Assessment of Center of Rotation of the Glenohumeral Joint

Marjolein van der Glas, Frans Vos, and Albert Vossepoel

Pattern Recognition Group, Delft University of Technology,
Lorentzweg 1, 2628 CJ Delft, The Netherlands,
{marjolein, frans, albert}@ph.tn.tudelft.nl,
http://www.ph.tn.tudelft.nl/

1 Introduction

During a total shoulder replacement the glenohumeral joint is substituted by a prosthesis. The joint is a loose ball-and-socket joint, in which the humeral head is the ball and the glenoid is the socket. Most important for successful surgery is that the center of rotation of the glenohumeral joint is maintained [1]. During motion, the two geometric centers of both spherical surfaces coincide in the center of rotation of the glenohumeral joint [1]. In this paper we present a new technique to automatically determine the 3D center of a sphere in 3D images, using the direction and strength of the gradient.

2 Methods

The Hough transform [2] is a well accepted method used for sphere detection in binary, i.e. segmented, images. The novelty in our approach is the use of unsegmented 3D images.

Consider a parameterization of a sphere by (x_0, y_0, z_0, r), where x_0, y_0, z_0 refer to the position of the center, and r refers to the sphere radius. For the center detection, a 3D parameter space is defined, containing a probability count for all possible sphere centers. The parameter space is filled by going through the following step for every voxel in the grey-value image:

1. Determine the orientation and magnitude of the gradient, using Gaussian derivatives.
2. Project the gradient vector in parameter space.
3. Increase the count of the corresponding voxels in parameter space by the gradient magnitude.

The maximum in the parameter space corresponds with the center of the sphere. From the sphere center, the radius is determined using the radial histogram of the gradient magnitude of the image with respect to the detected sphere center. The maxima in this histogram correspond with the radii of the spheres.

W. Niessen and M. Viergever (Eds.): MICCAI 2001, LNCS 2208, pp. 1207–1209, 2001.

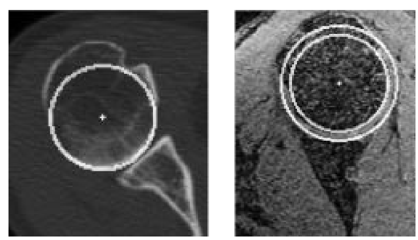
3 Results

Artificial images, of size 84x84x84 voxels, are created with solid or hollow spheres. The center of the sphere is determined, using different values for the sigma of the Gaussian derivatives (table 1).

Table 1. Distance between the determined and the real sphere center in voxels, for various radii (vertically) and signal to noise ratio of Gaussian noise (horizontally) determined with the optimal sigma (between brackets) for solid complete spheres

R	no noise	26 dB	20 dB	16 dB	14 dB	12 dB	10 dB
26.00	0.093 (1.0)	0.109 (1.0)	0.089 (1.5)	0.111 (1.5)	0.114 (2.0)	0.088 (2.0)	0.125 (2.5)
30.00	0.106 (1.0)	0.112 (1.5)	0.080 (1.5)	0.098 (1.5)	0.106 (2.0)	0.103 (2.0)	0.101 (2.5)
34.00	0.103 (1.0)	0.125 (1.5)	0.082 (1.5)	0.088 (2.0)	0.099 (2.5)	0.102 (2.5)	0.126 (2.5)
38.00	0.105 (1.5)	0.087 (1.5)	0.075 (1.5)	0.100 (2.0)	0.097 (2.0)	0.101 (3.0)	0.104 (3.0)

In clinical images of the glenohumeral joint, the position of the center and the radius of the approximate sphere are determined. In both CT and MRI scans the method automatically detects the sphere that fits onto the spherical humeral head (figure 1). If a fitting method had been used, the sphere would be fitted onto the entire top of the humerus, as shown in [3].



(a) (b)

Fig. 1. Result sphere determination (a) in CT, (b) in MRI.

4 Conclusion

The method described in this paper is used to detect the center of solid and hollow spheres with high accuracy. The method is robust to noise and it does not need a complete sphere in order to detect the center. It can be used on isotropic as well as non-isotropic sampled images. As no segmentation is required, it can be directly applied to clinical images.

Detection of the center of rotation of the glenohumeral joint can be used for pre-operative planning for shoulder replacements. It will help the surgeon to optimally position the shoulder prosthesis. Furthermore the determined spheres can be used for fast visualization of bone surfaces during surgery.

Acknowledgements

This research is part of the DIPEX (Development of Improved endo-Prostheses for the upper EXtremities) program of the Delft Interfaculty Research Center on Medical Engineering (DIOC, http://www.wbmt.tudelft.nl/mms/dipex/).

References

1. O. de Leest, M.R. Rozing, and et al. Influence of Glenohumeral Prosthesis Geometry and Placement on Shoulder Muscle Forces. *Clin. Orthop.*, 330:p. 222–233, 1996.
2. V.F. Leavers. *Shape detection in computer vision using the Hough transform.* Springer Verlag, 1992.
3. J.J. Jacq and C. Roux. Automatic detection of articular surfaces in 3D image through minimal subset random sampling. In *CVRMedMRCAS'97 proceedings*, volume 1205, pages 73–82. Springer, 1997.