Evaluation of an Anatomically Augmented Statistical Shape Model of the scapula: Model performance, validation and reliability of landmark selection

Conference Paper · September 2015

DOI: 10.13140/RG.2.1.4409.2242

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Evaluation of an anatomically augmented Statistical Shape Model of the scapula: Clinical validation and reliability of landmark selection

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Introduction

Statistical shape models (SSMs) have been extensively used in computer vision pipelines and in medical image processing field [1]. Despite its capability and wide usage in medical image segmentation, application of SSMs in surgical planning, biomechanics modeling, and clinical treatments has not been extensively explored. To use SSMs in biomechanical analysis as a clinical diagnostic tool, one would first require a necessary validation of their statistical integrity, computational stability, and prediction ability for clinically relevant areas.

The conventional robustness criteria used in building shoulder SSMs do not guarantee its clinical validity which can be determined by evaluating the SSM validation in the region of clinical relevance. Here, a novel method of building an augmented scapula SSM was presented and validated using anatomical landmark correspondence procedures along with the reliability of the landmark selection process.

Methods

CT scan images of 27 dry scapular bones were acquired using Siemens SOMATOM scanner. Each CT scan sample was segmented in Amira (v5.4.3, Visage Imaging) and used to acquire an isotropically remeshed surface (N = 15000 vertices). Following this, a recently developed integrated pipeline using Iterative Median Closest Point - Gaussian Mixture Model (IMCP-GMM) method was used to build an unbiased mean virtual shape [2] and global scapula SSM using a probabilistic Principal Component Analysis (PPCA) on mean virtual estimates of the scapular samples using a Statismo toolkit [2, 3] (Fig. 1).

Sixteen anatomical landmarks in clinically relevant regions of the scapula were manually selected by five observers, tested for their intra- and inter-observer reliability of selection (interclass correlation coefficients (ICCs)), and used to augment the SSM. Clinical validity was quantified as a distance between a manually selected anatomical landmark on original scapula instance (internal validity for training samples or external validity for outside samples) and a landmark transferred from an augmented (locally or globally) statistical shape model (Fig. 1). Mean landmark locations on 27 training scapulae selected by a randomly chosen observer were used to form the locally augmented SSM whereas mean landmark locations on 27 training scapulae selected by all five observers were used to form the globally augmented SSM.

Results

Excellent inter- (ICC > 0.81) and intra-observer (ICC > 0.67) reliability was found for landmark selection process. The standard error of measurement was extremely low for all intra-observer (< 0.3mm) and inter-observer (< 0.29mm) coordinates. For locally augmented SSM, the mean internal and external validity error ranged from 0.1mm to 0.55mm and from 1.1mm to 2.5mm. For globally augmented SSM, the mean internal and external error ranged from 0.22mm to 0.68mm and from 1.2mm to 3.1mm.

Conclusions

Current validity results suggest that further evaluations of the SSM in terms of sample sufficiency are warranted. However, the excellent reliability results would allow us to consider the use of the augmented SSM for automatic segmentation of the MRI applications and biomechanical studies of the shoulder complex.

References

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3.Luthi et. al., The Insight Journal, vol 1, 2012

Figures

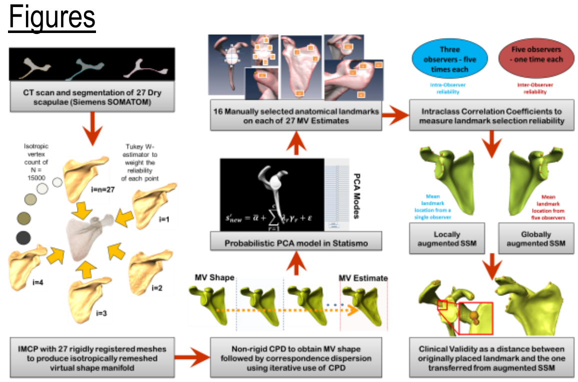

Fig. 1: Schematic Diagram of Clinical Validity quantification