

TELECOMUNICATION ENGINEERING

Department:
Signal Theory, Telematics and Communications

University of Granada



Master thesis

Comparison of Posturographic Body-sway Measurements with Inertial Data of Parkinson Patients

Written by:

Verónica Torres Sánchez

Supervised by:

D. Alberto Olivares Vicente

D. Alberto Olivares Vicente, profesor del dpto. de Teoría de la Señal, Telemática y Comunicaciones, como director del Proyecto Fin de Carrera de D^a. Verónica Torres Sánchez,

Informan:

Que el presente trabajo, titulado:

Comparison of Posturographic Body-sway Measurements with Inertial Data of Parkinson Patients.

Ha sido realizado y redactado por el mencionado alumno bajo nuestra dirección, y con esta fecha autorizamos a su presentación.

Granada, a XX de XXX de 2015 Fdo:

D. Alberto Olivares Vicente

Acknowledgements

Abstract

Abbreviations

Contents

1. Introduction	IX
1.1. Context	IX
1.2. Motivation	X
1.3. Goals	XI
1.4. Project structure	XII
1.5. State of the art	XII
1.5.1. Instrumentation	XII
1.5.2. Methods and procedure	XIII
1.5.3. Data Analysis	XIV
2. Hardware Description	XV
2.1. GaitWatch	XV
2.2. Force Platform	XV
2.3. Sensors based in cameras	XV
3. Synchronisation	XVII
3.1. Introduction and chapter's structure	XVII
3.2. Experiments	XVII
3.2.1. Data gathering Protocol	XVII

3.2.2. Design of code developed in Matlab	XVII
3.2.3. Results discursion	XVII

List of figures

1.1. Illustration of sensors distribution thought up by Intel and Mjf.[4]	XI
1.2. EMG, accelerometers y platform [12].	XIII
1.3. Illustration of the experiment with infrared-reflective markers[13].	XIII

List of tables

Introduction

1.1. Context

Parkinson's disease is a chronic and progressive movement disorder due to the malfunction and death of neurons in the brain. Some of these neurons produce dopamina, a chemical that sends messages to the part of the brain that controls movement and coordination. Thus, as Parkinson's disease progresses, the amount of dopamine produced in the brain decreases, leaving the person unable to control movement normally [1].

The disease must be diagnosed by an experienced neurologist. There are no tests that clearly identify the disease, but brain scans and blood test are sometimes used to rule out disorders that could give similar symptoms. One of the main concerns of people with PD is the fear of falling. First motor symptoms in this disease, like rigidity (stiffness of the limbs and trunk), bradykinesia (slowness of movement) and postural changes, contribute to risk of falling. Difficulties in the adaptation of neck and trunk cause postural instability, which, in turn, increase the possibility of suffering a fall.

The center of body mass of a person is situated below the navel and the legs work as a support base. In PD it is common that the center of mass goes out of support base. This fact causes losses of equilibrium in activities such as waking up, bending, spinning around quickly or walking. Also, falls can occur due to a damage in postural reflexes (a series of complex movements that we carry out in an automatic way in order to maintain the equilibrium when we get up and walk), postural changes (tendency to lean forward using short, quick steps and reduced arm movement) and freezing (inability to step that delays gait initiation or interrupts ongoing gait). Research in this field is of vital importance to contribute to the improvement of knowledge about the disease. Scientific research can be the base for field applications that help to improve the people life with PD. [2][1]

With this Project, we aim to continue the research line initiated by Dr. Alberto Olivares, member of the SIPBA (Signal Processing and Biomedical Applications) research group of the Department of Signal Theory, Telematics and Communications of the University of Granada, Spain, and Prof. Dr. Med. Kai Bötzel, head of the Motion Analysis and Deep Brain Stimulation Laboratory of the Department of Neurology of the Klinikum Grosshadern based in Munich, Germany. In his dissertation, Dr. Olivares explains in his Ph.D. thesis [3] different signal processing techniques to analyze information from inertial sensors to monitor human body motion. Specifically, our work will be focused on signal processing of data gathered by a force plate and a wearable motion analysis system based on inertial sensors. Nevertheless, this master thesis is part of a broader project which has many different layers (instrumentation, data gathering, firmware, signal processing) in which other people have been working during the last 5 years.

