3D Shape Description of the Bicipital Groove of the Proximal Humerus

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Introduction and Motivation

- The bicipital groove of the proximal humerus is located on the head of the humerus.
- The long biceps tendon is located in this groove; the BG serves to keep the tendon in its proper place as the arm moves.
- Disorders of the long biceps tendon are recognized as an important symptom generator in the shoulder.
- The shape of the bicipital groove can impact the long biceps tendon in a number of ways [1,3,4,6]:
  - A wide, shallow groove can favour tendon dislocation.
  - A shallow sloping medial groove wall can also favour dislocation.
  - A deep, narrow groove can favour tendon irritation.
  - Spurs in the groove walls can also favour tendon irritation and fraying.
- Current measurements of the bicipital groove are typically taken from non-tomographic radiographs and are quite primitive.
- We are therefore motivated to develop an effective approach to 3D shape description of the bicipital groove.
- This approach is inspired by the medial representation [2,5].

Material and Methods

- We have obtained 50 shoulder scans (40 MR, 10 CT) through a collaboration with NYU Medical Center, Hospital for Joint Disease.
- Segmentation of the groove from the surrounding tissue is done semi-automatically on the CT scans, due to the high contrast between bone and surrounding tissue. More manual assistance was required for the MR data, using a tool we built specifically for this purpose.
- The output of segmentation is a 3D spline surface fitted to control points lying on the surface of the bicipital groove (Fig. 1 (a)).
- A “top sheet” is then fitted to close the groove (Fig. 1 (b)).
- A “medial sheet” that bisects the medial and lateral walls of the groove is created (Fig. 1 (c) and (d)) such that:
  - At each axial slice, the medial sheet is orthogonal to the top sheet.
  - At each axial slice, the medial sheet lies in the deepest part of the groove (as measured from the top sheet).
  - Point values of maximum depth on the surface of the BG (Fig. 1 (c)) are used to determine a best-fit sheet (Fig 1. (d)).

Material and Methods (cont’d)

- The top sheet and medial sheet are used to compute the following distance fields:
  - A depth field (Fig. 2 (a)), which measures the distance between the top sheet and the bicipital groove wall.
  - A medial wall field (Fig. 2 (c)), which measures the distance between the medial sheet and the medial wall of the groove.
  - A lateral wall field (Fig. 2 (d)), which measures a similar distance to the lateral wall of the groove.
  - A width field (Fig. 2 (b)), which is the sum of the medial and lateral fields and shows the overall width of the groove.
- Measurements are then taken of these fields in order to detect abnormalities in the bicipital groove:
  - Large or small mean and maximum depth and width values indicate large or small depths and widths of the groove.
  - A medial wall field depicting a large first order gradient indicates a shallow sloping medial groove wall.
  - Large positive first order gradients in the depth field combined with small values in the width field indicate a deep, narrow groove.
  - Spurs in the groove walls are detected as rapid changes in the first order gradients of the medial and lateral walls and can be detected by examining their second order gradients.

Results

- Figures 1 and 2 show the results of this approach for a single data set.
- Two properties of the medial sheet:
  - Because it is positioned in the region of maximum groove depth, it is insensitive to irregularities in the groove walls.
  - Straightening the medial sheet makes it insensitive to irregularities in groove depth.
- Computation of the distance fields reduces a complex 3D shape description problem to a simpler 2D problem.

Conclusions and Future Work

- Effective 3D shape description of the bicipital groove of the proximal humerus is relevant to predicting and diagnosing several types of shoulder injury.
- An approach to shape representation inspired by the medial representation reduces the 3D problem to a simpler 2D problem.
- A novel approach to the placement of a medial sheet reduces the sheet’s sensitivity to irregularities in the groove walls.
- The primary direction of future work is to extend meaningful quantitative measurements from the 2D distance fields and correlate them to specific types of shoulder injury.

References: