Acquisition and Interpretation of Upper Limbs Tremor Signal in Parkinsonian Disease

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Abstract: - The paper describes a method for measurement and visualization of upper limbs tremor, making use of digital camcorders for registration of moving point light sources. The measurement is done separately for the three principal planes of the Cartesian coordinate system. The present work contains a description of the measurement stand and measurement method, the obtained results and the prospects for application of the method in assistance of medical diagnosis. In the long term prospect the described method will assist in examinations and evaluation of the upper limbs tremor for patients with Parkinsonian disease. The proposed procedure does not require any additional efforts from the patients and what's more it can be used for measurement, processing and analysis of arbitrary object vibrations in 3D space. The presented method of tremor measurement considerably enhances the currently applied acquisition techniques, which usually reduce the measurement space to 2D.

Key-Words: - tremor, 3D analysis, biomedical signal processing, signal interpretation, Parkinson's disease, image analysis

1. Introduction

Pathological tremor of human body manifests itself by periodic, alternating muscle contractions, what is mainly caused by the so called extra-pyramidal disorders, including Parkinsonian disease. The effect of pathological disorders in PD is a tremor of some body parts, predominantly facial mucles, shoulders and upper limbs. The tremor classification with respect to vibration frequency includes the division into various frequency bands and attribution to particular types of illness. The tremor frequencies observed in PD patients are mainly assessed in the 3-7 [Hz] band, but some tremor forms may additionally exhibit vibrations in 8-12 Hz band. Another type of illness, which also exhibits the tremor symptoms, is the so called essential tremor (ET), which is one of the most common diseases of that type beside the Parkinson disease. Vibration frequencies described in the literature for that type of illness are attributed to the 4-9 Hz frequency band. Majority of typical ailments is characterized by presence of vibration frequencies in some specific bands, but the vibration frequency bands often overlap (to some extent), what can results in discrepancies in their diagnoses.

The present measurement methods for such type of tremor, mainly making use of digital tablets connected as peripheral devices to a computer, enable the data acquisition from a 2D surface and in some cases give pressure as an additional information, thus they are not capable of accurate registration of free vibrations in space. Taking into account the necessity to measure all the essential characteristics of the disorder the authors have decided to elaborate a new, fully noninvasive method, making use of digital camcorders and point light sources placed directly on the examined moving object.

2. Tremor measuremet and analysis using digital tablets

The basic parameters for an objective evaluation of the disorder development are the amplitude and frequency of the tremor [2]. Both features can be obtained by methods making use of the electronic tablets (called also digital or graphical tablets). The

most frequently applied test is the drawing of Archimedean spiral by following a provided reference pattern [3],[5],[6]. During the examination the data from the tablet are transferred to the computer, using the RS232 or USB port, and then analyzed by an application working under Windows operating system.

The measurements take place in the X-Y plane, and an additional parameter is provided by registration of the pressure exerted by the patient on the tablet surface, what offers and additional information regarding the pathology. The tablet's spatial resolution is 2540 lpi, the drawing accuracy is of the order of +/-0.25 mm, at maximum data transfer equal to 200 points/second. The pressure is registered in the 0-1024 scale. The application running in the PC computer collects from the tablet (with average time period of 10.5 ms) three parameters: X-axis position, Y-axis position and the pressure of the pen. The pressure of the pen is an additional indicator, however it cannot be considered as an information concerning the vibrations along the third axis of the Cartesian system, i.e. the Z axis.

Because of variable sampling period an interpolation of data is carried out, setting the sampling period on exact value of 10ms. The spiral drawn by the patient can be also watched on the computer screen.

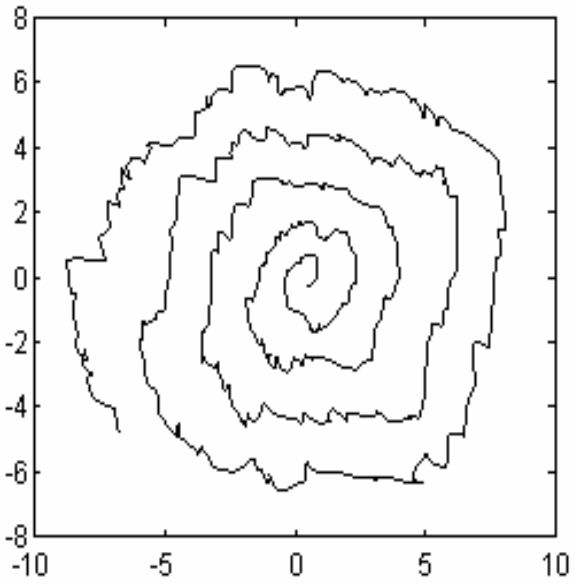

Fig.1. Typical examination making use of the digital tablet

Fig.1 shows examination results for one of the patients in the form of an Archimedean spiral pattern drawn by hand. Both axes are scaled in centimeters.

