In-vivo experiments of 3D femoral shape estimation using two 2D fluoroscopic images

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***Abstract*— In medical diagnostic imaging, the X-ray CT scanner and the MRI system have been widely used to examine 3D shapes and internal structures of living organisms and bones. However, these apparatuses are generally large and very expensive. Since an appointment is also required before examination, these systems are not suitable for urgent fracture diagnosis in emergency treatment. However, X-ray/fluoroscopy has been widely used as traditional medical diagnosis. Therefore, the realization of the reconstruction of precise 3D shapes of living organisms or bones from a few conventional 2D fluoroscopic images might be very useful in practice, in terms of cost, labor, and radiation exposure. The present paper proposes a method by which to estimate a patient-specific 3D shape of a femur from only two fluoroscopic images using a parametric femoral model. First, we develop a parametric femoral model by the statistical analysis of 3D femoral shapes created from CT images of 56 patients. Then, the position and shape parameters of the parametric model are estimated from two 2D fluoroscopic images using a distance map constructed by the Level Set Method. Experiments using in vivo images for hip prosthesis patients are successfully carried out, and it is verified that the proposed system has practical applications.**

I. Reconstruction of 3D femoral shape from two 2D fluoroscopic images

The parametric femoral model was created by the following procedure. By applying PCA to 56 samples of 3D femoral shapes, we extracted the most significant 50 principal components, standard deviation, and corresponding principal vectors for each point of the parametric femoral model. Therefore, the general 3D shape of a femur is expressed by the parametric femoral model with an average 3D shape, several principal vectors, and several (up to 50) shape parameters.

Then, the position/attitude and shape parameters of the parametric model are estimated from two 2D fluoroscopic images [1]. The 2D/3D registration algorithm utilizes the contour lines of the silhouette of the 2D image and the projected contour lines of the 3D model. After the 2D distance map from the contour lines is created using the Fast Marching Method, the parametric femoral model is placed at an arbitrary position and the 2D projection image of the 3D model is calculated. Then, contour lines of the projected image and corresponding 3D patches of the 3D model are extracted. Finally, the force which is calculated from the 2D distance map at the projected contour points is applied directly to the corresponding 3D patch, and the optimum position and the shape parameters are estimated.

We conducted in vivo experiments for hip prosthesis patients. We estimated the position and 10 shape parameters from the silhouette of the femur. The precise 3D shapes of patients ' femurs were measured precisely by CT scanner. The average errors of the estimated femoral shapes for four patients are shown in Fig.1. In these figures, "0" in the horizontal axis shows the case in which only the position is estimated without parameter estimation. The experimental results show that the average error between the estimated shape and the actual shape is approximately 0.8 mm to 1.1 mm for the in vivo experiments. One example of average, actual, and estimated shapes for Case 4 is shown in Fig.2. From this figure, we verified that the errors in the femoral head and lesser trochanter are reduced.

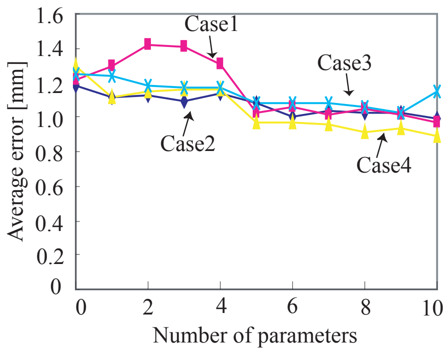

Fig. 1. Average error for the number of estimated shape parameters for the femurs of four patients

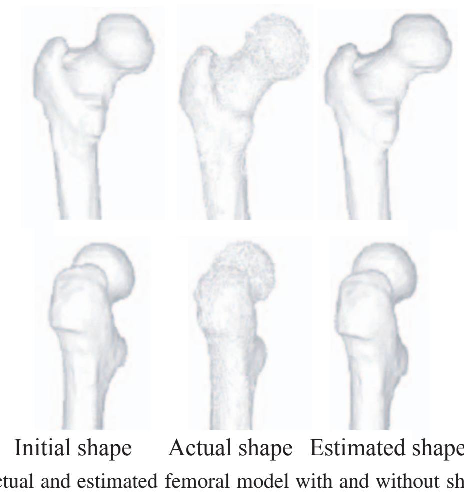

Fig. 2. Actual and estimated femoral model with and without shape parameter estimation for Case 4

References

[1] R. Kurazume et al., "3D reconstruction of a femoral shape using a parametric model and two 2D fluoroscopic images," *In Proc. IEEE Int. Conf. Robotics and Automation*, pp. 3002–3008, 2007.