AUTOMATIC PROSTHESIS SEGMENTATION IN 3D FLUOROSCOPY

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Abstract

3D video-fluoroscopy can accurately estimate in-vivo kinematics of joint prosthesis. To this aim, for each of the hundreds of frames of an acquisition, a 3D surface model of the prosthesis is registered to the relevant contours on the 2D X-ray projections. Commercial software only provide simple edge detector (e.g. Canny) followed by a time consuming manual procedure to delete the undesired contours. A fast and robust semi-automated prosthesis segmentation method, combining region growing and level set methods, is proposed to speed up the analysis and to reduce the human interaction.

3D Fluoroscopy

Dataset:

- Mono- or bi- planar low-dose X-ray projection of moving joint;
- DICOM series $(1024 \times 1024 \times n_{frames})$ at $5 - 50$ fps: non uniform lighting field, soft-tissue superimposition, highly noisy;
- 3D surface model of each component (CT, CAD) of the joint;

Pose estimation algorithm [1]:

1. Perspective projection model;
2. Calibration, distortion correction;
3. Edge detection;
4. Back projection of contour points;
5. Projection lines vs 3D surface RMSD minimization (tangency, Adaptive Distance Maps);

Output:

- frame by frame pose estimation $[P_x, P_y, P_z, \theta_x, \theta_y, \theta_z]$;
- errors <1 mm <1 deg.

References

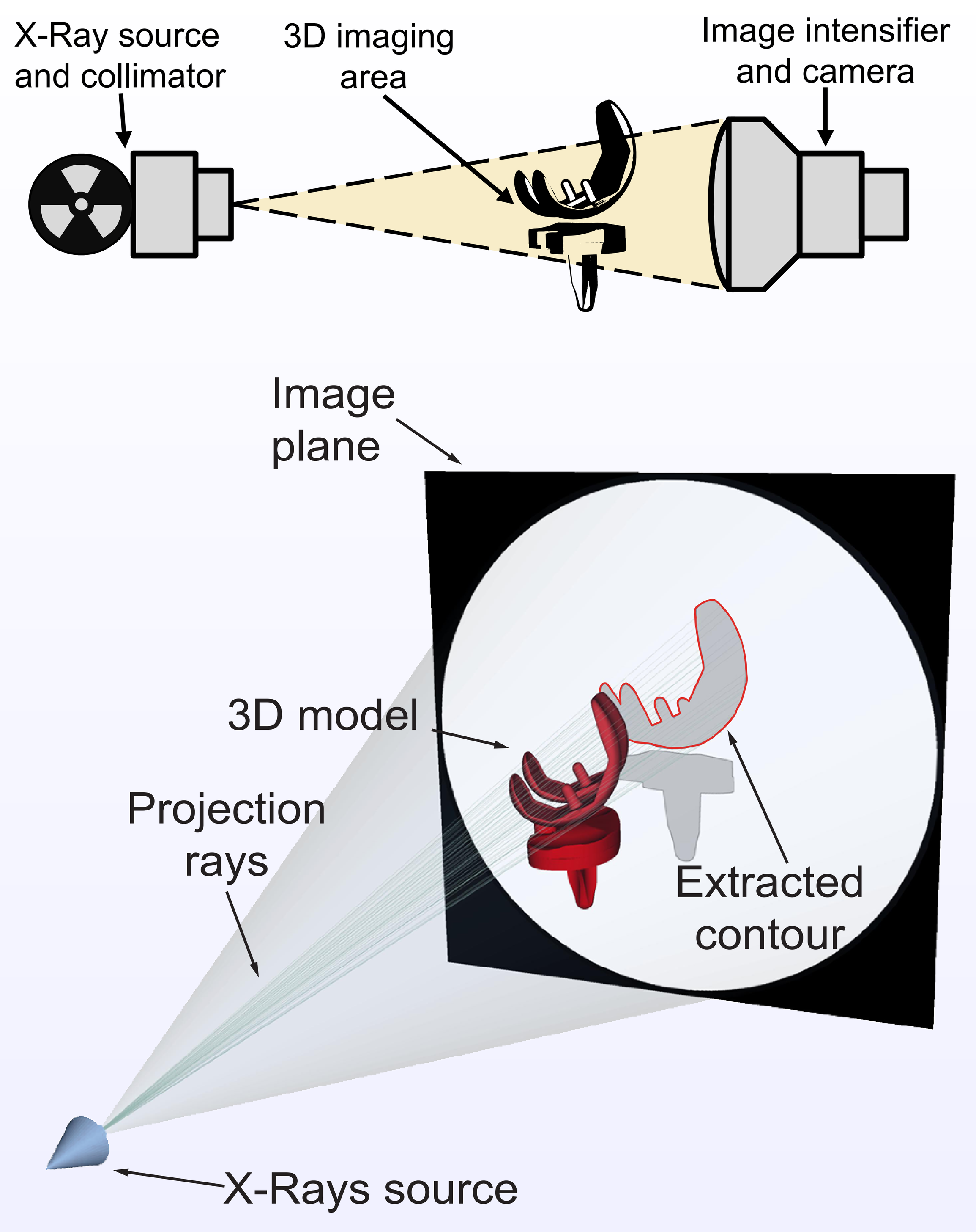
[1] Zuffi S., et al., in *Medical Imaging, IEEE Transactions*, vol. 18, 1999, pagg. 981-991;

[2] Sapiro G.*Cambridge University Press*, 2001, p. 223. ISBN 9780521790758;

[3] Pratt W. K. *John Wiley & Sons, Inc.*, Los Altos, California, 2007;

[4] Sethian J. A., *Cambridge University Press*, 1999.

