MEASUREMENT AND EVALUATION OF GRASPING IN VIRTUAL REALITY
(Merjenje in ocenjevanje prijemanja v navideznem okolju)

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- Assessment of Grip Force Control
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Hand Function

Assessment of Hand Function

Why evaluate hand function?
- Neural/neuromuscular diseases, CNS injury, trauma
- Follow progress of therapy/disease
- Find optimal treatment for a patient

Assessment of hand function:
- Hand function test: Jebsen, Fugl-Meyer, Smith, ADL
- Manual Muscular Test (MMT)
- Maximal voluntary grip force (MVGF)
Rehabilitation in Virtual Reality (VR)

- What is Virtual Reality?
- VR-augmented vs. VR-based rehabilitation

VR rehabilitation of hand function:
- Jack et al. 2001, VR-enhanced stroke rehabilitation
- Chuang et al. 2002, A VR-based system for hand function analysis
- Merians et al. 2002, VR-augmented rehabilitation of patients following stroke
VR Rehabilitation

Virtual Environment TRAINING

Virtual Environment ASSESSMENT

Sensory System

Patient

Assessment of Grip Force Control
Tracking Task

- What is a tracking task?

- Previous studies:
  - Medicine, rehabilitation, pharmacology, (Wetherell 1996, Jones 2000)
  - Analysis of grip force control in children (Blank et al. 2000)
  - Patients with Parkinson’s disease (Vaillancourt et al. 2001, Kunesch et al. 1995)
  - Training of sensory-motor functions (Kriz et al. 1995)
Grip Measuring Device
Assessment of Grip Force Control in Healthy Subjects

- Effect of age on the grip force control: 12 children (10y), 10 younger adults (25-35y), 10 older adults (50-60y)
- Effect of hand dominancy on performance
- Obtain a control group for subsequent measurements

Sinus Tracking

- Target Tracking (Patient C10, Right Hand, Lateral Grip)
- Target Tracking (Patient S1, Right Hand, Lateral Grip)
- Target Tracking (Patient T3, Right Hand, Lateral Grip)

Child (10 years old)
Older Adult (54 years old)
Young Adult (27 years old)
Results: Accuracy of Tracking in Different Age Groups

Assessment of Grip Force Control in Patients with Neuromuscular Diseases

- Evaluate the effect of neuromuscular diseases on ability to control the grip force in different grips

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Age</th>
<th>Diagnosis</th>
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<td>28</td>
<td>FSHMD</td>
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<td>SMA2</td>
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<td>F</td>
<td>50</td>
<td>SMA3</td>
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<tr>
<td>P8</td>
<td>M</td>
<td>23</td>
<td>LGMD</td>
</tr>
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<td>M</td>
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<td>M</td>
<td>26</td>
<td>BMD</td>
</tr>
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<td>46</td>
<td>SMA3</td>
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<tr>
<td>P19</td>
<td>M</td>
<td>24</td>
<td>BMD</td>
</tr>
</tbody>
</table>

* control group: 9 healthy subjects
Ramp Target Tracking

Ramp Task – Right Hand, Lateral Grip

Target
Patient P15
Patient P16

Sinus Tracking - Patient P6, Left Hand, Palmar Grip

Patient #1:
Target
Grip Force

Sinus Tracking - Patient P5, Left Hand, Palmar Grip

Patient #2:
Target
Grip Force
Group
- Healthy Subjects
- Patients - Group B
- Patients - Group A

Healthy Subjects

Sinus Target Tracking

Group A
- Cylindrical
- Lateral
- Nipper Pinch
- Tip Pinch
- Spherical

Group B
Assessment of Grip Force Control after Botulinum Toxin (BTX) Treatment

- Evaluate the effect of BTX treatment for spasticity on grip force control
- Follow BTX treatment in 38 year-old female patient (8 years post traumatic brain injury)

