Interaction forces in climbing: Cost-efficient complementation of a 6dof instrumentation

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SMS-Lab: Daily business

Feedback

Athlete

Instrumentation

Patient

2

Instrumentation

2
SMS-Lab goes climbing

Feedback

Athlete

Analysis

Instrumentation
## Instrumentation: State-of-the-Art

<table>
<thead>
<tr>
<th>Year</th>
<th>dof</th>
<th>Number of Holds</th>
<th>Measuring Principle</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lechner 2013</td>
<td>3</td>
<td>1</td>
<td>Load Cells</td>
<td>Performance</td>
</tr>
</tbody>
</table>

Fuss & Niegl, 2008
Simnacher et al., 2011
Aladdin & Kry, 2012
Lechner et al., 2013

**dof** - degrees of freedom
**number of holds**
**measuring principle**
**goal**
1. Generation: Four hand holds

(1) 
(2) 
(3) 
(4)
18

25°
Swiss National squad measured

- 11 athletes
- Up to 40 trials / athlete
Example: All trials of one athlete

Hand hold 1
What’s going on?
Thus, instead of 4, ALL
Goal

Complementation of 6dof instrumentation

• Cost-efficient instrumentation
• Equivalent performance analysis
Approach: Consider existing data

1. Analyze measurements
   => Contact time, regrips, load changes

2. Reduce sensor complexity
   => Main loading direction

3. Develop 6dof complementation
Workflow

1. Principal component analysis
2. Simulated 1dof data
3. Performance metrics
4. Paired two one-sided test
5. Development
Principal component analysis

<table>
<thead>
<tr>
<th></th>
<th>hold 1</th>
<th>hold 2</th>
<th>hold 3</th>
<th>hold 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PC_1$ magnitude, direction</td>
<td>0.93, (0.79)</td>
<td>0.89, (0.83)</td>
<td>0.52, (0.14)</td>
<td>0.89, (0.97)</td>
</tr>
<tr>
<td>mean $\gamma$ (SD) [$^\circ$]</td>
<td>28.6 (11.9)</td>
<td>20.8 (8.8)</td>
<td>-9.8 (16.0)</td>
<td>11.6 (10.4)</td>
</tr>
</tbody>
</table>
1dof mainly applicable
Sensor Unit
- Phidget – CZL635
- 2x4 weighing cells (4x50kg)

Amplification Unit
- Phidget Bridge – 1046_0
- Data Rate: 125Hz
- Resolution: 24bit
- USB connection
Features

Easy to exchange holds
Features

- Easy to exchange holds
- Adaptable to multiple wall designs
  - Small dimensions
  - Wall thicknesses from 10 to 35 mm
Features

- Easy to exchange holds
- Adaptable to multiple wall designs
  - Small dimensions
  - Wall thicknesses from 10 to 35 mm
- Not visible for climber
Sensor specifications

- **Crosstalk:**

<table>
<thead>
<tr>
<th>Force direction</th>
<th>$F_{Nx}$</th>
<th>$F_{Ny}$</th>
<th>$F_{Nz}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>measured</td>
<td>$F_x$</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>crosstalk [% $F_N$]</td>
<td>$F_y$</td>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

$F_{Nx} = 500N$, $F_{Ny} = 300N$, $F_{Nz} = 500N$
Sensor specifications

- Crosstalk:  
- Sensitivity:  $< 0.2N$
- Creep:  $0.86\% / \text{h at } F_N$
- Temp. drift:  $0.28\% / ^\circ\text{C}$
- Displacement:  $< 2\text{mm at } F_N$
## 2dof vs 6dof

<table>
<thead>
<tr>
<th>Feature</th>
<th>2dof</th>
<th>6dof</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linearity</strong></td>
<td>&lt; 2.0% $F_{Nx}$</td>
<td>&lt; 0.05% $F_{Nx}$</td>
</tr>
<tr>
<td></td>
<td>&lt; 10.0% $F_{Ny}$</td>
<td>&lt; 0.18% $F_{Ny}$</td>
</tr>
<tr>
<td><strong>Hysteresis</strong></td>
<td>&lt; 0.4% $F_{Nx}$</td>
<td>&lt; 0.04% $F_{Nx}$</td>
</tr>
<tr>
<td></td>
<td>&lt; 2.6% $F_{Ny}$</td>
<td>&lt; 0.05% $F_{Ny}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.12% $F_{Nz}$</td>
</tr>
</tbody>
</table>
Undercling?

- Additional sensors to measure z-component
- Bearing for added z-sensor row
Instrumentation done. Next?

**Feedback**

**Athlete**

**Analysis**

**Instrumentation**
Thank you.

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