Outline



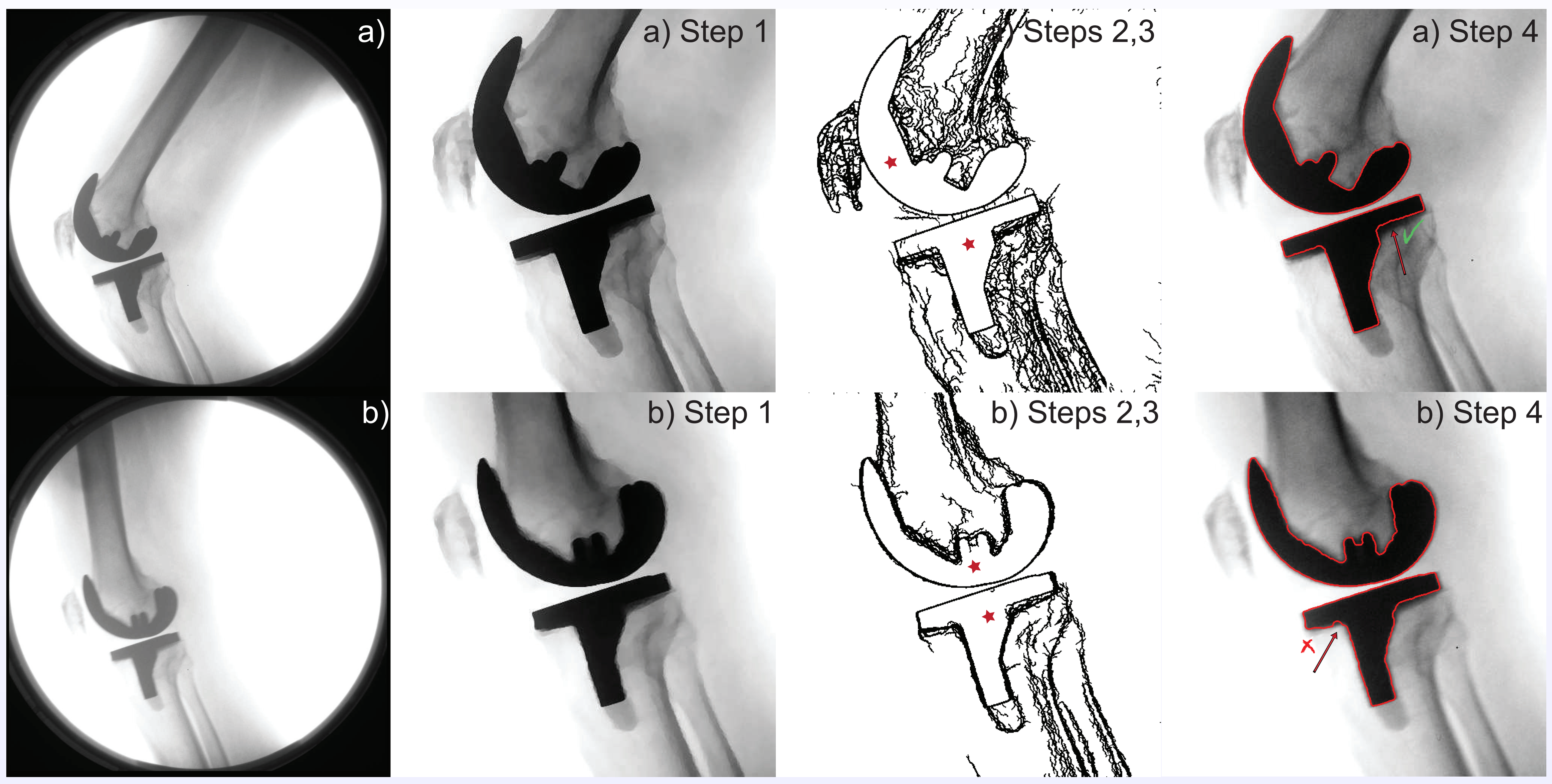
Methods

The new semi-automatic algorithm requires the user to provide only one seed and the choice of one threshold level. For each image the following procedure is followed:

1. Level-set edge preserving anisotropic diffusion filter [2]:
$$\begin{cases} I_t = gK|\nabla I| + \nabla g \cdot \nabla I & \text{in } \Omega \times]0, \inf[\\ \frac{\partial I}{\partial n} = 0 & \text{in } \partial\Omega \times]0, \inf[\\ I(0) = I_0 & \text{in } \Omega \end{cases}$$
where $g = \frac{1}{1+|\nabla I/\beta|}$ is an edge indicator and K is the curvature;
2. Binary mask of g (thresholding, and morphology-based operations);
3. Seeding and region growing [3];
4. Contour refining with Malladi-Sethian [4].

Results

The computational time is ~1 min per segment (AMD Turion64 X2 2.00 GHz, RAM 2.00 GB laptop), ~5-10 s of which of user interaction only. The traditional methods need ~1-2 min completely born by the user. The algorithm can efficiently avoid cemented part (a4), but is negatively affected by image blurring (b4).



Discussion & Conclusions

The present work represents a first evaluation study of the application of well-known segmentation algorithms in the specific contest of 3D fluoroscopy. Promising results were obtained allowing the improvement of the analysis of prosthesis kinematics in term of automation and reduction of the user interaction. A batch processing will also allow to automate the seeding step. A metric based on the gradient magnitude could allow to automatically eliminate the blurred contours. A short manual procedure is still useful to eliminate wrong contours in case of components overlapping.