IMAGE

1.2. Motivation

Parkinson's disease is the second most common neurodegenerative disorder, it is extended globally and affects as much to men as to women. PD is more common among the population over 60 years old. It is estimated that seven to ten million people worldwide are living with Parkinson's disease. To this date, there is no cure to PD, so all efforts are focused on improving or prolonging the functionality of the patient for as long as possible. Therefore, it's an incentive to work in this field. [2][1]

Furthermore, Intel and Michael J. Fox Foundation have recently teamed up to create a sensor technology and analytics platforms for Parkinson's treatment and monitoring. Fox Foundation CEO Todd Sherer told Fast Company. "Parkinson's is a motor disorder for the most part, with slowness of movement, tremors, falls, problems sleeping, and many disease symptoms. The way it is measured right now requires episodic periodic visits to a neurologist, who puts patients through fairly subjective and coarse clinical tests, there are many 1-2-3-4 scales. What we need to advance is research that is a much more consistent and objective measure of the disease. People live with Parkinson's 24 hours a day, 7 days a week, not just when they're in the doctor's office." [4]

The goal is tracking the symptoms and progress of Parkinson's disease day by day, and using this information to research on the disease in depth.



Figura 1.1: Illustration of sensors distribution thought up by Intel and Mjf.[4]

Diane Bryant, senior vice president of Intel’s Data Center Group, said in a release [4]. ”Emerging technologies can not only create a new paradigm for measurement of Parkinson’s, but as more data is made available to the medical community, it may also point to currently unidentified features of the disease that could lead to new areas of research” .

1.3. Goals

The main goal of this project is to perform a thorough analysis of Anticipatory Postural Adjustments (referred to as APA in the remainder of this document) of both healthy subjects and PD patients. APAs can be used to characterize step initiation deficits in subjects with PD and also as a differentiating factor which may help early diagnosis of the disease.

To this purpose, we will make use of a database gathered by the medical team in Munich. The database contains both data from a force plate and inertial sensors. The patients wear the motion monitoring system containing the inertial sensors while they step on and down the force plate.

Once the measurements are made, the main objective is to determine whether it is possible to use inertial sensors to extract the information provided by the force plate. That is, we will evaluate the correlation between inertial sensor measurements and the force plate measurements in order to study the feasibility of the wearable device to study APAs in an ambulatory way.

Additionally, we will try observing if APAs are homogeneous in healthy subjects and the differences with PD patients. If that is the case, we would be able to build a classifier which is able to distinguish healthy subjects from PD patients based on the data measured by the wearable device and/or the force plate.

In a nutshell, the ultimate goal is to determine whether doctors can substitute force plates (which strongly limit the range of action of the patients) by the inertial wearable system (which allows ambulatory).

1.4. Project structure

1.5. State of the art

We will start studying some current devices used for body monitoring as well as their benefits.

Later we will search the methods and experimental procedures used in several studies to analyse of Anticipatory Postural Adjustments in different cases, as well as their applications.

Finally, we will speak about the common calibration techniques, signal processing and classification.

1.5.1. Instrumentation

There are several device types used to measure APAs. The most important are: electromyograph, force platform, inertial sensors and devices based on cameras.

Electromyography (EMG) is a technique that gives us information about the electrical activity produced by skeletal muscles (See figure [1]). The electromyograph can detect the electrical activity due to an electrical potential difference generated by muscle cells. It's very useful to analyse posture, locate injuries like muscle paralysis and the place where they are. [5] [6].

So far, most of realised studies have included like measurement devices, among other things, a platform sensitive to force and pressure. However, the cost and complexity of APAs measurement with a traditional movement analysis, using force platform and EMG System limit their applications in the clinical practice. Therefore, small inertial sensors are used recently because they are cheaper and more portable. But even so, we have used this platform, considering the possibility to ignore it in the future. [7] [8].

Devices based on commonly used inertial sensors are IMU (inertial measurement unit), It's an electronic device that measures and reports about speed, orientation and gravity force of equipment, using the combination of accelerometers and gyroscopes. In addition, you can combine it with magnetometers, but in this case, the device is called MIMO. Some current MIMO are: 3DN-GX4-45 [9], xsens-mvn [10] y mvn-biomech [11], all of them use Microelectromechanical Systems (MEMS).

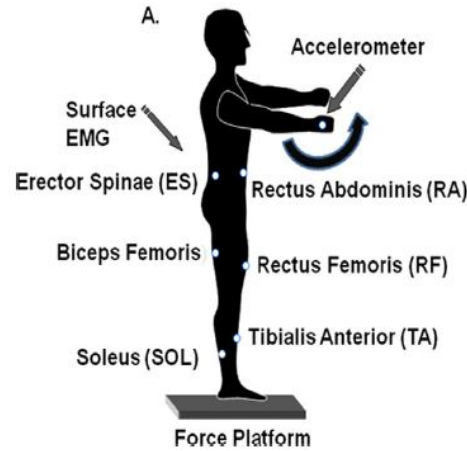


Figura 1.2: EMG, accelerometers y platform [12].

There are infrared-reflective markers that give us a complex posture measurement. They are attached to the body and can provide information about postural strategies, so we can know if the subject uses the ankle strategy or the hip strategy. For example, figure [2] shows the System.

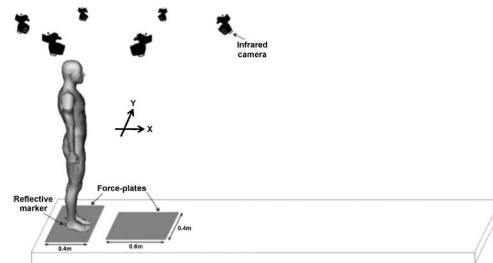


Figura 1.3: Illustration of the experiment with infrared-reflective markers[13].

As mentioned previously, it's possible to use sensors based in cameras that generally are part of a optical System of movement capture such as Kinect. [14].

1.5.2. Methods and procedure

So far, a lot of studies about Anticipatory Postural Adjustments are been done, mainly in the last six years. The finality of the most of this research is be able to deepen knowledge about the posture prior to step initiation, and whether there are postural patterns and conditions on which they depend.

If we analyse the state of the art of APAs, we can find that first investigations tried to verify whether APAs are associated to voluntaries movements or no, this hypothesis was confirmed and the conclusion was it's more probable that the adjustments don't appear if step initiation isn't planned. It's essential for balance control in gait initiation because we can use this knowledge to prevent the falls in some people with movement difficults.[15][16][13][17][18]

After of this, researchers tried to explain the influence of other variables, such as several exercises that estimulate different muscles and the reaction of others[12]; the age influence for generating postural patterns [19] [20]; the signal type that initiates the movement (visual or auditory) due that it affect initial posture [15][21][22][23]; the fear to fall because it can do that patients adopt different postures[26]; neurodegenerative disease, like Parkinson and Multiple Sclerosis[7][24][25][26], or cerebral palsy, like hemiplegia and diplegia, [26], generate differences in the APAs too.

All these studies are very important in medical applications. For example, As mentioned previously, there are diseases that affect central nervous System, so it affects the mobility too. Then, it causes falls in many occasions, therefore the people that suffer the fall have fear of fall again. The fact that fear of fall causes variations in the APAs doing people fall again, can help us to prevent them.

1.5.3. Data Analysis

In the last years, it has carried out a lot of Works about calibration of accelerometers and gyroscopes, although the most of them show little variation with others studies done before. One of the most important research [27]explains one form to do the calibration putting the acceleromentes in six different positions and applying simple algebraic algorithms to the obtained data. The gyroscope is calibrated of different form, using a process based in a known rotation. Also, there are others with the same fundament.

There are other methods that try to be more precise, increasing the number of positions where we record the data [28]. Also, there are others type of calibration techniques like algorithms based in basic algebraic calculation or in FIR filters. [3]

As for estimation of orientation for human-body monitoring, if we study the works done so far, we can see that almost all use a Kalman filter. However, the result with lower signals isn't very accurate.[3]

Finally, we will analysis the state of the art of movement recognition in human and classifiers. Quickly, we can see a lot of information about classification because there are a lot of articles and books about this. However, there are others type of studies, which we focus on it [29], that explains methods for human activity recognition based on a sensor weighting hierarchical classifier. This study shows different classification forms that we can use depending on the activities, such as walking or running.

Hardware Description

2.1. GaitWatch

2.2. Force Platform

2.3. Sensors based in cameras

Synchronisation

3.1. Introduction and chapter's structure

3.2. Experiments

3.2.1. Data gathering Protocol

3.2.2. Design of code developed in Matlab

3.2.2.1. Selection, reading and obtaining of information from the excel file

3.2.2.2. Extraction of the forceplate data

3.2.2.3. Calibration of the GaitWatch data

3.2.2.4. Synchronisation

3.2.3. Results discursion

Bibliografía

- [1] Parkinson's disease fundation. <http://www.pdf.org/>.
- [2] Parkinson's disease. <http://en.wikipedia.org/wiki/Parkinson>
- [3] A.Olivares. 'signal processing of magnetic and inertial sensor's signals applied to human body motion monitoring'.
- [4] Why intel and the michael j. fox foundation are teaming up to create wearable tech for parkinson's. <http://www.fastcompany.com/3034433/why-intel-and-the-michael-j-fox-foundation-are-teaming-up-to-create-wearable-tech-for-parkin>.
- [5] Marcio J. Santos, Neeta Kanekar, and Alexander S. Aruin. The role of anticipatory postural adjustments in compensatory control of posture: 1.electromyographic analysis. *Journal of Electromyography and Kinesiology*, 20:388–397, 2010.
- [6] Electromiografia. <http://www.bioingenieria.edu.ar/academica/catedras/bioingenieria2/archivos/apu>
- [7] M.Mancini, C. Zampieri, P. Carlson-Kuhta, and L. Chiari and F.B.Horak. Anticipatory postural adjustments prior to step initiation are hypometric in untreated parkinson's disease: an accelerometer-based approach. *European Journal of Neurology*, 16:1028–1034, 2009.
- [8] Vennila Krishnan, Alexander S.Aruin, and Mark L.Latash. Two stages and three components of the postural preparation to action. *Exp Brain Res*, 212:47–63, 2011.
- [9] 3dm-gx3-45. <http://www.microstrain.com/inertial/3dm-gx3-45>.
- [10] Mvn-biomech. <http://www.xsens.com/products/mvn-biomech/>.
- [11] Xsens-mvn. <http://www.xsens.com/products/xsens-mvn/>.
- [12] Gay L. Girolami, Takako Shiratori, and Alexander S. Aruin. Anticipatory postural adjustments in children with hemiplegia and diplegia. *Journal of Electromyography and Kinesiology*, 21:988–997, 2011.

