Nové metody a postupy v oblasti přístrojové techniky, automatického řízení a informatiky 2010
Ústav přístrojové a řídicí techniky ČVUT v Praze, Odbor přesné mechaniky a optiky
Technická 4, 166 07 Praha 6

DYADIC STOCHASTIC PROCESS FILTERING IN POSTUROGRAFY

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Abstrakt: The main article goal is in stochastic process analysis improvement. Research is dealing with data taken from clinical posturography checkup. Data are filtered by ensemble empirical mode decomposition (EEMD) which plays role of dyadic filter and start step of presented framework. The framework employs Fourier Transform and result is used for human upright stand modeling covered by Metropolis-Hastings algorithm.

Key words: Posturography, Fourier Transform, Dyadic filtering, Markov Chain Monte Carlo

1. Introduction

The study of human postural control is an active area of biomedical research, vital to improving our understanding of human balance, evaluation and rehabilitation of individuals affected by disorders. Postural control is critical to most of activities in everyday life. Any balance movement disorder could lead to an increased likelihood of falls, potentially resulting in injury and even death. Human regulation of balance is a complex multi-sensory feedback process which includes outputs from three main sensor types. Those sensors are relevant to balance investigation (i.e. vestibular system, vision, and somatosensation).

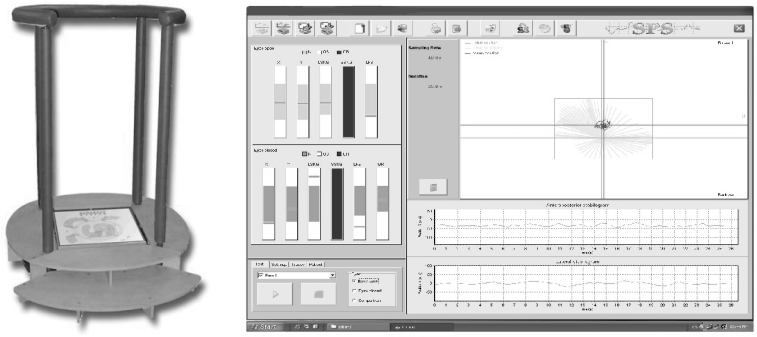

Fig. 1. Synapsys Posturography System (SPS) with implemented force platform for S.O.T test. SPS is used for subject checkups (Synapsys, Marseille – France). SPS results panel scrolling on the right side.

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2. From classical to dyadic filtering approaches

Many classical methods for subject sway (upright stand) analysis have been developed or improved over several last years and decades. The most of them treated the signal as to linear and stationary data set or other limitations were postulated in order to make analysis suitable for a particular checkup. These methods were mostly dealing with Fourier analysis theory (FAT) only [2][3]. This point caused issue in discovering important deviances placed inside the investigated signal.

The force platform (FP) acceptance (Fig.1) gave researches a powerful tool for subject's sway analysis over Centre of Pressure (CoP) investigation as the tool of static posturography [1]. CoP approach gives force value free of any subject's movement moments which is caused by quiet upright stand which is more reliable for true value definition.

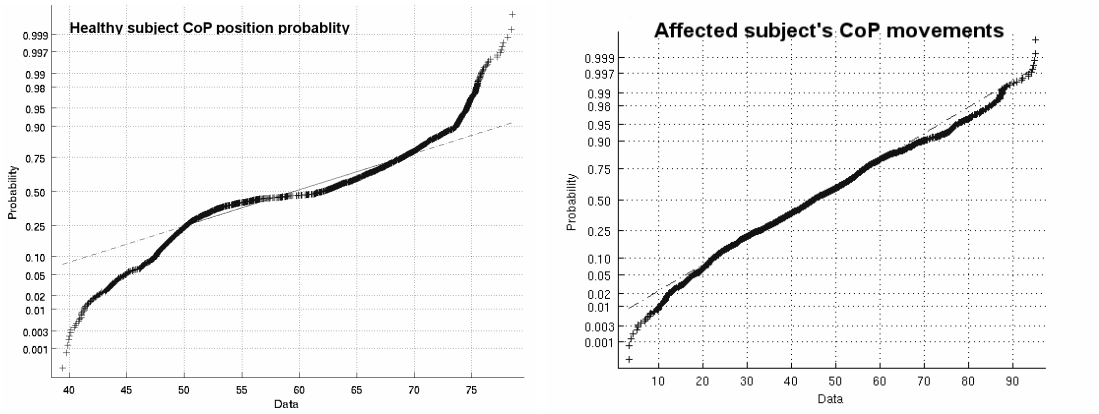

Fig. 2: Healthy and affected subject's movement analysis over CoP. Healthy subject behaves more complex compare to any affected one (Affected on the right side).

