A Fine-Grained Analysis of Post-Stroke Motor Function Using Wearable Motion Sensors

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INTRODUCTION

Every year, approximately 795,000 people experience a new or recurrent stroke in the US, an event that is a leading cause of the motor deficit [1]. Existing clinical studies demonstrate that motor function can be recovered through rehabilitation. To select the most appropriate rehabilitation programs, it is important to accurately assess the patient's current motor function. Traditionally, the assessment is based on the observations on the patient's motor behavior using standard clinical rating scales. However, this strategy has two drawbacks. First, since the assessment is based on the clinician's subjective judgments, the accuracy and consistency may vary significantly across clinicians. Second, the rating scales cannot record the details of the motor performance, thus failing to precisely evaluate the patient's progress during rehabilitation. To bridge the gaps, we present a methodology for fine-grained assessments of post-stroke motion functionalities using wearable motion sensors. Our approach provides quantitative evaluations on motor function based on sensor signals and acts as a significant complement to the standard clinical rating scales.

MATERIALS AND METHODS

We use MotionNode (Fig.1) [2] as our wearable sensing platform. MotionNode is a 6-DOF inertial measurement unit (IMU) specifically designed for human motion sensing applications. It integrates a 3-axis accelerometer (±6*g*) and a 3-axis gyroscope (±500*dps*). The sampling rates for both accelerometer and gyroscope are set to 100 Hz.

Fig.1. MotionNode platform

Different from the existing motor function assessment methods in which the whole segment of motor task is mapped to a single point in the feature space [3], our fine-grained approach divides the streaming sensor data from each motor task segment into a sequence of fixed-length window cells whose length is much smaller than the duration of the motor task itself. Features that capture the intrinsic characteristics of the motor behavior are extracted from each window cell to form a local feature vector. As a result, each motor task segment is transformed into a sequence of local feature vectors, which forms a trajectory in the feature space. This fine-grained trajectory representation is beneficial in the sense that it captures the details of the motor behavior and helps clinicians to track the patient's progress during rehabilitation.

RESULTS

To evaluate the performance of our approach, two subjects with limb hemiparesis from stroke were recruited at two rehabilitation centers in Los Angeles. Each subject wore the MotionNode on the forearm and was asked to perform five upper limb motor tasks from the Fugl-Meyer Assessment (FMA) [4]. The test was videotaped. Each task was assigned a score based on the FMA scale by a physical therapist.

As an example, Fig.2 shows the result of one segment of motor task *flexor synergy*. We calculate motion intensity as the feature which acts as an indirect measure of the strength of the subject's motor behavior. The red line and blue line represent the task performed by the unaffected and affected limb respectively. The corresponding FMA score was 12/12 and 8/12. As shown in Fig.2, our approach is capable of capturing the timing and pattern differences between the limbs (there exist two peaks for the unaffected limb which does not appear for the affected limb). In comparison, a difference of 4/12 FMA score cannot provide such details.

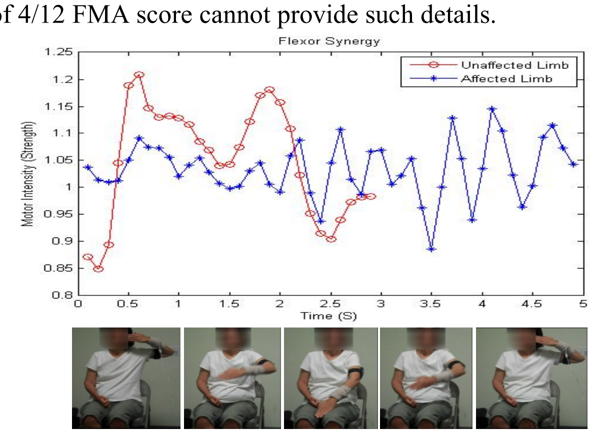

Fig.2. The fine-grained trajectory representation on Flexor Synergy

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