Motion Tracking for portable biomechanic measures

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The ERGANE Project

• Ecological detection of work related pathologies
  – Workers in unstructured environments:
    • Construction
    • Craftsmanship
    • Farmers
The ERGANE Project

- Pathologies caused by repetitive actions with dangerous postures and loads: high impact on health and economy
- System for tracking and analysis of workers in ecological conditions
- Motion capture aided by wearable technologies
- Grasp force estimation by surface EMG matrix
MoCap: background

- Wearable sensors based motion reconstruction
  - Inertial sensor units
  - Models of human kinematics
  - Sensor fusion
MoCap: Kinematics

• Model of the human upper limb

<table>
<thead>
<tr>
<th>Frame</th>
<th>$a_i$</th>
<th>$\alpha_i$</th>
<th>$d_i$</th>
<th>$\theta_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>$\pi/2$</td>
<td>0</td>
<td>$\theta_1$</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>$\pi/2$</td>
<td>0</td>
<td>$\theta_2 - \pi/2$</td>
</tr>
<tr>
<td>3</td>
<td>$l_{ua}$</td>
<td>0</td>
<td>0</td>
<td>$\theta_3 + \pi/2$</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>$\pi/2$</td>
<td>0</td>
<td>$\theta_4 + \pi/2$</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>$l_{fa}$</td>
<td>$\theta_5$</td>
</tr>
</tbody>
</table>
MoCap: UKF

• Process model

\[ \vartheta_i(k + 1) = \vartheta_i(k) + T_s \dot{\vartheta}_i(k) + \frac{1}{2} T_s^2 (\ddot{\vartheta}_i(k) + \nu_k) \]
\[ \dot{\vartheta}_i(k + 1) = \dot{\vartheta}_i(k) + T_s (\ddot{\vartheta}_i(k) + \nu_k) \]
\[ \ddot{\vartheta}_i(k + 1) = \ddot{\vartheta}_i(k) + \nu_k \]

• Measurement model

\[ \omega_s = R_p^s (\omega_p^p + \dot{\vartheta}_{p+1} z_0) \]
\[ \ddot{x}_s = R_p^s \ddot{x}_p^p + S(\omega_s) r_{p,s}^s + S(\omega_s)^2 r_{p,s}^s + R_0^s g^0 \]
\[ m_s = R_0^s m^0 \]
MoCap: Results

• Joint variables estimation
MoCap: Results

- RMSE and Correlation

<table>
<thead>
<tr>
<th>Joint</th>
<th>$E_{\theta_i}$ [deg]</th>
<th>$C_{\theta_i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>7.03</td>
<td>0.95</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>6.03</td>
<td>0.87</td>
</tr>
<tr>
<td>$\theta_3$</td>
<td>4.95</td>
<td>0.99</td>
</tr>
<tr>
<td>$\theta_4$</td>
<td>9.93</td>
<td>0.98</td>
</tr>
<tr>
<td>$\theta_5$</td>
<td>11.29</td>
<td>0.85</td>
</tr>
</tbody>
</table>

\[
C_{\theta_i} = \frac{\sum_{j=1}^{N} (\theta_i - \bar{\theta}_i)(\tilde{\theta}_i - \bar{\tilde{\theta}})}{\sum_{N} (\theta_i - \bar{\theta}_i)^2 \sum_{j=1}^{N} (\tilde{\theta}_i - \bar{\tilde{\theta}})}
\]

\[
E_{\theta_i} = \frac{1}{N} \sqrt{\sum_{j=1}^{N} (\theta_i - \bar{\theta}_i)^2}
\]
MoCap: Results
MoCap: Results
ERGANE: Directions

- Refinement of online tracking
  - 7 DOF (submitted)
  - Position calibration (submitted)
  - Improved performance
- Integration of EMG
- Test on workers
MoCap: Further Implementations