3. Registration and analysis of the tremor using digital camcorders

An essential feature of the Parkinsonian disease is the presence of resting tremor, which usually affects the upper limbs, patient's head and the lower parts of the face [1],[4]. The above-mentioned symptoms of resting tremor are usually reduced during execution of physical activities [7],[8]. Therefore it is very essential to ensure that the measurement is undisturbed and the examined motion is absolutely free.

The essence of the new registration method is the application of three coupled digital video cameras for registration of the upper limb tremor. The new method enables the measurement of displacements along all axes of the Cartesian coordinate system X-Y-Z, without disturbances caused by the wrist resting on the plane.

The registration of the limb tremor is done by tracing the motion of a point light source, attached to a special band fastened to the patient's body. Alternative measurement versions are possible, making use of one light source or two light sources at the same time. The tremor registration is carried out by three digital camcorders.

A. Description of the measurement stand

The data acquisition takes places in a restricted space, in the form of a cube, with the length of each side equal to 0.3m. Such a volume enables the registration of the limb tremor with enough extra space around the object and gives as well a possibility to adopt the measuring stand to examinations of other types of vibrations. The layout of the whole measuring stand is shown in Fig.2.

Because the picture obtained from each camcorder is two dimensional the measurement exhibits some redundancy, i.e. each camcorder registers vibrations along two axes of the coordinate system, but only one of them is mainly used.

Such a solution is necessary to make sure that the measurements of the vibration vectors are complete and no data loss has occurred by e.g. obscuring the light source by the examined object. Additionally it should be noticed that the registration accuracy depends on the object's distance from the camera's lens (sensor), and the examined object can freely move within the outlined measurement space. In such a situation each camera refers to the results from the neighboring one in order to predetermine the proper scaling factors

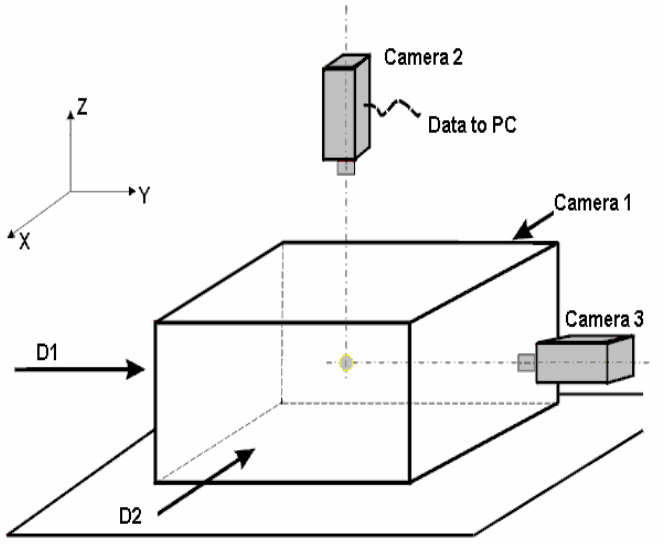

Fig.2. Global view of the experimental setup for vibration measurement using camcorders in X-Y-Z space.

The cameras have been equipped with the KAC-1310 sensors, of the XVGA (1280x1024) resolution and a programmable FPGA chip, with the module responsible for image acquisition, its conversion to a binary form and the detection of the point light source. It is also possible to monitor the current picture on-line both with a grayscale palette and the detection of the light spot. All cameras work with the light spot sampling frequency around 56 Hz, what should be safely enough for tremors related to PD, which exhibit frequencies around 4-7 Hz [2]. The cameras are time-synchronized by software, so that all readouts of coordinates in every camera are taken in the same moments, what is necessary for full reconstruction of the motion trajectory.

