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Development of method for quantifying essential tremor using a small optical device

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HIGHLIGHTS

- We examined the feasibility of using a small optical device (Leap Motion) to quantify tremor frequency and amplitudes.
- Three algorithms were proposed and tested to provide different quantifications of finger movement of patients with essential tremor.
- A potable optical device with appropriate algorithms could be used to quantify tremor characteristics in clinical environments.

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ABSTRACT

Background: Clinical assessment scales are the most common means used by physicians to assess tremor severity. Some scientific tools that may be able to replace these scales to objectively assess the severity, such as accelerometers, digital tablets, electromyography (EMG) measurement devices, and motion capture cameras, are currently available. However, most of the operational modes of these tools are relatively complex or are only able to capture part of the clinical information; furthermore, using these tools is sometimes time consuming. Currently, there is no tool available for automatically quantifying tremor severity in clinical environments.
New method: We aimed to develop a rapid, objective, and quantitative system for measuring the severity of finger tremor using a small portable optical device (Leap Motion).
Results: A single test took 15 s to conduct, and three algorithms were proposed to quantify the severity of finger tremor. The system was tested with four patients diagnosed with essential tremor.
Comparison with existing method: The proposed algorithms were able to quantify different characteristics of tremor in clinical environments, and could be used as references for future clinical assessments.
Conclusions: A portable, easy-to-use, small-sized, and noncontact device (Leap Motion) was used to clinically detect and record finger movement, and three algorithms were proposed to describe tremor amplitudes.

1. Introduction

Essential tremor (ET) is a common movement disorder in the adult population, and its prevalence increases with age (Grimaldi and Manto, 2010). Although tremor may not cause immediate threat to life, it affects the quality of daily life (Grimaldi and Manto, 2010). Clinical assessment scales are usually used, by trained clinicians, to assess ET severity, such as the Fahn–Tolosa–Marin (FTM) Tremor Rating Scale, and Washington Heights–Inwood Genetic Study of Essential Tremor (WHIGET) Scale (Louis et al., 1997; Stacy et al., 2007). Past research has indicated that scores based on clinical assessment scales may not be sufficient to distinguish subtle changes in the degree of mild tremor or the severity of tremor over a certain period (Hess and Pullman, 2012). Moreover, the clinical scores may not be sufficient to determine the effect of therapy objectively in clinical practice (Hess and Pullman, 2012).

Therefore, several studies over the past decade have focused on developing instrumented systems and methods for quantifying the parameters of tremor (Bain et al., 1993; Gao, 2004; Grimaldi and Manto, 2010). For instance, accelerometers, digital tablets,

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cameras, optical devices, and assessment methods for neuromuscular physiological signals were used for quantification of tremor. However, these methods have their advantages and disadvantages. Accelerometers are usually only used to assess the frequency of finger tremor. The advantages of accelerometers include small size, and relatively high sampling frequency (could be hundreds of times the frequency of finger tremor). However, a drawback of accelerometers is that they need to be attached to the fingers, which may affect the inertia and motion performance of fingers. Additionally, the assessment results of accelerometers include the gravity factor, which has to be removed for the quantification of the tremor amplitude. In contrast, using cameras as assessment method is not affected by gravity, but the frequency of image capture is relatively low and the subsequent data processing is usually time consuming. Neuromuscular physiological signals, such as surface electromyography (EMG) data, can provide information on muscle contraction, including the relationships among the motions of antagonistic muscles, motor unit recruitment, and muscle firing frequency, and can be used to explain the role of muscles in tremor. Although muscle contraction causing or during tremor could be measured by surface EMG, the EMG signals do not correlate well with the tremor amplitudes. Therefore, the EMG results still could not represent the real amplitude of tremor. Optical motion capture devices are also employed for quantifying movements, and their characteristics include high temporal and spatial resolution, as well as providing complete three-dimensional (3D) movement information. However, the subsequent information processing is time consuming, spatial calibration is needed before the measurement, and the procedure is complex and may not be suitable for clinical use. Considering the aforementioned methods, there has been no relatively general standard or scientific method for evaluating the severity of tremor in clinical practice (Elble et al., 1996, 2006; Grimaldi and Manto, 2010; Wile et al., 2014).

