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

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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 clinician's subjective judgments
    • Standard clinical rating scales such as Fugl-Meyer Assessment (FMA) and Wolf Motor Function Test (WMFT) cannot 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

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

Our Method

• Wearable Motion Sensor
  • 3-axis accelerometer (± 6g), 3-axis gyroscope (± 500 dps)
  • Sampling rate: 100 Hz

• Fine-Grained Post-Stroke Motor Function Analysis Framework
  • Sliding Window
  • Feature Extraction
  • Pattern Recognition

Results

• Motor Task:
  • Flex 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

Details

• Small Window Case
  • Divide the streaming sensor data from each motor task segment into a sequence of fixed length window with 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. Example include:
    • Motion Intensity (MI):
      \[
      MI(t) = \sqrt{\sum_{i=1}^{N} (x_i(t))^2}
      \]
    • Normalized Signal Magnitude Area (NSMA):
      \[
      NSMA = \frac{1}{2} \sum_{i=1}^{N} x_i(t)
      \]
    • 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

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 database to include more patients
  • Develop signal processing algorithm 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: JewelWine, developed at USC Institute for Creative Technologies.