EVALUATION OF JOINT COHERENCE USING FUSIONNED DATA: APPLICATION TO THE GLENO-HUMERAL JOINT DURING ELEVATION

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INTRODUCTION

Human motion analysis based on skin markers aims at estimating bony structure movement. However its main drawback is soft tissue artifact (STA)[1] and, consequently, it requires biomechanical models. The purpose of our study was to compare results from the application of several models to the ones obtained using fusionned morphological data from medical imagery and kinematic data. Performance was investigated using a custom designed joint coherence index.[2]

METHODS

The upper right limb of one volunteer was imaged with a CT scan. This acquisition was consecutive to a motion analysis while all skin markers remained attached to the subject. 116 markers were positioned on the scapula, the arm, the forearm and the anatomical landmarks as recommended for upper limb motion estimation by the ISB.[3] A shoulder elevation movement was investigated in this study.

Bones and skin markers surface reconstruction were obtained after semi-automated segmentation with the commercially available medical imaging software Amira (4.1.2, Mercury Computer Inc.). Skin markers were ordered as distinct clusters for each bone of interest (scapula and humerus) while gleno-humeral (GH) joint surfaces (glenoid cavity and humeral head) were manually segmented.

A ball and socket joint was utilized to model the GH joint and bone movement was determined using Challis' method.[4] Biomechanical models used to define GH joint centre locations and investigated here were helical axis (HA),[5] bias compensated method,[6] SCoRE,[7] Normalization Method (NM)[8] and Gamage's method.[9] Centre locations were estimated using proper motion captures.

A coherence index (CI) was developed[2] in order to evaluate joint congruence. It takes into account the average distance between the opposite joint surfaces as well as the number of facing vertices. CI is set using medical imaging data as the reference position and runs from 0 to 1 (perfect congruence).

CI returned by the above mentioned methods were compared to the ones generated using a centre of rotation obtained with a robust fitting of scalable quadric surfaces to joint surfaces.[10] This method is based on shape–function analysis and will be referred as morphological method in this study.

RESULTS AND DISCUSSION

Coherence indices for three consecutive cycles of upper arm elevation-depression (E-D) are presented Figure 1. Important differences can be noticed between CI obtained with the morphological model when compared to the ones produced using the other models. The latter models follow a similar pattern during upper limb elevation.

The morphological model performed better than every other model regarding the coherence index as this one was always included in a 0.85-0.96 range even though it was not reaching 1.

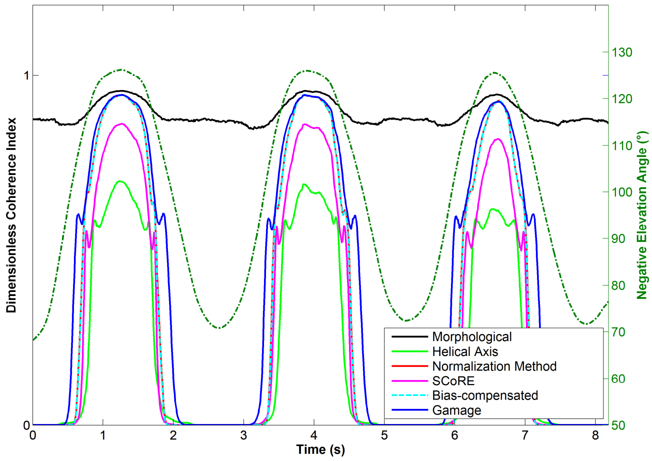

Figure 1: Coherence indices versus time in humeral E-D cycles for different models estimating the GH joint centre.

NM and bias-compensated models showed almost identical CI during the movement as well as Gamage's model when elevation is above 95°. SCoRE and HA models performed second worse and worse of the models investigated, respectively.

CIs were all increasing from this elevation angle until humerus reached its maximum elevation. This result was expected as CT scan image used to set CI was performed with the subject supine, arm elevated and this movement was bringing joint surfaces towards the reference position.

CONCLUSIONS

Morphological model performed better than the other models under investigation and should be used as the GH joint centre, when required data are available. However its CI value did not reach 1 and varied with scapulo-humeral elevation. Consequently future research should aim at looking either for a better GH centre location or to use another model than the ball and socket for the GH joint.

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