The limb tremor measurements have been carried out using a wrist-band with a special LED light source of enhanced light emission intensity, which could be fastened to various parts of the limb. The mass of the light source is negligible in comparison to the body mass and the possibility to fasten the light source to an arbitrary part of the limb makes the system very flexible and allows its universal applications. The proper choice of camera positions allows free entrance for the examined object and enables simultaneous measurements from two directions, labeled in Fig.2 as D1 and D2. Fig.3 presents a photo of the whole measuring stand during the examination.

B. Computer assisted visualization and analysis of the registered data

For data acquisition service and configuration of camera parameters special control software has been used, and its main control panel has been shown in Fig.4. The software enables simultaneous visualization of the light source in the measurement space from all three cameras, readout of the light spot coordinates and its continuous registration as well as the correction of the following camera parameters: gain (coarse and fine), contrast, light spot exposure time, the threshold for its detection, sampling period, and the working mode with the interleaved image, when simultaneous registration of vibrations of two light sources is possible. The data obtained in the acquisition process are saved to a text file, what enables further data import and their analysis in other applications.

Fig.3. Registration of the patient's upper limb tremor.

The analysis of the obtained data has been carried out in MATLAB. The application created in that programming environment executes the preliminary processing and high-pass filtration of the signal and then determines the temporal and spectral characteristics, spectrograms and power spectrum density (PSD) plots, separately for each axis and their resultant sum for translation, velocity and acceleration. After consulting the physicians the application has been appended to work out a series of parameters useful for the analysis of the data like: maximum, average and minimum tremor amplitude, dominant frequency and the maximum value of PSD, percent ratio of the PSD maximum in relation to total PSD in the 1Hz vicinity, as well as differences and rations of the determined amplitudes. All the above-mentioned parameters are calculated for every axis and for their resultant motion. Fig.5 presents the reconstruction of the patient's tremor trajectory in the measurement space. The application also offers a very intuitive graphical user interface, what makes it very user-friendly.

The application makes analyse of recorded tremor in both time and frequency domain. In time domain we calculate maximum, mean and minimum amplitude of tremor. In frequency domain the application calculate FFT and PSD parameters and spectrogram of the tremor. Those parameters are assigned for X, Y, Z axis and for resultant of them, as a square root of sum X, Y and Z to the power of two.

Part of the interface, together with the motion characteristics and the parameters determined for one of the axes has been shown in Fig.6.

The applications of the described measuring stand are not limited only to the tremor measurements in the strictly medical sense. Within the measurement space the data acquisition can be done for any point light source for any object of the size which allows its total or partial placement in the working space of the stand.

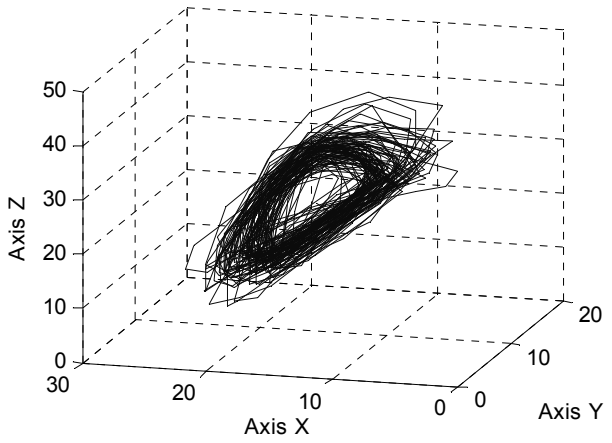

Fig.5. Reconstruction of the patients limb tremor trajectory in the measurement space.

A good example can be offered by a qualitative evaluation of the limb and/or manipulator arm tremor as well as their linear and angular velocity.

4. Conclusions

The computer assistance in vibration measurement and the possibility of cooperation with specialized peripheral devices considerably enhances the data acquisition procedure itself as well as the forms of their visualization and detailed analysis. The methods presently applied for tremor measurements, like the examples of hand-writing or drawings of Archimedean spiral allow only a coarse and subjective evaluation of the tremor. The application of digital camcorders is a solution which allows to determine the values of the tremor amplitude and its frequency, what can be used for objective evaluation and allows the execution of a more exact classification. PD is characterized by resting tremor which is reduced during particular physical activities. The described method, making use of digital camcorders allows the resting tremor measurement without any external disturbances.

