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Action tremor analysis from ordinary video sequence

Zdenka Uhríková, Otakar Šprdlík, Václav Hlaváč and Evžen Růžička

Abstract— **This paper focuses on tremor frequency analysis from the video sequence. In order to analyse the video data, the signal needs to be extracted from the video using the intensity change of the local area in time. Next, the power spectral density is used for the frequency estimate from the signal. Finally the results obtained from the video are compared with one of the standard measuring techniques for tremors - accelerometers.**

I. INTRODUCTION

Tremor is a rhythmic movement of a body part caused by involuntary contractions of reciprocally innervated muscles. Various neurological disorders produce action tremor affecting typically hands during intentional movements. With the later stages of the disease, the symptoms become very bothering and they interfere with motor abilities of the person such as writing, eating and other elementary tasks.

Routine clinical investigation by a neurologist only estimates the severity of tremor at rest, in static positions and during intentional movements.

Besides the clinical examination, the standard method for measuring the tremor is with the accelerometers or with electromyography [1].

Uniaxial accelerometers, most commonly used accelerometers, are measuring the acceleration in one direction. An accurate placement of the uniaxial accelerometer is crucial so it will record the principal direction of the tremor.

The popularity of triaxial accelerometers is rising, and the advantage is obvious: three axis are measured, so there is a possibility to see different accelerations in different axis.

Electromyography (EMG) is also a way to tremor analysis. EMG is usually recorded with the surface electrodes.

Mathematically speaking, tremor is an oscillating time series, and its frequency can be easily obtained by transforming the series into frequency domain.

Timmer et al. [2] proposed a method based on data driven smoothing of the periodogram which allows automatic estimation of variety of the spectra - different kind of tremors. They also found a method for selecting significant peaks at different frequencies. The practical experiments were performed with accelerometers attached to the dorsum of the hands while the subject was sitting comfortably in the chair.

Z. Uhríková and V. Hlaváč are with the Faculty of Electrical Engineering, Czech Technical University in Prague, Karlovo nám. 13, 121 35 Prague 2, Czech Republic {uhrikz1, hlavac}@cmp.felk.cvut.cz

O. Šprdlík is with the Faculty of Electrical Engineering, Czech Technical University in Prague, Karlovo nám. 13, 121 35 Prague 2, Czech Republic sprdlo1@control.felk.cvut.cz

E. Růžička is with the First Faculty of Medicine, Charles University in Prague, Kateřinská 32, 121 08 Prague 2, Czech Republic eruzi@lf1.cuni.cz

O'Suilleabhain and Matsumoto [3] studied 35 patients with different kinds of tremor with the surface EMG technique. The time-frequency analysis was applied to data (duration 1-3 min) from different parts of the body such as biceps or wrist. Power spectral density (PSD) was estimated by the Welch method of averaging periodograms. Signal-to-noise ratio was used to identify significant peaks.

Let us mention one more experimental technique for tremor analysis proposed by Asyali et al [4]. An infrared LED was attached to patient's body part and the video sequence of the tremor was recorded with an ordinary video camera. A basic principle of image analysis, thresholding, was used here to detect the LED in the image. Detected positions over the time in the video were used for further analysis. The parametric PSD estimation was used as the length of video sequence was not known in advance.

Considering the non-medical computer vision area, rhythmic or periodic motion such as walking or hand clapping has been studied in more detail. An example is work of Liu and Picard [5] who used periodicity templates to localise and characterise temporal activities. In [6], the space-time patches were used to localise the represented periodic activity in the video. Correlation of 'small' video clips (space-time patches) with the larger sequences in all three dimensions was performed.

The interest of this work lies in more elementary periodic motion, which has higher frequency, around 4-12 Hz, and small oscillation (few millimetres to few centimetres). Detection of elementary periodic motion was studied in [7] by searching for visually important segments from cooking videos containing repetitive motions such as cutting, mixing or whipping, and using this information for indexing videos.

In [8] a periodic motion was detected in video by differencing two consecutive frames. The signal was collected over the time and its frequency was studied by the Fourier analysis. Using several criterions, the dominant frequency was selected.

Our proposed solution requires videos of the patient taken by normal video camera, the only additional hardware needed is a computer for processing. It can be also used for any archive video, which is usually available for educational purposes in most hospitals or medical schools. The method offers that previously taken videos can be analysed for the frequency of the tremor and the progress of the disease can be tracked back to the past. We believe that the privacy issues are not a problem here, as often only parts of the body need to be recorded and the patients identity is thus hidden.