Static posturography is carried out by placing the subject in a standing posture, up right stand in our case, on a FP connected to sensitive detectors, which are able transmit tiny oscillation of the subject's body (Fig.2). Received data are filtered by EEMD[2] before any consequent analysis (Fig.3). Filtering eliminates non valuable signal parts and helps in important segments definition.

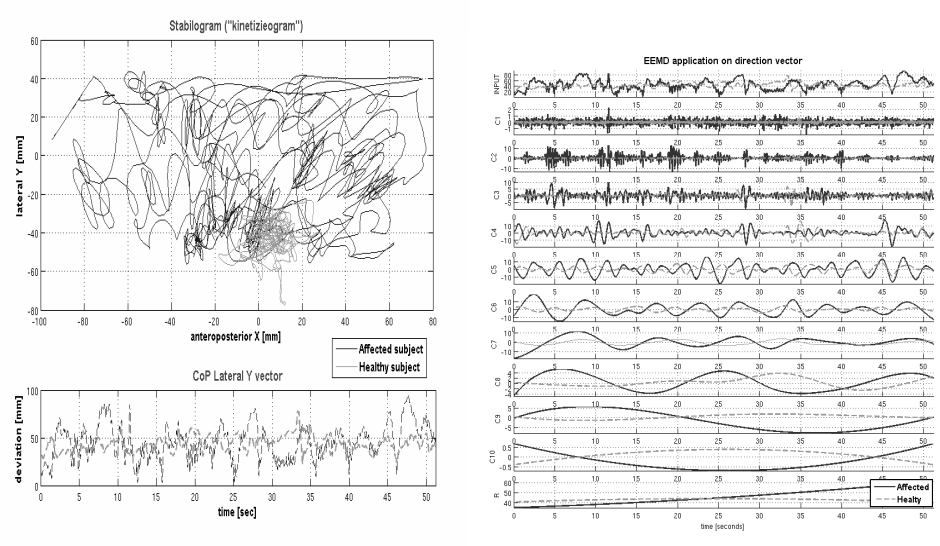

Fig. 3: a) Stabilogram example of affected and healthy subject. There are no visible disorders from subject's signal deviances, only possible to confirm instability. b) EEMD example application $CoP_y(t)$ over Lateral Y vector to extract IMF Functions. Specific disorders started to be projected as fluctuations even in time domain. EEMD works here as dyadic filter band

Highlighted segments in filtered signal are treated by FAT in the next step (Fig. 4) of our approach. FAT is applied to move data to energy-frequency domain where subjects body oscillation are visible in comparison to the individual disorder. The intent of approach is increase sensitivity according to common techniques used in posturography evaluation. The other intent is to provide valuable technique for human movements modeling which could help in any subject analysis and diagnose.

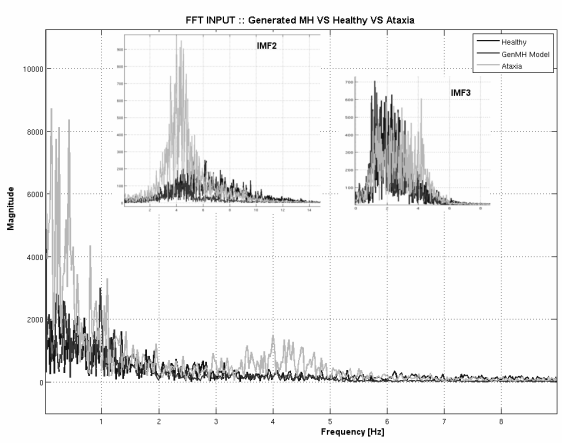

Fig. 4: Example of M-H healthy subject model, healthy and affected real subject. Similar behaviour to healthy subject is projected even in energy-frequency domain which satisfies expectation. H-M modelling is valuable tool in next research.

3. Close to up right stand modeling

In previous text has been pointed out a body movement modeling over CoP investigation. CoP is measured by FP [1] utilization which is implemented in SPS (Fig.1.). Investigated subject goes through the defined S.O.T. [10]. The S.O.T. objectively identifies movement disorders by accessing the patient's ability to make effective use of visual, vestibular, and proprioceptive information. Data are filtering by EEMD[1][2][3] to increase sensitivity of specific signal deviances which could provide part of true result. For modeling similar data set is used Markov Chain Monte Carlo method (MCMC) [1]. The Metropolis-Hastings algorithm (M-H) [1] as one of MCMC algorithms will be touched in next reading.

