Non-contact measurement of tremor for the characterisation of Parkinsonian individuals: comparison between Kinect and Laser Doppler vibrometer

L Casacanditella¹, G Cosoli¹, MG Ceravolo², EP Tomasini¹
¹Department of Industrial Engineering and Mathematical Sciences, Università Politecnica delle Marche, via Brecce Bianche, 60033 Ancona, Italy
²Department of Experimental and Clinical Medicine, Università Politecnica delle Marche, via Tronto 10/a, 60126 Ancona, Italy

E-mail: g.cosoli@univpm.it

Abstract. Parkinson’s disease is a progressive neurodegenerative disorder affecting the central nervous system. One of its main and most evident symptoms is the tremor, which usually manifests at rest with varying intensity during time. An important diagnostic challenge is the differential diagnosis between Parkinson’s disease and the other most widely represented tremor syndrome, i.e. Essential (or senile) tremor. At present there are no standard methods for the quantification of tremor and the diagnosis of both Parkinson’s disease and Essential tremor is mainly done on the base of clinical criteria and by using rating scales. The aim of this work is to objectively and non-invasively assess the tremor linked to the quoted diseases, using non-contact techniques: Laser Doppler Vibrometer (LDV) and Kinect for Windows device. Two subjects with Parkinson’s disease and one with Essential tremor were tested in different conditions: at rest, during a cognitive task, with forward stretched arms and in “Wing position”. The results from data processing in terms of tremor frequency seem to be comparable, with a mean deviation of 0.31 Hz. Furthermore, the values computed are consistent with what is stated in the literature (i.e. 4-12 Hz). So, both LDV and Kinect device can be considered suitable to be used as an objective means for the assessment and monitoring of Parkinson’s disease tremor, helping the clinician in the choice of the most suitable treatment for the patients.

1. Introduction
According to the World Health Organization (WHO), hundreds of millions of people worldwide are affected by neurological disorders, such as epilepsy, Alzheimer disease or other dementias and Parkinson’s disease (1). Parkinson Disease (PD) is a progressive neurodegenerative disorder of the central nervous system (2–4). It is characterised by several features (both motor and non-motor symptoms (5–7) – the motor signs are caused mainly by dopamine deficiency (8)) that appear slowly over time and can impact significantly on functional and cognitive capabilities of the subject (9–11). Furthermore, it has also a substantial economic impact on society (12,13), considering a rising prevalence of the pathology with age. In fact, it is possible to state that the prevalence of PD (per 100.000) is equal to (14):
- 41 in 40-49 years;
• 107 in 50 to 59 years;
• 428 in 60 to 69 years;
• 1087 in 70 to 79 years;
• 1903 in older than age 80.

Some differences in prevalence of PD by geographic location and gender can be detected (15–18). Among its motor signs, e.g. bradykinesia, rigidity and tremor, the last is the most evident and embarrassing one (19): it is an involuntary rhythmic oscillation, quite regular, of a body part around a fixed point, along a unique plan. This phenomenon is stressed when that body part is at rest condition, in fact rest tremor is the most common and easily recognised symptom (20). However, due to the erratic occurrence of tremor and its varying intensity over time, it can be difficult to either detect or quantify this symptom. Therefore, it would be important to provide the clinicians with objective quantitative measurements of Parkinson’s disease symptoms, in order to help the diagnosis and personalise the treatment (21–23). Moreover, when the differential diagnosis between tremor syndromes becomes challenging, like in subjects with atypical tremor, the support of quantitative measures able to characterize the frequency and time course of involuntary movements could be useful.

In the literature, it is possible to find studies related to the measurement of tremor by means of triangulation sensors and accelerometers (24), but also displacement and velocity sensors and electromyography (25), gyroscopes (26) and laser diodes (27).

The aim of this work is to quantitatively measure the tremor frequency in the upper limbs of Parkinsonian individuals by means of two different non-invasive and non-contact sensors: a Laser Doppler Vibrometer (already used for non-invasive measurements of several physiological parameters (28–33)) and the Kinect device. This study is intended to be a pilot step for an objective evaluation that can be useful for a reliable quantitative assessment of tremor in Parkinson’s disease.

2. Materials and methods

2.1. Measurement setup

Three subjects complaining for tremor syndrome (2 male, 1 female, mean age = 67 years, average disease duration = 17 years) were enrolled into the present pilot study; they were included because of the manifestation of unilateral or bilateral tremor affecting the upper limbs. The subjects were tested in different conditions: at rest or during the execution of a cognitive task, seated or standing. All the measurements were carried out in the morning, while undergoing their daily treatment. Two of the tested patients (subjects 2 and 3 in the Results section) were affected by Parkinson’s disease, while subject 1 suffered from essential tremor (34,35), the most common “movement disorder” (36), which is more evident during voluntary actions, both in postural and in kinetic situations. In the literature, the frequency of the essential tremor is in the range 4-12 Hz (37).