The additional advantage of the method is the possibility of tremor registration in the X-Y-Z space, what allows vibration analysis along each of the axes of Cartesian coordinate system. The described method is not limited to the measurement of the upper limb tremor present in patients with Parkinsonian disease. Vibration frequency for diseases accompanied by limbs tremors seldom exceeds 12 Hz, what offers a possibility for extending the set of diseases, which can be examined.

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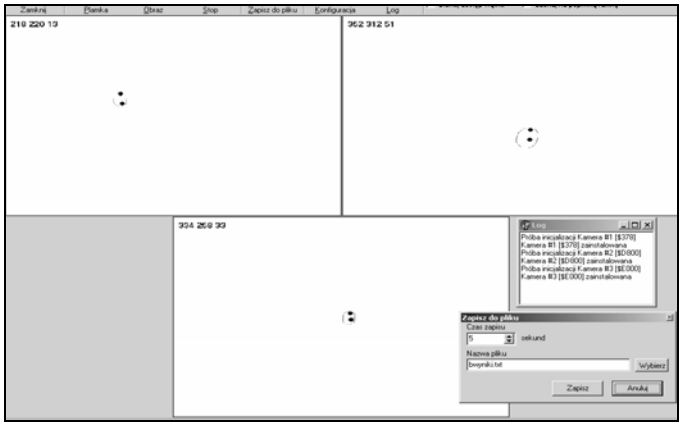

Fig.4. The control panel for visualization, control and recording of the data obtained from three cameras.

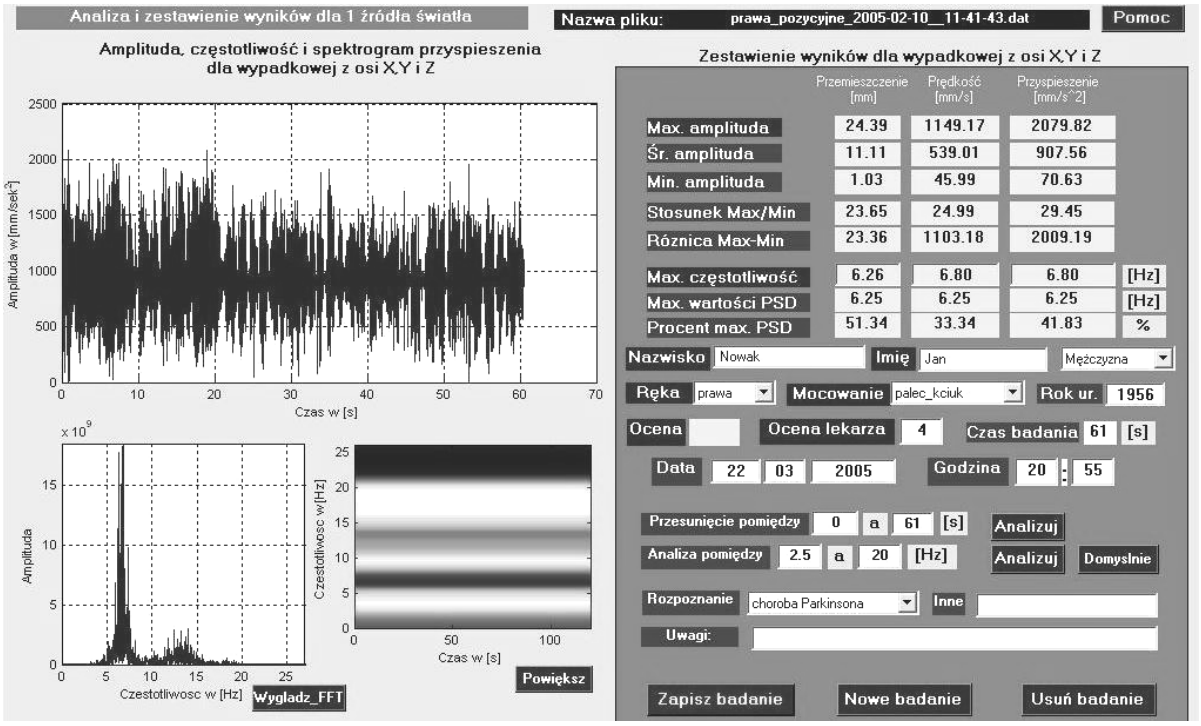

Fig.6. Presentation of a part of the application interface, together with the results of analysis for the data obtained from the cameras.