unit to distunguish between Parkinson patients and healthy subjects.

1.3 Motivation

Advanced PD can increasingly diminish quality of life, since patients are dependent on help from others to accomplish daily tasks. Early diagnosis of PD could optimise early treatment. Currently new drugs are being developed and are expected to decelerate or stop the course of the disease in early stages [8]. Moreover an objective PD classification could evaluate longterm treatment success, also while testing new drugs and treatment methods.

1.4 State of the art

There are several methods and devices to assess Parkinson's disease and to analyse anticipatory postural adjustments. They differ in terms of practicability, accuracy, validity, portability, and cost. The state of the art at the beginning of the project is described below.

1.4.1 Rating scales

A commonly used rating scale is the Unified Parkinsons Disease Rating Scale (UPDRS), which is a short test performed by a physician [9]. The patient is rated on 31 different items (see Table 1.1) with a score of 0 (normal) to 4 (severely affected). Another method is the rough, but widely utilised and accepted Hoehn and Yahr scale (HY). Parkinsonian motor impairment is categorised in 5 stages: Unilateral (Stage 1) to bilateral disease (Stage 2) without balance difficulties, to the presence of postural instability (Stage 3), loss of physical independence (Stage 4), up to being wheelchair- or bed-bound (Stage 5) [10]. Without the need of complex technical devices they are relatively simple to perform. Klerk et al. [9] mentioned the disadvantages, such as subjectivity, short observation periods and unfamiliarity of the environment that both rating methods bring along.

Mentation, mood and behavior	Activities of daily living	Motor examination
Intellectual impairment	Speech	Speech
Thought disorder	Salivation	Facial expression
Depression	Swallowing	Tremor at rest
Motivation/initiative	Handwriting	Action or postural tremor of hands
	Use of eating utensils	Rigidity
	Dressing	Finger taps
	Hygiene	Hand movements
	Turning in bed	Rapid alternating movements of hands
	Falling	Food agility
	Freezing when walking	Arising from chair
	Walking	Posture
	Tremor	Gait
	Sensory Complaints	Posture stability
		Body bradikinesia and hypokinesia

Table 1.1: Unified Parkinson's Disease Rating Scale items adapted from [2]

1.4.2 Instrumentation

In addition to the named subjective rating scales, there are different devices used to quantify gait and posture and assess them objectively. All of them come with certain pros and cons. The following devices have been used:

- Electromyographs: Electromyography is a technique for evaluating the electrical activity of skeletal muscles. Successive action potentials generated by muscle cells are measured, by means of needle electrodes inserted into the muscle, and displayed on a cathode-ray oscilloscope. Thus medical abnormalities can be detected. The instrument used to capture the visual recording, termed electromyogram, is called electromyograph. [11].

- Force plates: Force plates quantify the ground reaction force (GRF), which is the force exerted to the human body by the ground. The GRF is a three-dimensional vector with three orthogonal components. One component along the direction of gravity, one parallel to the ground in the sagittal plane, and one parallel to the ground in the frontal plane. Those are vertical planes that divide the body in left and right halves, and ventral and dorsal sections, respectively. A force plate usually gives an electrical voltage proportional to the force in each of the three directions. Force plates can be characterised according to the following criteria: Sensitivity in Volts per Newton, crosstalk (indication of vertical force if a horizontal force is applied and vice versa), repeatability (similar results under the same load), and time- and temperature drift [12].

- Inertial measurement units: Devices that use a combination of inertial sensors like accelerometers and gyroscopes are referred to as inertial measurement units (IMUs). If they also include magnetic field sensors (magnetometers), they are called magnetic inertial measurement units (MIMUs). With these devices the orientation of the body can be obtained with up to nine degrees of freedom, provided that triaxial accelerometers and magnetometers are used, respectively [13].

  Accelerometers measure the acceleration of an object relative to an inertial frame. Since acceleration cannot be measured directly, the force exerted to a reference mass is obtained and the resultant acceleration is computed according to Newton's second law $\mathbf{F} = m \cdot \mathbf{a}$ [14].

  Gyroscopes are used to measure angular velocity

1.4.3 Classification

There are several research projects dealing with APA analysis and PD classification, as the evaluation of posture and gait are key components of the clinical evaluation of PD [15].

Klerk et al. [9] developed a measurement system called PD Monitor, implementing an Activity Classifier that quantifies tremor and bradykinesia in the arm, tigh, and trunk, ambulant and over long periods of time. They validated their measurements with video records, which were rated by physicians using the UPDRS and concluded that "the PD monitor can be used for a detailed evaluation of the PD motor symptoms in order to optimize treatment." [9].

Mancini et al. [4] found that the 11 untreated early-to-middle stage Parkinson's patients that took part in their study have a significantly smaller peak COP displacement towards the stepping leg and peak trunk acceleration towards the stance leg, compared to the 12 age-matched healthy control subjects, even though step velocity and step length were not different. The results show that lateral APAs are impaired in early, untreated PD and that it is detectable with inertial sensors. As well as force plate-based, also acceleration-based extracted features can be used to detect impairments equally well. Due to the fact that the acceleration signal can be easily obtained via a sensor on a belt, no matter if in clinical or home environment, APA detection by means of accelerometers is considered as a useful way to characterise patients in early stage of PD without evident clinical symptoms. [4] proposes further studies to determine the relation between small APAs and the probability to develop start hesitation and freezing.

Palmerini et al. [15] states that PD classfication could deliver a tool to follow the progression of the disease during the entire course to examine the efficiency of treatment. They studied classification of PD subjects using triaxial accelerometers on the lower back at L5 level and an ad hoc wrapper feature selection technique and achieved satisfactory accuracy of 93.75%. 20 early-mild PD subjects and 20 healthy age-matched control subjects had to perform two simple tests (quiet standing, Timed Up and Go test), in two evaluations over a 1-year follow-up, to test accuracy and robustness over time. As well as [4] they found that lateral dynamics i.e. range of motion are impaired in early-mild PD and suggest further investigation on validity of measures in later stages.

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