A FINE-GRAINED ANALYSIS OF POST-STROKE MOTOR FUNCTION USING WEARABLE MOTION SENSORS

USC Viterbi School of Engineering

Ming Hsieh Department of Electrical Engineering

Mi Zhang[1], Belinda Lange[2], Chien-Yen Chang[2], and Alexander A. Sawchuk[1]

[1]Signal and Image Processing Institute, Ming Hsieh Department of Electrical Engineering, University of Southern California, Los Angeles CA 90089

[2]Institute for Creative Technologies, University of Southern California, Playa Vista CA 90094

Introduction

- Background
  - Stroke is a leading cause of motor deficit
  - Every year, approximately **795,000** people experience a new or recurrent stroke in the US
  - Motor function can be recovered through physical rehabilitation
  - Traditional physical rehabilitation assessment has two major drawbacks
    - ❑ Assessment is based on the clinicians' subjective judgments
    - ❑ Standard clinical rating scales such as Fugl-Meyer Assessment (FMA) and Wolf Motor Function Test (WMFT) can not provide the details of motor performance
- Problem Statement
  - Develop a quantitative method to automatically analyze and evaluate post-stroke motor function
- Challenges
  - Need a tool to precisely capture patients' physical motion
  - Need to build a motion model that is able to capture the details of motor behavior

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Our Method

- Wearable Motion Sensor
  - 3-axis accelerometer (± 6g), 3-axis gyroscope (± 500dps)
  - Sampling rate: 100 Hz
- Fine-Grained Post-Stroke Motor Function Analysis Framework
  - Sliding Window
  - Feature Extraction
  - Pattern Recognition

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Details

- Small Window Cell
  - Divide 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 (0.1 second)
- Feature Extraction
  - Extracted from each window cell to form a local feature vector
  - Features that capture the intrinsic characteristics of the motor behavior. Examples include:
    - ❑ Motion Intensity (MI): $MI(t)=\sqrt{a_x(t)^2+a_y(t)^2+a_z(t)^2}$
    - ❑ Normalized Signal Magnitude Area (SMA): $SMA=\frac{1}{T}\left(\sum_{t=1}^{T}|a_x(t)|+\sum_{t=1}^{T}|a_y(t)|+\sum_{t=1}^{T}|a_z(t)|\right)$
    - ❑ Averaged Rotation Energy (ARE): The mean value of the energy over three gyroscope axes
  - Each motor task segment is then transformed into a sequence of local feature vectors, which forms a trajectory in the feature space
- Pattern Recognition
  - Extract pattern interesting to physical therapists

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Data Collection

- Participants
  - 2 patients with limb hemiparesis from stroke are recruited at **Precision Rehabilitation Center** at Long Beach and **Rancho Los Amigos National Rehabilitation Center** at Downey
- Motor Tasks
  - 5 upper limb motor tasks from the Fugl-Meyer Assessment (FMA) are performed
    - ❑ Flex Synergy
    - ❑ Hand Behind Back
    - ❑ Shoulder Flexion to 90 degree
    - ❑ Shoulder Flexion from 90 to 180 degree
    - ❑ Pronation / Supination Elbow Flexed
  - Each participant performed each motor task 6 times
  - Each task was assigned a score based on the FMA scale (0, 1, 2) by a physical therapist

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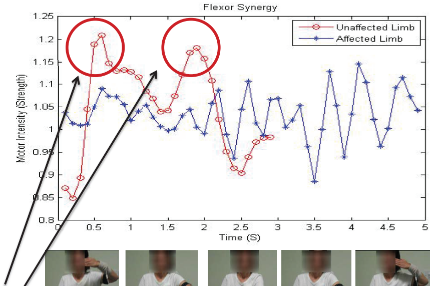
Results

- Motor Task:
  - Flexor Synergy
- Horizontal Axis:
  - Time (Second)
- Vertical Axis:
  - Motion Intensity
- Unaffected limb:
  - Red curve
  - FMA score: 12/12
- Affected limb:
  - Blue curve
  - FMA score: 8/12
- There exist two peaks for the unaffected limb which do not appear for the affected limb



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Conclusion and Future Work

- Conclusion
  - 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
- Future Work
  - Build a large dataset to include more patients
  - Develop signal processing algorithms to automatically capture patterns that are important to physical therapists to track patients' progress during rehabilitation
  - Integrate with other sensing modalities, such as vision sensor (Microsoft Kinect)

Images from Kinect-based rehabilitation tool: Jewel Mine, developed at USC Institute for Creative Technologies

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