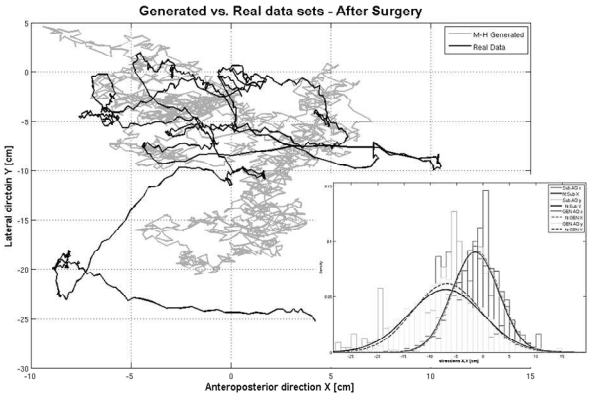

Fig. 5: Example of M-H model vs. Real data of subject's after surgery. Stabilogram has drawn CoP behaviour in X,Y plane. Histogram on the left bottom side has shown similar movements distribution functions over the FP.

MCMC methods are following our general idea of human CoP model. The M-H algorithm can draw samples from any probability distribution $P(x)$, requiring only that a function dominating the density can be calculated at x.The algorithm generates a next Markov chain in which each state x^{t+1} depends only on the previous state x^t. The algorithm uses a proposal density $Q(x';x^t)$, which depends only on the current state x^t. This proposal is "accepted" as the next value $x^{t+1}=x'$ if α is drawn from $U(0,1)$ satisfies condition (Eq.1)

$$\alpha < \min\{\frac{P(x')Q(x^t;x')}{P(x^t)Q(x';x^t)},1\} \tag{1}$$

If the proposal is not accepted, then current value of x is retained $x^{t+1}=x^t$.The M-H algorithm is smartly applicable on generating samples based on priori knowledge obtained from previous CoP density function investigation. Next step is to take advantage of this knowledge in body movements modeling (Fig.5.).

4. The nearest future improvement and final discussion

Described framework is vital to be used even in Human centre of gravity (CoG) modeling. CoG can be designed in way of inverted pendulum (Fig.6) as simple concept, which could be driven in future study. The inverted pendulum [1] represents well described and defined mechanical and mathematical case. Mechanical model could be controlled by PID regulator, which introduces possibility of unique coefficients setup. Proportional, integral and derivative values could be defined and modified based on individual subject data set.

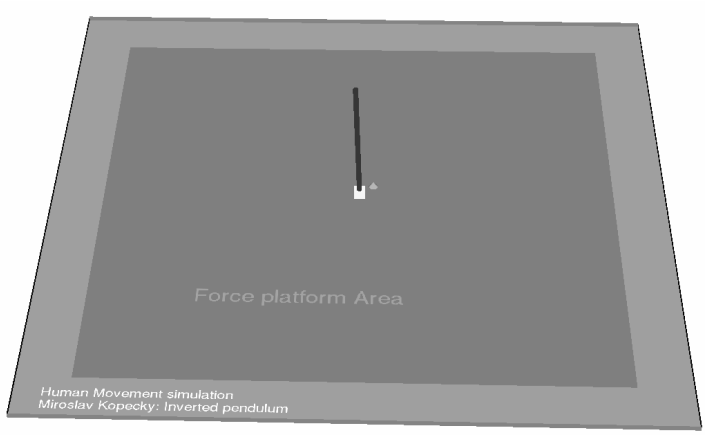

Fig. 6: MATLAB/SIMULINK model example of inverted pendulum of CoP movement regulated by PID controller; Cart movements (small cube on the bar bottom) is done by M-H generated or real measured values. These values are transmitted via small cone (right up cart corner). Pendulum simulates CoG movement during upright stand (sway) on FP.

Dyadic filtering, H-M algorithm and FT are opening possibilities in better understanding to human movements and its model. Such way could open the door in pattern defining for particular disorders or affection which could cause step forward in current medicine. Checkup would be less dependent on personal Doctor's opinion where could be subject damaged.

Acknowledgement

This article has been supported by SGS grant id number: 10-800500

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