Results: BTX Treatment
Results: Before and After BTX Treatment

Tracking Error in BTX Treatment, Sinus Task

Training of Grip Force Control
Training of Patients after Stroke

- Evaluation and training of grip force control in post-stroke patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Gender</th>
<th>Hemiparesis</th>
<th>Time since onset</th>
<th>Grasp trained</th>
<th>Score at entering</th>
<th>Score at leaving</th>
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<td>28</td>
<td>M</td>
<td>right</td>
<td>19 months</td>
<td>lateral</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>P2</td>
<td>20</td>
<td>M</td>
<td>left</td>
<td>6 months</td>
<td>cylindrical</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>P3</td>
<td>19</td>
<td>F</td>
<td>right</td>
<td>1 month</td>
<td>lateral</td>
<td>48</td>
<td>50</td>
</tr>
<tr>
<td>P4</td>
<td>44</td>
<td>M</td>
<td>right</td>
<td>1 month</td>
<td>lateral</td>
<td>10</td>
<td>12</td>
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<td>F</td>
<td>left</td>
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<td>50</td>
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<td>3 months</td>
<td>lateral</td>
<td>12</td>
<td>21</td>
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<tr>
<td>P7</td>
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<td>lateral</td>
<td>42</td>
<td>47</td>
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<tr>
<td>P8</td>
<td>36</td>
<td>F</td>
<td>right</td>
<td>6 years</td>
<td>cylindrical</td>
<td>22</td>
<td>22</td>
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<tr>
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<td>72</td>
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<td>1 month</td>
<td>cylindrical</td>
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<td>39</td>
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<td>P10</td>
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<td>M</td>
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<td>4 months</td>
<td>cylindrical</td>
<td>25</td>
<td>30</td>
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</table>

* Modified Ross functional test (max score 50)
Training Tasks

Maximal grip force:

Randomized ramp target:

Randomized rectangular target:

Modulated sinus target:

Patient P6, Beginning of Training, rrmse=0.915

Patient P6, End of Training, rrmse=0.317

Patient P6, Beginning of Training, rrmse=1.7

Patient P6, End of Training, rrmse=1.41

Patient P6, Beginning of Training, rrmse=1.65

Patient P6, End of Training, rrmse=0.507
Grip Force Tracking System

- ... evaluation of grip strength, muscle fatigue and grip force control
- ... to follow the progress of disease or influence of physical or medicamental therapy on patients
- ... as a training method in rehabilitation after stroke or hand injury
Multi-fingered VR Rehabilitation System

Multi-fingered Grasping in VR

- ... design device to measure of fingertip forces and torques in three fingers
- ... use of isometric input for VR manipulation
- ... develop VR based assessment and rehabilitation system
3By6 Finger Device

F/T measurement → F/T on VR object → Kinematics & Dynamics → Graphic Rendering

{ F = m . a }  
{ F = G . fc }  

Evaluation of therapy  
Patient Database (MS Access)
Multi-fingered grasping and manipulation

\[ G_i = Ad^T_{C_i} \cdot B_{C_i} \quad \Rightarrow \quad F_0 = [G_1 \ldots G_i] \cdot \begin{bmatrix} f_{C_1} \\ \vdots \\ f_{C_i} \end{bmatrix} \quad \Rightarrow \quad F_0 = G \cdot f_c \]

\[ f_c = (f_{C_1} M_1 \ddot{x} + f_{C_2} \dddot{y} + \ldots + f_{C_n} \dddot{y} g = f_{C_m}) \]
VR Tasks

Task 1: Open the Safe
Task 2: Fill the Jar

Healthy Subject     Chronic Post-Stroke Patient

Position Trajectory

Initial position
water tap
position of the jar
Task 3: Elastic Torus
Task 4: Tracking Task

Healthy Subject

Chronic Post-Stroke Patient
Conclusions

- Advantages of VR Rehabilitation:
  - Patient motivation (simple VR vs. complex VR)
  - Adaptability based on patient base-line
  - Automatic data storage
  - Safety
  - Cost efficiency – reduced medical costs

- Disadvantages:
  - Transfer of skills to functional tasks
  - Lack of computer skills of PT’s
  - Expensive equipment
  - Infrastructure for telerehabilitation
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Thank You!

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