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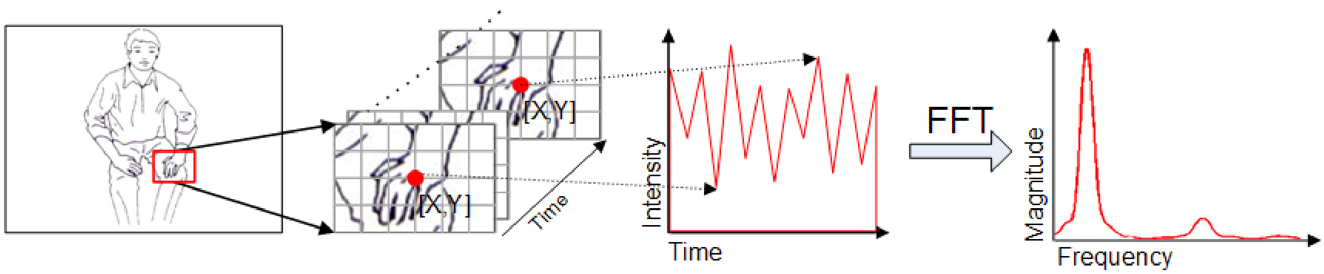
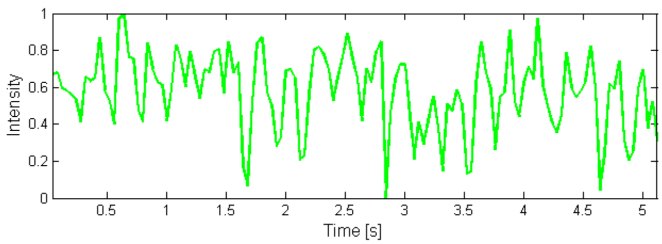
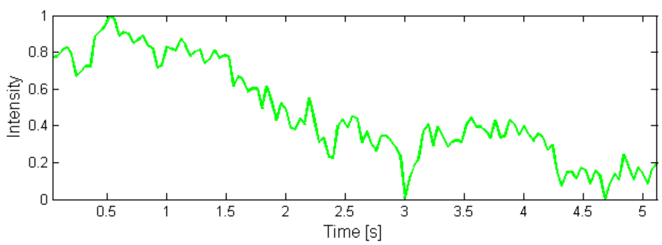


Fig. 1: Pipeline of the signal extraction and processing from the video. First the area of interest is selected. Than the grid is laid over the area of interest and the intensities over the time are collected. Last, the frequency is calculated.



(a)



(b)

Fig. 2: (a) Typical progress of point intensity demonstrating periodicity caused by motion. (b) Example of noisy signal with no significant intensity change that would lead to periodicity.

II. THE METHOD

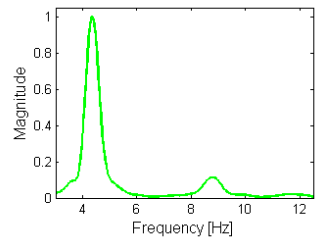
The method described in this paper is based on capturing the video sequence and its following analysis.

We assume that the video of a patient was shot from a tripod and that the sampling frequency is known. It is 15 or 25 frames per second for typical video cameras. When these two assumption are met, the proposed method consists of two basic steps: signal extraction and signal analysis.

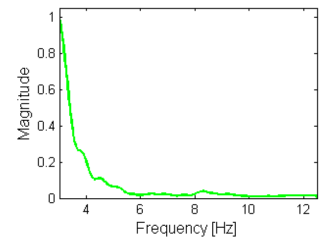
A. *Signal extraction from video*

The parts of interest were manually labeled in the first frame of the video. The interest of this study lay in the hand tremor, so the area with left and right hand was marked. See Figure 1a for illustration.

Considering further only the area with the hand, a grid of 5×5 pixels was laid over the hand. The intensities of points on the grid over the time were collected for analysis (See Figure 1b). The grid typically consists of more than 100 points, which gave us more than 100 point intensity series in the time. For higher precision, all of them were processed, otherwise the noise or some motion disturbances may negatively affect the final result.



(a)



(b)

Fig. 3: Examples of the frequency analysis. (a) Clearly detected frequency around 4 Hz (b) No dominant frequency detected.

B. *Processing*

The collected signal is expected to be periodic if there was some tremor. The idea is that a moving body part in front of background causes changes in the intensity of the single point from skin color to background color and back. Figure 2a and Figure 2b show an example of collected data - signal with clear periodicity as well as noisy data.