The aforementioned means are not convenient for using in clinical environments. Consequently, a method for assessment of tremor and with characteristics such as small size, low cost, convenient operation, and rapid completion of data analysis would be of great help in clinical practice. The purpose of this study, therefore, was to develop an instrumented system to automatically quantify tremor characteristics in clinical environments to assist physicians for diagnosing the types and severity of tremor.

2. Materials and methods

We integrated a hardware system using a commercial available optical system, Leap Motion (described below), and developed algorithms to quantify movement characteristics. We first verified the hardware system performance to ensure the suitability of quantifying tremor characteristics, and then conduct testing on patients with tremor to validate the feasibility of tremor quantification.

2.1. System integration

The hardware system was integrated using an optical device, Leap Motion (Leap Motion Inc., USA). Leap Motion, a non-contact optical device commercially available since 2012, 45 g in weight, that could detect motion in three-dimensional space using two infrared cameras, was employed in this study. According to the manufacturer specifications, the accuracy of Leap Motion in spatial measurement can reach 0.01 mm and the capture frequency can reach 200 Hz (camera frequency). However, according to past studies, the error of spatial measurement in a static measurement is approximately 0.2 mm (Weichert et al., 2013) and the average spatial error in continuous motion is 0.4 mm (Guna et al., 2014). In addition, three operation modes of Leap Motion can be used: high-speed (with less resolution); balance mode (with intermediate resolution); precision mode (with highest resolution). A previous study tested the performance of Leap Motion in a well-controlled environment using the ‘precision mode’ and found that the device cannot provide consistent sampling frequency, averaged around 40 Hz mm (Guna et al., 2014). To ensure stable capturing resolution and sampling frequency in future clinical applications, we tested different operation modes and sampling rate for reading data from Leap Motion into a computer, and found that using the ‘balance mode’ with 50 Hz of sampling frequency (50 frames per second of data reading from Leap Motion to the computer) could provide the most consistent sampling frequency. Therefore, the Leap Motion was setup to operate with the balance mode, and the data collection rate was at 50 Hz.

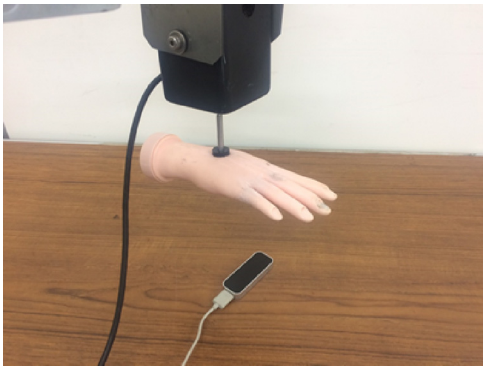

Fig. 1. Hardware system performance testing setup. A plastic hand model was attached to an electromechanical vibrator. The movement of the fingers was captured by Leap Motion below the hand and an accelerometer attached to the junction of the plastic hand and the vibrator simultaneously.

Previous studies have only focused on the accuracy of Leap Motion in measuring spatial movement of objects; however, no study has performed any analyses of simple harmonic motion with a relatively high spatial frequency, such as tremor of fingers. The suitability of this instrument for measuring the tremor amplitude remains unclear. Therefore, we verified the performance of Leap Motion with embedded tracking model on detecting finger tremor movement. To mimic finger tremor, a plastic hand model was attached to an electromechanical vibrator (ET-132-2, Labworks Inc., Costa Mesa, California, USA) (see Fig. 1); a continuous simulated tremor was then provided by setting a vibration frequency and amplitude of the vibration (hardware capacity: maximum frequency of 11 kHz and maximum amplitude, peak-to-peak, of 12 mm). The simulated tremor frequency used in this experiment was 3–8 Hz, corresponding to the common range of essential tremor (Grimaldi and Manto, 2010). An accelerometer (shock sensor) was affixed to a finger on the hand model, and the simulated tremor amplitudes were calculated by double integrating the measured acceleration with time. The results were compared with position measurements from the Leap Motion. A correlation between measurements from Leap Motion and actual finger movement was then determined for further use.

2.2. Subject testing

Four subjects clinically diagnosed with ET participated in the experiments. All subjects were right-handed. Subject’s characteristics and FTM scales (Jankovic and Tolosa, 2007; Stacy et al., 2007) evaluated by an experienced neurologist are shown in Table 1. The subjects were instructed to take only half the dose of the prescribed medications for trembling, so that they were able to show clinical symptoms without seriously affecting their daily activities. All experimental procedures were approved by the Institutional