

# KINEMATIC ESTIMATION OF THE ROTATION CENTER OF THE GLENOHUMERAL JOINT FOR A DIGITAL MANIKIN

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## INTRODUCTION

“Digital manikin” is software used for designing automobile or workspace. The reach envelope of a digital manikin differs from that of an actual human even if they have the same posture and body proportion. The main cause is the difference of the anatomical structure around the shoulder between the two. In order to improve the shoulder structure of a digital manikin, it is important to know the motion of the rotation center of the glenohumeral (GH) joint. This study aims to propose a simple estimation method of the rotation center (GH center).

## METHODS

Various methods have been proposed (e.g. Meskers et al., 1998; Veeger, 2000; Stokdijk et al., 2000) to estimate the GH center. However, these methods need to measure the surface landmarks on the scapula, which is difficult to find. On the other hand, Bao and Willems (1999) developed an estimation method under the geometric constraints of the segment model around the shoulder complex. This model is suitable for a digital manikin because of their similarity. Referring to them, we developed a simple method, using pre-established “positioning motion” and three or more markers. This is, so to speak, a dynamic calibration of the GH center.

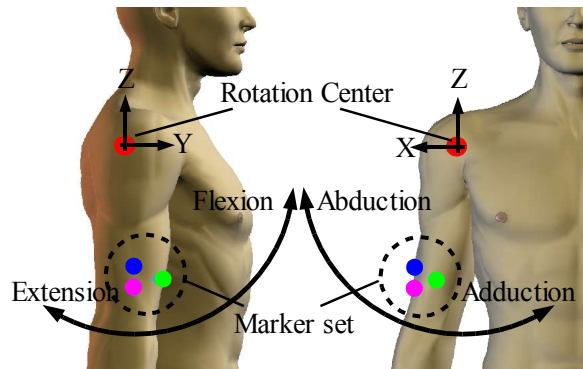
In developing the estimation method, three conditions are assumed for the positioning

motion. They are (1) Torso movement is negligible. (2) Skin movements are negligible. (3) Arm moves without a displacement of the scapula. Thus, the range of motion of the arm is limited.

Under these conditions, the GH center can be estimated by following two kinematic solutions. (a) The GH center is fixed to a point in the absolute coordinate system during a very short time even if the arm is moving. Therefore, the GH center is calculated by solving a linear formula which is composed of the condition that the distance between the GH center and each of three markers does not change during a very short time. (b) The GH center in the upper arm coordinate system is fixed in the head of humerus. Namely, if the posture of the upper arm can be measured, the GH center is calculated using the matrix of the coordinate transformation from a standard posture. The constant position vector of the GH center from the marker set is optimized by minimizing the difference between these two solutions during the positioning motion. Using this marker set and the estimated position vector, the GH center in the absolute coordinate system can be estimated easily.

## SIMULATION

In order to decide the optimal positioning motion, effect of the skin movements was simulated using a virtual model shown in Figure 1. The random errors (maximum 5

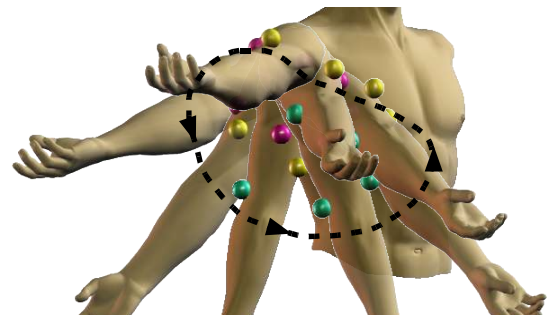


**Figure 1:** Virtual human upper arm model  
The range of motion around the GH joint was established at 120° flexure and abduction, and 40° extension and adduction.

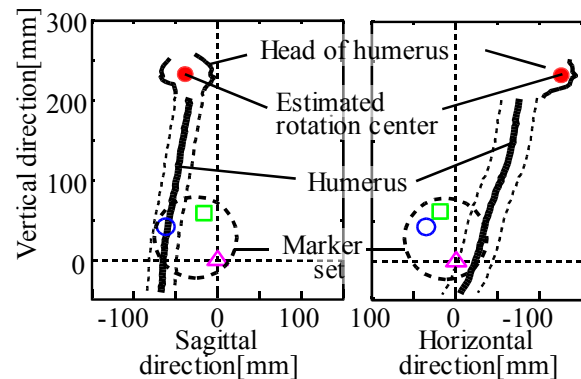
mm for each direction) were given to the three markers to represent the displacement due to skin movements. The GH center was estimated as the model moved its upper arm within a limited range of motion (condition 3). We found (1) The error in vertical direction (Z) became large when the range of motion was too small. (2) The error in sagittal direction (Y) was canceled out by flexion and extension. (3) The error in horizontal direction (X) was canceled out by abduction and adduction. From these results, the optimal positioning motion was determined as the compound motion of 60° flexion, 10° extension, 90° abduction, and 30° adduction as shown in Figure 2. When this motion was given to the virtual model, the error in the GH center (X, Y, Z) was (2.9, 2.4, 1.8) [mm].

## VALIDATION AND DISCUSSION

For the purpose of verifying this method, an actual subject (age 22, male) was measured. The location of the head of humerus and three markers were measured using an MRI system. The estimated GH center during the positioning motion was found in the head of humerus as Figure 3. Consequently, it is concluded that this method is useful to estimate the GH center accurately and easily. In addition, this method is applicable to



**Figure 2:** The optimal positioning motion  
Four basic motions are combined.



**Figure 3:** Estimated rotation center for an actual subject

other 3-D joints, because this method is independent of shoulder structure.

## SUMMARY

This study proposed an estimation method of the rotation center of the glenohumeral joint that is applicable to a digital manikin. Using this method, the GH center fixed in the upper arm coordinate system can be estimated.

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