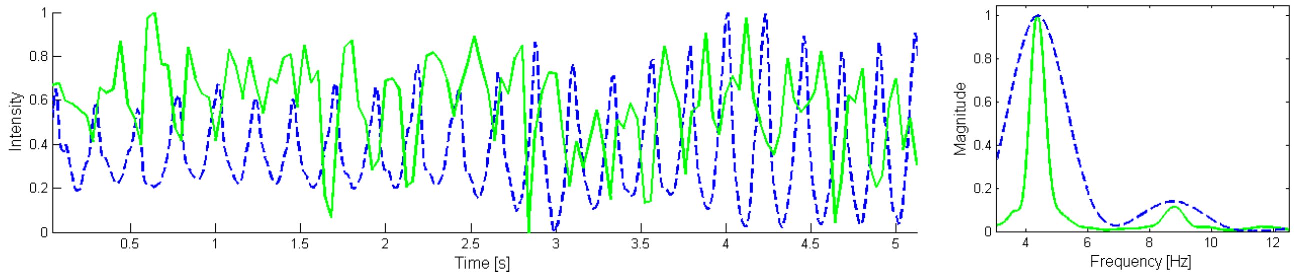
The Fourier transform works very well for frequency extraction. Power spectral density was used for analysis as this is widely used technique for processing the signal from accelerometer and worked well also for the video signal.

As mentioned above, the power spectra from all points were computed together to avoid the distractions from single points caused by noise. The movement of the hand is expected to be to be consistent, so these spectra can be added to get one final spectrum. This will eliminate the noise, and if two strong frequencies were present, two peaks will have been seen in the result as well. See the example frequency spectra in Figure 3.

The same method was used to analyse the signal from accelerometers. All axis were analysed separately, as frequencies may differ here.

III. EXPERIMENTS

The pilot study was conducted with patients with action tremor mostly in their hands. The set of standardized postures was prepared to examine the tremor: resting hands on armrests, hand resting on armrest with fingers extended, hands



(a) (b)

Fig. 4: Comparison of video signal (green solid line) and signal from accelerometers (blue dashed line). (a) The signal progress (b) Computed frequencies for signals in (a).

stretched forward and the 'wings' position (hands bended opposite to each other in front of the chest). Each exercise was performed for 20 seconds and repeated twice.

The signals from accelerometers were used for validation. Inertial measurement units (Xsens MTx) were attached on the back of both hands and the data were directly transferred to computer. The recording frequency of the accelerometer was 100 Hz and it was measuring acceleration in X, Y, and Z direction among other quantities.

Video data were obtained with the Sony Camcorder (DCR-PC350E) mounted on the tripod to avoid camera movement, the recording frequency was 25 frames per second, non-interlaced option was used.

Pathological tremors have usually the frequency between 4 to 12 Hz, for which the recording frequency of camera 25 fps is sufficient (recalling the Nyquist sampling theorem).

Over 250 samples were available for analysis, out of which 160 samples contained visible tremor. Only results from samples with visible tremor are presented here. The frequencies obtained by both measuring methods, the camera and accelerometers, were compared. See Figure 4a for signal from the accelerometer and the camera at the same time. The result of frequency analysis is in Figure 4b.

IV. RESULTS

Using the video analysis, the frequency of the visible tremors was detected in all 160 samples. The accuracy was compared against the frequency from the accelerometer which was used as the ground truth. The comparison of the two measurements is in Figure 5.

The difference between the frequency from video and accelerometer was more than 0.2 Hz only in 14% of data. It is necessary to say that in more than half of those cases the signal from accelerometer showed different frequencies in different axis.

V. CONCLUSIONS AND FUTURE WORK

We presented technique for measuring and analysis of the tremor frequency from the video data. The nature of the technique allows to analyse even archived videos of patients which is a huge advantage in comparison to other methods.

According to the results we showed that the technique for measuring the frequency from the video is valid and it has a potential to be used in practice. The differences from the accelerometers technique were small, and were rarely more than 0.2 Hz.

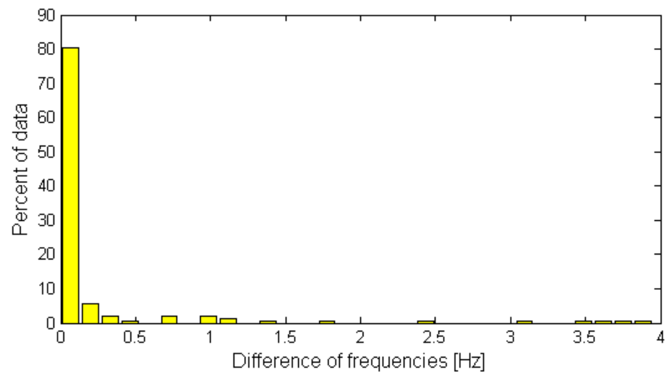


Fig. 5: Differences between measurements of frequency from video and from accelerometer data.

In future we plan more detailed analysis based on exact amplitudes obtained from the accelerometers data and also continuous analysis during the whole sequence to see whether and how is the frequency changing in time. More patients are going to be examined within the study.

VI. ACKNOWLEDGMENTS

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