AUTOMATIC ANALYSIS OF MR SEQUENCES FOR THE DIAGNOSIS OF LIGAMENT LESIONS

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Abstract: To date the diagnosis of carpal instabilities due to ligament lesions relies on a qualitative examination of the patient's wrist. This paper presents a novel system where sequences of magnetic resonance images are automatically analysed to measure the motion of seven wrist bones. Resulting motion graphs provide a quantitative basis for diagnostic as well as scientific purposes. As the imaging method is non-invasive up to twelve wrist positions can be measured giving a detailed insight into the bone's motion.

Introduction

In many cases articular damages cannot be diagnosed through an examination of a single image. A motion analysis of a joint's bones might be necessary to make a reliable diagnosis [1,2]. Examples are lesions of the ligaments and cartilage of the knee or in the cervical and lumbar regions of the vertebral.

This paper presents a novel system to diagnose lesions of the ligaments of the wrist (carpal instabilities [3]). The method is particularly well-suited to aid in the diagnosis of the *scapho-lunate instability*. This damage is a common injury after accidents involving the wrist. The lesion occurs when the ligaments between the Scaphoid and the Lunate are torn [4].

Methods

Motion graphs (Fig. 1) show the rotation as well as the translation of the carpal bones. The measurement is performed relative to an anatomic co-ordinate system defined by the distal end of the Radius.

Compared to other applications [5] a motion analysis of wrist bones is more difficult because there are many bones with a similar shape which complicates their identification. Furthermore some of the bones may tilt, that is they may rotate around axes not perpendicular to the view plane. This results in a varying appearance of the bones in the sliced magnetic resonance (MR) images.

The overall system comprises the following components:

- *Image acquisition* – For each wrist position 12 layers of the hand are acquired.

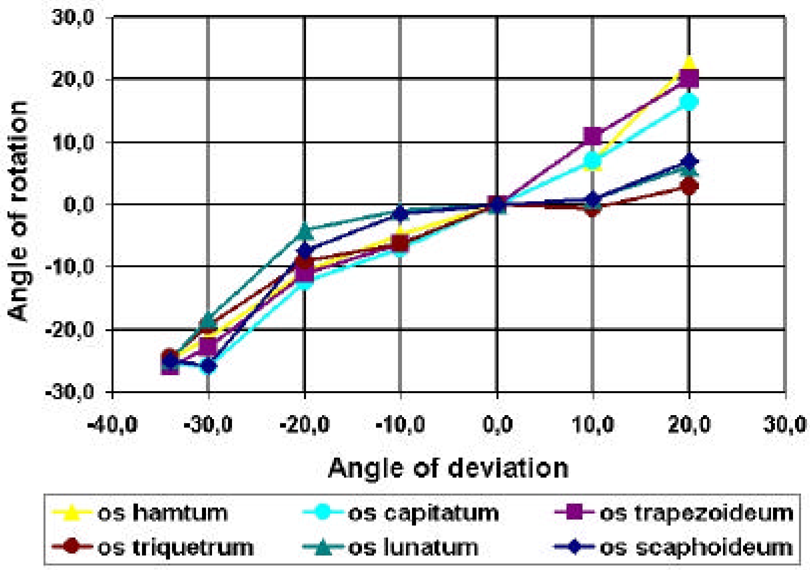

Figure 2: Motion graph – Collection of measurement results for several wrist positions. This graph shows the rotation of the wrist bones for a healthy patient. The rotation of each bone is normalised to its angle at the wrist's neutral position.

- *Layer selection* – An approach based on the Fourier-Mellin transform [6] allows for the selection of an MR layer which is best suitable for the measurement by comparing the input layers with a reference image.
- *Segmentation* – An adaptive threshold is applied to an automatically selected region of interest (ROI). To obtain a higher precision the algorithm is applied in two stages to the ROI of the wrist and to smaller ROIs of the individual bones.
- *Identification of the bones* – Constrained by their possible motion the relevant bones are identified through an analysis of the shape and position of a set of candidate bones.
- *Measurement of translation and rotation* – For each bone its major axis and centroid is determined (Fig. 2).
- *Motion graphs* – The measurement results of usually about 8 different positions of the wrist are collected (Fig. 1).

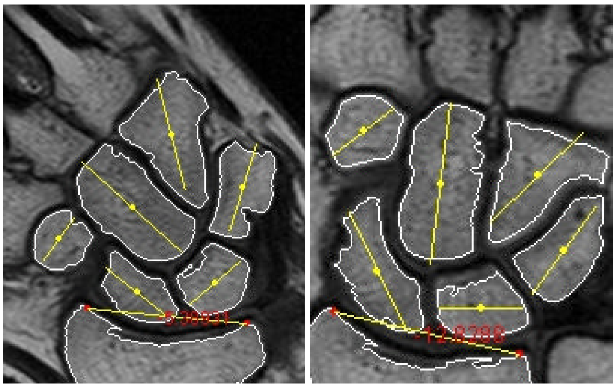

Figure 1: Measurement of translation and rotation - For each bone its major axis and centroid is determined. The anatomic reference co-ordinate system is derived from measuring salient feature points of the Radius. This examples shows a radial and an ulnar wrist position.

Results

The performance of the system is demonstrated by automatically measuring the motions of the bones of 158 wrist positions of 20 patients to date. A resulting number of 1106 bones were identified correctly. The segmentation was highly successful for the most relevant bones Scaphoid, Lunate and Radius (Tab. 1).

Table 1: Success rate for automatic segmentation of the carpal bones in 158 wrist positions

Os hamatum	77.8 %
Os capitatum	94.9 %
Os trapezoideum	90.5 %
Os triquetrum	89.2 %
Os lunatum	94.3 %
Os scaphoideum	96.8 %
Radius	97.5 %

A good segmentation was also obtained for other carpal bones, allowing the system to be applied to the diagnosis of other carpal instabilities as well.

Discussion

Based on the measurements the system delivers it is now possible to prepare highly relevant statistics which will provide a comparative basis for future diagnosis and generally to investigate the normal kinematics of the wrist as well as its pathomechanics. Unlike other approaches where markers are implanted in cadaveric specimens [7] the method presented in this paper is non-invasive, produces no radiation and hence allows for a more realistic analysis of a large number of healthy as well as pathological wrists beyond the application of a diagnostic tool.

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