Computer-aided biomechanical gait-analysis in Parkinson’s disease

Motivation

Parkinson’s disease (PD) is a neurodegenerative disorder of the central nervous system, characterized by progressive gait impairment. Clinical criteria for the diagnosis of PD are partially based on gait dysfunction. In advanced stages gait impairment changes frequently during the day within hours from severely impaired to hyper- and dyskinetic movement. The assessment of this motor fluctuations is limited due to the subjective rating of these changes. To maintain patient’s quality of life, it is crucial to get an objective classification of gait symptoms in order to adequately manage treatment for an individual PD patient.

Background

We have established a sensor based biomechanical gait-analysis system that enables reproducible, objective, rater-independent assessment of gait symptoms. The aim was to generate an independent rating of gait impairment.

Parkinson’s disease – main symptoms [1]
- Brady- and Akinesia – slowing of motor activities
- Rigidity – stiffness and rigidity of muscles
- Tremor – trembling of extremities
- Postural instability- impaired balance

Rating of motor symptoms
- UPDRS – Part III (Unified Parkinson’s disease rating scale) [2]

Definition of Disease Level
- Hoehn & Yahr [2]
  - Drawback: Rater dependent and subjective!
  - Goal: “Objective” measure for gait disorders

Sensor platform and setup

The complete sensor setup is shown in figure 5.

Running shoe: adidas_1 smart ride
- Magnetic in-sole pressure sensor (integrated in the heel of the shoe)
- Embedded microcontroller unit for data recording

Wireless sensor platform: SHIMMER
- Embedded sensor network running TinyOS
- SD card, Bluetooth and IEEE 802.15.4
- Used sensors: Accelerometer, gyroscope

Data collection

Standardized exercises
- 10-meter walk [6]
- Walk on spot
- Heel-toe tapping [2]
- Circling foot movement

Patient and control data
- 45 PD patients
- 43 healthy controls

Gait signals and features

Feature extraction and selection
290 features for regular gait and 174 features for the other 3 exercises were extracted. With a sequential backwards, this selection features were selected that contribute most to the differentiation between classes.

Significant gait feature examples
- Dominant frequency
- Information about gait velocity
- Energy in frequency bands – indicates PD typical gait disorders [7]
- Extremum analysis – features depending on minima and maxima
- Entropy – a measure of the average information content [4]

Classification results

The extracted features are used to classify patient data for different classification tasks using a leave-one-subject-out-cross-validation [5].

The number of features is equivalent to the dimension of the feature space. Example in figure 7 shows two features and consequently 2 two dimensional feature space.

The task of the classifier is to build a decision boundary in a n-dimensional feature space.

Used classifiers are the Support Vector Machine (SVM) [5] and the Linear Discriminant Analysis (LDA) [5].

Summary and conclusion

This pilot study shows that biomechanic gait analysis may be an important and complementary means to support treatment in PD. Future biomechanic validation studies will help to monitor gait disorders. This will help to modify and adjust treatment thus rationalizing therapeutic decisions.

References