EXPERIMENTAL VALIDATION OF FINITE HELICAL AXIS CALCULATION AND RELIABILITY

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Introduction

Whenever the kinematics of two bone segments are studied with 3-D-measurement-systems the question of measurement precision and reliability of the calculus arises. This problem is very delicate when movement of the knee joint is analysed by use of finite helical axis (FHA). There are various algorithms of determination which are very sensitive to noisy data, therefore data filtering becomes necessary (WOLTRING et al 1985).

We propose a simple experimental assembly permitting a quick comparison of theoretical and experimental results of joint motion analysis using different algorithms and filtering methods.

Methods

The assembly proposed here is a 4 bar linkage (see figure 1) which approximates the knee joint. The pivots A and B and the solid 1 are fixed whereas the pivots C and D and the solid 2 remain mobile. The movement of the solid 2 is contained in the plane P, its instantaneous centre of rotation M is the intersection point between the straight line (AC) and the straight line (BD). This geometrical determination thus offers the theoretical solution.

The experimental solution on the other hand consisted in fixing 4 LED markers onto each solid. Their positions were recorded with an opto-electronic tracking system (OPTOTRAK, Northern Digital).

In a next step we calculated the position and the orientation of the FHA using the parameters of RODRIGUES (BISSHOPP 1969) extracted with the help of the CALEY transformation (MLADENOV 1991).

Finally in order to compare the experimental with the theoretical solution we determined the distance Δ between the point M and the FHA, and the angle α between the FHA and the normal to the plane P.

We calculated the distance Δ and the angle α with raw data (case 1), by interpolating the parameters of RODRIGUES with a 6 degree polynome (case 2) and by filtering these parameters with a low pass filter of 20Hz, 10Hz, 5Hz, 2Hz, and 1Hz (case 3 to 7).
Results

We found that the interpolation and the low pass filter of 20 Hz resulted in the least difference between theoretical and experimental determination of the location of the FHA (case 3).

All of our results are resumed in the following tables:

<table>
<thead>
<tr>
<th>Distance Δ (mm)</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>6.41</td>
<td>1.23</td>
<td>1.19</td>
<td>1.31</td>
<td>1.86</td>
<td>4.50</td>
<td>7.09</td>
</tr>
<tr>
<td>Maximum</td>
<td>93.42</td>
<td>4.01</td>
<td>4.57</td>
<td>6.57</td>
<td>10.18</td>
<td>68.85</td>
<td>12.28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angle α(°)</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>15.06</td>
<td>0.84</td>
<td>0.81</td>
<td>0.80</td>
<td>0.79</td>
<td>2.25</td>
<td>5.02</td>
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<tr>
<td>Maximum</td>
<td>102.44</td>
<td>3.68</td>
<td>3.88</td>
<td>4.72</td>
<td>5.98</td>
<td>135.10</td>
<td>179.20</td>
</tr>
</tbody>
</table>

Discussion

Using this assembly, we are able to confirm that the calculation of the FHA with raw data is not exploitable. Furthermore it is necessary to realise an interpolation and/or a filtering. Nevertheless we have found that the methods of filtering and of interpolation are generating border effects that have to be taken notice of during the final analysis.

For conclusion, it can be said that our assembly is permitting a rapid and easy way of testing the calculation of the FHA, but also to measure the positive or the negative effects of interpolation methods or the methods of filtering that are used in order to reduce the effect of noisy data.

Bibliography


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