ANALYSIS OF HUMAN TREMOR USING HIGH SPEED CAMERA

Zenon Kuder
Bachelor Degree Programme (3), FEEC BUT
E-mail: xkuder00@stud.feec.vutbr.cz

Supervised by: Milan Rychtárik
E-mail: rychtarik@feec.vutbr.cz

ABSTRACT

This project investigates the possibility of using the Olympus iSpeed 3 high-speed camera and light-emitting diodes in visible light spectrum to analyse human tremor of upper limbs. Moreover, it discusses possible realization of a measurement apparatus including software implemented in the Matlab environment.

1 INTRODUCTION

A measurement system for human tremor using visible-spectrum LED, as opposed to classical approach using accelerometers, can avoid the accelerometers' drawbacks, such as susceptibility to electrical interference, decreased low-frequency response and non-linear characteristics. Similar project was developed using IR LED at Yasar University [1].

The frequencies of the two main types of tremor are 3-7 Hz for parkinsonian at rest and 6-12 Hz for physiological and parkinsonian during activity (e.g. muscle contraction) [2].

2 SYSTEM COMPONENTS

The measurement system proposed in this project can be divided into several subcomponents, as depicted in the figure 1. These components are independent and can be replaced individually.

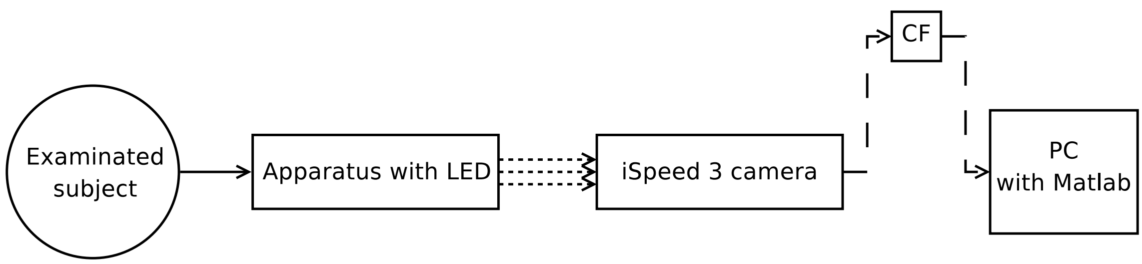

Figure 1: Block diagram of the measurement system

A set of simple light-emitting diodes in visible spectrum attached to fingers was used as the light source. The camera used was Olympus iSpeed 3. This high-speed camera can record as fast as 2 000 FPS in the full resolution of 1280x1024. This speed, however, is unnecessary for the tremor measurement, since human tremor doesn't occur at frequencies higher than 15 Hz [1, 2]. To meet the sampling theorem criteria [3] it should be enough to use any camera with FPS 30 or higher and an appropriate resolution.

The focus of this project was on the software used for the analysis. The software was written in the Matlab® environment.

3 SOFTWARE

The software offers a user-interface with all the settings. The file from the camera needs to be transferred manually using Compact Flash or other means offered by the camera. The user then opens the file, sets the thresholds, frame-rate, distance-to-pixels ratio etc.

In the current version, the following plots are available: trajectory, speed in time domain, acceleration in time domain, speed spectrum and acceleration spectrum.

3.1 SPACE DOMAIN

The trajectory plot is a 2D representation of all the points the fingers have been to, without time resolution.

3.2 TIME DOMAIN

The speed is stored as a matrix of differences between light-spot positions in consecutive frames for each finger and then converted to mm/s:

$$dso_{i,k}\left[\frac{\mathrm{mm}}{\mathrm{s}}\right] = \frac{DTP\left[\frac{\mathrm{mm}}{\mathrm{px}}\right]\cdot dso_{i,k}\ [\mathrm{px}]}{(RF\ [\mathrm{Hz}])^{-1}}, \tag{1}$$

where DTP is the user-entered distance-to-pixels ratio in mm/px and RF is the real frequency, i.e. FPS, for all the i spots and k frames.

The acceleration matrix is computed as a difference of all the consecutive speed values, each value divided by the time difference, i.e. RF^{-1}.

3.3 FREQUENCY DOMAIN

The key of tremor analysis lies in the frequency domain. We consider the input to be stochastic and ergodic as long as the subject is kept in the same condition. The current version of the software uses the modified periodogram method to estimate the power spectral density (PSD).

The windowed sequence of length N is divided into M parts of $N' = N/M$ samples. The M value is user-defined and higher values reduce the noise, but also decrease the frequency resolution. Spectrum is computed for each of these parts and the mean value of these spectra is used as the PSD estimate S_{ff} [3]:

$$S_{ff}(\omega) \approx \frac{1}{M}\sum_{w_i=1}^{w_M}\frac{1}{N'}|F_{w_i}(\omega)|^2. \tag{2}$$

A sample output of the speed PSD estimate can be seen in the figure 2. This was a test measurement for a healthy male. Left hand was measured and the muscles were contracted to simulate activity. The *M* value was set to 16, window function was Hamming and samples on frequencies below 1.5 Hz were considered low-frequency drift and set to zero. Only two fingers were plotted for clarity.

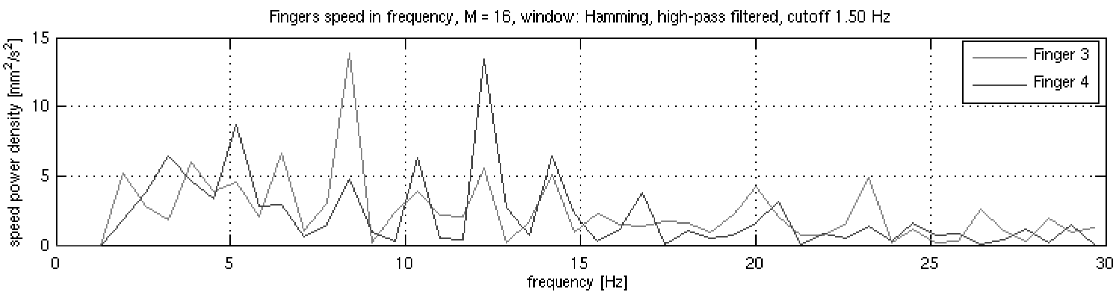

Figure 2: Sample plot, speed in frequency domain

Although there is still a considerable amount of noise, there are visible peaks at 8 and 12 Hz, which match the expected range for physiological tremor, i.e. 6-12 Hz.

The noise level could be improved by recording longer videos. Since the camera's RAM is limited, it would be necessary to decrease the time or space resolution, measure several video shots of the same subject in the same condition or use a different camera.

4 CONCLUSION

A non-invasive, low-cost, simple, portable, universal tremor measurement system was proposed. The main disadvantages are slow analysis, too much human input needed and too short sample recordings.

Nevertheless, the preliminary results indicate that this system can potentially measure human tremor even for healthy individuals and most of the drawbacks can be addressed by improving the software and using different camera settings.

This system could also be further improved by for example employing higher-order statistical methods to classify the tremor, as proposed in [4].

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