Two non-invasive and non-contact measuring instruments were used:
• A Laser Doppler Vibrometer, LDV (PDV 100 by Polytec (38), sensitivity: 0.2 V/(mm/s)), measuring the velocity of the surface displacement;
• A Kinect for Windows device (39) (frame rate: 30 Hz; image resolution: 480 pixels x 640 pixels; depth measurement distance: 0.5-4.5 m), measuring both a colour image (by means of an RGB camera) and a depth image (by means of a depth sensor, composed of an IR projector and an IR camera).

The subject was asked to relax and sit on a chair with armrests. The LDV laser beam (HeNe, Class II, visible (38)) was directed perpendicularly on the hand of the patient, at a distance of 1 m; the signal was sampled with a sampled frequency of 1 kHz. At the same time, the RGB and the depth cameras of the Kinect device were used to record videos during the tests. The measurement setup is reported in ‘figure 1’.
Different kinds of test were performed:

1. At rest: the subject was seated, with the back leaned against the seatback of the chair, the elbows at 90°, the forearms laid on the armrests and the hands out of the supports;
2. At rest with a consequent cognitive task: the subject was seated and he was asked to do a cognitive task (e.g. to count backwards out loud);
3. “Wing position”: the subject was asked to stand up and stay with the arms lifted on a plane parallel to the floor, the elbows bended with an acute angle, the hands in front of the chest, with the palms downwards;
4. With the arms stretched out: the subject was asked to stand up and stay with the arms lifted in front of the shoulders, on a plane parallel to the floor, with the palms downwards.

The second test is intended to increase the subject’s stress, highlighting the tremor (even when it is latent). In the third and the fourth tests, the assumption of a determined position is useful to evaluate the so-called re-emergent tremor (40).

The four tests are represented in ‘figure 2’. Each kind of test had a duration of 20 s.
2.2. Data processing

The signals extracted from LDV and Kinect device were processed in order to compute the tremor frequency. The two sensors required the use of different processing techniques in order to obtain the frequency value. Both the signals were processed in MATLAB® (41) environment.

In particular, with regard to LDV signal, the processing procedure consisted in the following steps:
- Removal of the mean value of the signal;
- Filtering with a 3rd order Butterworth low-pass filter (cutoff frequency = 20 Hz);
- Fast Fourier Transform (FFT) of the signal, in order to evaluate its spectral components.

An example of such a processing procedure is reported in ‘figure 3’.

On the other hand, two different approaches were applied to the signals from the Kinect depth camera:
- One approach to extract the tremor in the direction orthogonal to the sensor field of view. In this case, the colour image was used; the processing steps were the following:
  - Selection of the Region of Interest (ROI);
  - Conversion into black and white pixels, depending on the intensity;
  - Computation of centroids;
  - Fast Fourier Transform;
- The other approach to individuate the tremor in the direction parallel to the sensor field of view. In this case, the depth map was used; the processing stages were the following:
  - Selection of the Region of Interest (ROI);
  - Computation of the mean value;
  - High pass filtering (cutoff frequency = 0.5 Hz);
  - Mean removal;
  - Fast Fourier Transform of the signal.

An example of signals from Kinect sensor is reported in ‘figure 4’.

![Figure 3. LDV signal processing: 1) raw signal after mean removal; 2) filtered signal; 3) frequency content of the signal](image-url)
3. Results
The results obtained from LDV and Kinect sensors (in particular, the frequency of the tremor) were compared.

The results in terms of tremor frequency, measured by means of LDV and Kinect sensor, for the 3 subjects in the different kinds of test, are reported in ‘table 1’. It is possible to observe that they are comparable, with an average deviation of 0.31 Hz.

No significant differences in terms of tremor frequency can be identified between subjects with essential tremor (subject 1) and the other two (subjects 2 and 3).

Table 1. Tremor frequency measured by means of LDV and Kinect sensor in the three tested subjects during the different kinds of test

| Subject | Sensor | At rest | Cognitive task | Stretched arms | Wing position |
|---------|--------|---------|----------------|----------------|---------------|
| 1       | LDV    | 4.7     | 4.3            | 2.1            | 5.6           |
|         | Kinect | 4.5     | 4.3            | 2.1            | 5.5           |
| 2       | LDV    | 3.7     | 4.9            | 5.6            | 5.5           |
|         | Kinect | 3.4     | N.A.           | 5.2            | 5.6           |
| 3       | LDV    | 4.4     | 4.6            | 2.3            | 5.6           |
|         | Kinect | 4.1     | 4.7            | 1.9            | 4.2           |

4. Discussion and conclusions
The results from this preliminary study allow the authors to state that both Laser Doppler Vibrometer and Kinect device are able to detect and characterize upper limb tremor in terms of frequency, providing a suitable measurement tool towards a quantitative assessment of this condition. They are comparable in terms of performance in quantifying the tremor frequency; however, it is possible to say that, for sure, Kinect device is preferable in terms of cost (for this reason, it would be possible to use it even in home environments), while LDV requires simpler data post-processing techniques.

Moreover, the obtained results are in line with those reported in literature, both referring to rest tremor (3-7 Hz) (42) and to essential tremor (4-12 Hz) (37).
In the future, it would be interesting to further exploit the videos recorded by the Kinect camera and in particular its ability to detect anatomical landmarks, which are useful to reconstruct the trajectory of a specific movement.

5. References

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