- [13] Teddy Caderby, Georges Dalleau, Pierre Leroyer, Bruno Bonazzi, Daniel Chane-Teng, and Manh-Cuong Do. Does an additional load modify the anticipatory postural adjustments in gait initiation? *Gait and Posture*, 37:144–146, 2013.
- [14] Kinect. <http://www.microsoft.com/en-us/kinectforwindows/>.
- [15] W.E. McIlroy and B.E. Maki. Do anticipatory postural adjustments precede compensatory stepping reactions evoked by perturbation? 164:199–202, 1993.
- [16] E. Yiou, T. Hussein, and J. LaRue. Influence of temporal pressure on anticipatory postural control of medio-lateral stability during rapid leg flexion. *Gait and Posture*, 35:494–499, 2012.
- [17] M-C. Do S. Bouisset. Posture, dynamic stability, and voluntary movement posture, stabilité dynamique et mouvement volontaire. *Neurophysiologie Clinique/Clinical Neurophysiology*, 38:345–362, 2008.
- [18] Neeta Kanekar and Alexander S. Aruin. Aging and balance control in response to external perturbations: role of anticipatory and compensatory postural mechanisms. *American Aging Association*, 36:1067–1077, 2014.
- [19] Séverine Bleuse, François Cassim, Jean-Louis Blatt, Etienne Labyt, Philippe Derambure, Jean-Daniel Guieu, and Luc Defebvre. Effect of age on anticipatory postural adjustments in unilateral arm movement. *Gait and Posture*, 24:203–210, 2006.
- [20] Estelle Palluel, Hadrien Ceyte, Isabelle Olivier, and Vincent Nougier. Anticipatory postural adjustments associated with a forward leg raising in children: Effects of age, segmental acceleration and sensory context. *Clinical Neurophysiology*, 119:2546–2554, 2008.
- [21] Antonia Ypsilanti, Vassilia Hatzitaki, and George Grouios. Lateralized effects of hand and eye on anticipatory postural adjustments in visually guided aiming movements. *Neuroscience Letters*, 462:121–124, 2009.
- [22] Vincent Nougiera, Normand Teasdaleb, Chantal Bardb, and Michelle Fleuryb. Modulation of anticipatory postural adjustments in a reactive and a self-triggered mode in humans. *Neuroscience Letters*, 260:109–112, 1999.
- [23] C. TARD, K. DUJARDIN, J.-L. BOURRIEZ, P. DERAMBURE, L. DEFEBVRE, and A. DELVAL. Stimulus-driven attention modulates the release of anticipatory postural adjustments during step initiation. *Neuroscience*, 247:25–34, 2013.
- [24] Jebb G. Remelius, Joseph Hamill, Jane Kent-Braun, and Richard E.A. Van Emmerik. Gait initiation in multiple sclerosis. *Motor Control*, 12:93–108, 2008.

-
- [25] Chris J.Hass, Dwight E.Waddell, Richard P.Fleming, Jorge L.Juncos, and Robert J.Gregor. Gait initiation and dynamic balance control in parkinson's disease. *Arch Phys Med Rehabil*, 86, 2005.
 - [26] L. M. HALL, S. G. BRAUER, F. HORAKb, and P. W. HODGES. The effect of parkinson's disease and levodopa on adaptation of anticipatory postural adjustments. *Neuroscience*, 250:483–492, 2013.
 - [27] Kian Sek Tee, Member, IAENG, Mohammed Awada, Abbas Dehghani, David Moser, and Saeed Zahedi. Triaxial accelerometer static calibration. *WCE*, 3:6–8, 2011.
 - [28] Frédéric Camps, Sébastien Harasse, and André Monin. Numerical calibration for 3-axis accelerometers and magnetometers. *IEEE International Conference on Electro/Information Technology*, 9:217–221, 2009.
 - [29] Oresti Baños, Miguel Damas, Hector Pomares, Fernando Rojas, Blanca Delgado, and Olga Valenzuela. Human activity recognition based on a sensor weighting hierarchical classifier. *Springer-Verlag*, 2012.

