Decision Support for Stroke Rehabilitation Therapy via Describable Attribute-based Decision Trees

V. Venkataraman\textsuperscript{1,2}, P. Turaga\textsuperscript{1,2}, N. Lehrer\textsuperscript{2}, M. Baran\textsuperscript{2}, T. Rikakis\textsuperscript{3}, and S. L. Wolf\textsuperscript{4,5}

\textsuperscript{1}School of Electrical, Computer and Energy Engineering, Arizona State University
\textsuperscript{2}School of Arts, Media, and Engineering, Arizona State University
\textsuperscript{3}School of Design, Carnegie Mellon University
\textsuperscript{4}Emory University School of Medicine
\textsuperscript{5}Center for Visual and Neurocognitive Rehabilitation, Atlanta VA Medical Center

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What is Stroke?

• Most common neurological disorder

• Rapid loss of brain function due to disturbance in blood supply
  – Inability to move limbs
  – Inability to formulate speech
  – Visual impairments

• WHO study reveals 15 million people suffer a stroke every year
Repetitive task therapy is the standard protocol for treatment.

Validated Clinical Scales
- Wolf Motor Function Test (WMFT)
- Fugl Meyer Assessment (FMA)
- Motor Activity Log (MAL)

Insufficient support by insurance for long-term therapy

What is the way forward?
- Have low cost portable systems at home supplementing the therapist
Towards Early Hospital Discharge

• A study\(^1\) on 1277 stroke survivors has reported
  – Reduced length of stay by 13 days
  – Reduced overall mean costs being 15% lower than traditional care
  – No significant difference in effect in mortality or other clinical outcomes

• Another long-term study\(^2\) on 86 stroke survivors:
  – 42 patients received early-hospital discharge and home-based rehabilitation therapy
  – 44 patients received traditional rehabilitation therapy at the hospital
  – No significant difference in clinical outcomes between the two groups after 6 months
  – Reduced length of hospital stay and hence lower costs


The HAMRR system\(^3\) is used to monitor wrist and torso movements of a stroke survivor during rehabilitation therapy.

- The system uses four optitrack cameras, a computer and speakers to provide audio and visual feedback during therapy treatment.
- One reflective marker on the wrist
- A torso rigid plate (with four reflective markers on the corners)
- The table can house a variety of objects to provide personalized therapy

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What is the paper about?

- Develop a new therapist rating protocol for component-level assessment
  - Individual aspect of movement described by kinematic features
  - Preliminary exercise is to investigate the relationship between kinematic evaluation and therapist rating of performance

- Learn a kinematics-based decision tree model for movement quality assessment
Traditional clinical measures do not provide information on impairment on a component-level.

A score of 3 on WMFT does not necessarily indicate the type of impairment.

A component-level rating protocol allows for focused rehabilitation therapy.

Proposed therapist rating protocol allows training our kinematic evaluation module.

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**TABLE I: The Rating Rubric for Movement Quality Assessment Provided to Therapists**

<table>
<thead>
<tr>
<th>Score</th>
<th>Trajectory</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Does not ever reach the target</td>
<td>Demonstrates compensatory shoulder movement with compensatory torso movement in more than one plane</td>
</tr>
<tr>
<td>2</td>
<td>Demonstrates profound deviation from a direct path during the reaching phase, which may be affected by but is not limited to one or more of the following secondary factors: Synergy, Ataxia and Spasticity</td>
<td>Demonstrates compensatory shoulder movement with trunk compensatory movement mainly in one plane</td>
</tr>
<tr>
<td>3</td>
<td>Demonstrates slight deviation (relative to how the rater would perform the task) from a direct path during the reaching phase</td>
<td>Demonstrates noticeable compensatory shoulder or trunk movement</td>
</tr>
<tr>
<td>4</td>
<td>The trajectory appears to be similar to that of the rater if he/she were performing the task</td>
<td>The shoulder and trunk are positioned in a manner similar to the rater if he/she were performing the task</td>
</tr>
</tbody>
</table>

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Kinematic Features: Wrist Trajectory

- **Trajectory Error**
  \[ E_{hor}(i) = x(i) - x_{ref}(i), \quad i = 0, \ldots, N - 1 \]
  \[ \hat{E}_{hor} = \max_{0<i<N-1} (E_{hor}) \]

- **Jerkiness**
  \[ J = \int_{t_{som}}^{t_{eom}} \sqrt{\left( \frac{d^3x}{dt^3} \right)^2 + \left( \frac{d^3y}{dt^3} \right)^2 + \left( \frac{d^3z}{dt^3} \right)^2} \, dt \]

- **Velocity Bellness**
  \[ B_{NA} = \frac{\int_{t_{1st}}^{t_{eom}} v(t) \, dt}{\int_{t_{vmax}}^{t_{eom}} v(t) \, dt} \]

- **Peak Speed**
  \[ V_{max} = \max_{t_{som}<t<t_{eom}} [v(t)] \]
Kinematic Features: Torso Analysis

- Torso Compensation Score

\[
\hat{R}_x(i) = \begin{cases} 
  R_x(i) & \text{if } R_x(i) > T_1 \\
  0 & \text{otherwise}
\end{cases}
\]

\[
C_x = \frac{\sum_{i} \hat{R}_x(i)}{\sum_{i} R_x(i)}
\]
Decision Tree Model

- Simplest and Intuitive way to use features
Comparison between impairment level (with 4 being least impaired and 1 being most impaired) given by component-level score for wrist trajectory and decision tree predictions. The Pearson correlation coefficient was found to be 0.8049.

Comparison between impairment level (with 4 being least impaired and 1 being most impaired) given by component-level rating for compensation by therapist and decision tree predictions. The Pearson correlation coefficient was found to be 0.9129.
In this work we have developed

- A component-level therapist rating protocol to assess the quality of wrist and torso movements.
- A computational framework
Thank You

Questions?