

Robotised 3D registration under intra-operative US imaging

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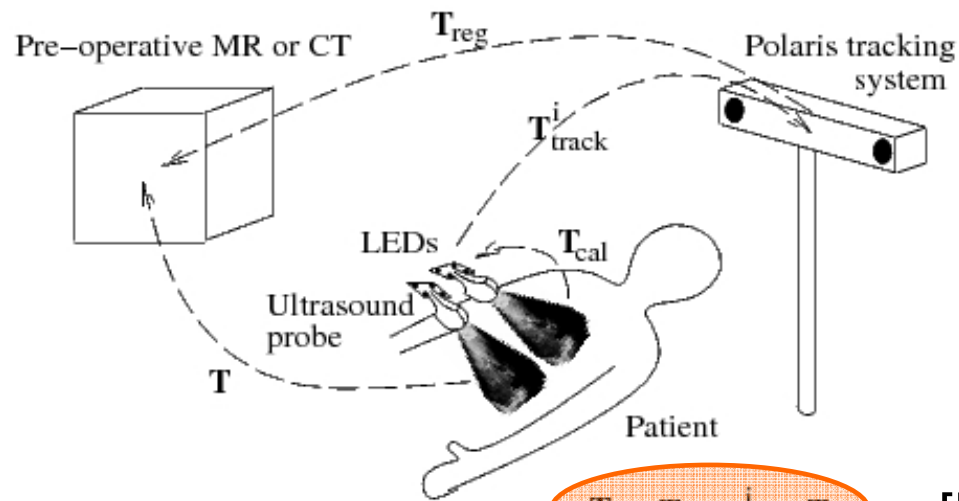


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The INRIA logo, consisting of a stylized white 'R' inside a square, followed by the letters "INRIA" in a white, serif font.

Context

- Minimally invasive surgery
 - Pre-operative 3D volume in MRI/CT imaging modality
 - Registration with intra-operative US slices
 - Assistance during the surgical intervention



$$T = T_{reg} T_{track}^i T_{cal}$$

[Penney01]



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ICP algorithm
Similarity measure minimization

$$T = T_{reg} \cdot T_{track} \cdot T_{cal}$$

Tracking device

Mechanical device

US probe mounted on the end effector of a robotic arm
US probe pose given by the robot kinematics



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$$T = T_{reg} \cdot T_{track} \cdot T_{cal}$$

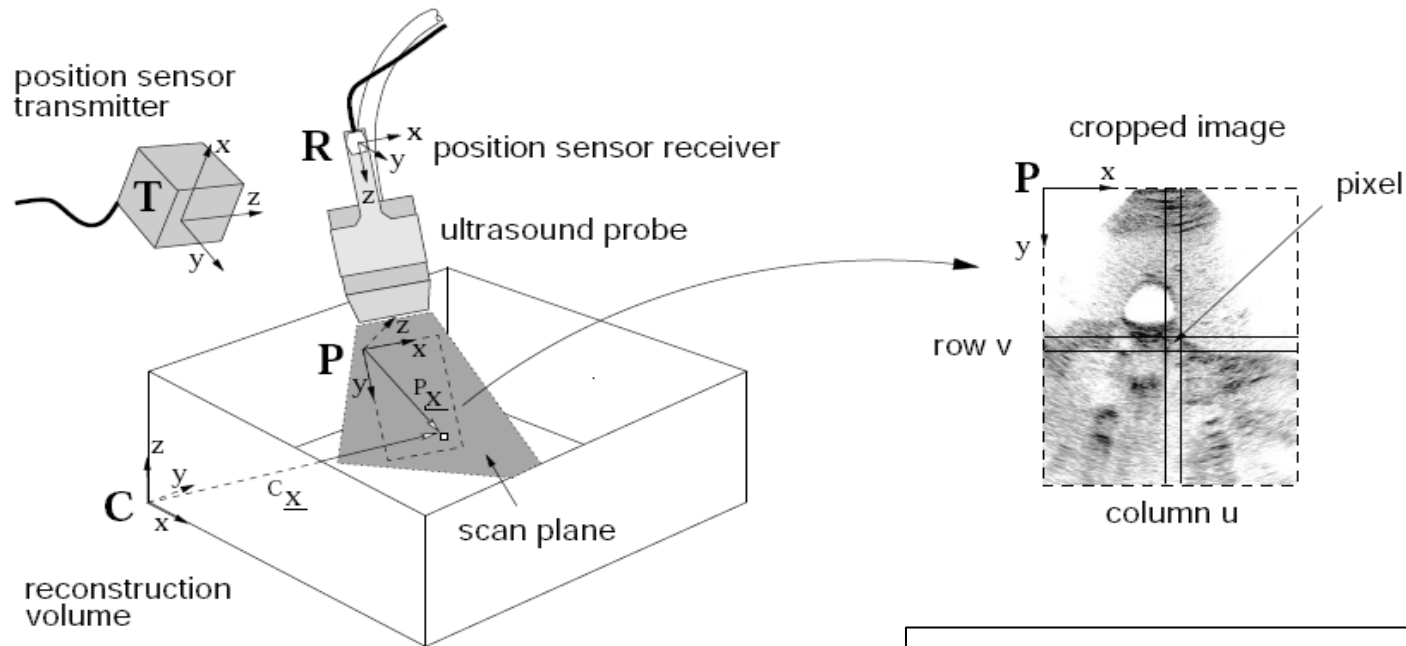
US probe calibration



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Calibration



□ Calibration process

- Known geometry phantom scan
- Features detection in B-scans
- Equations system resolution by Levenberg-Marquardt algorithm

$$C_{\underline{x}} = C T_T T_R R T_P P_{\underline{x}}$$

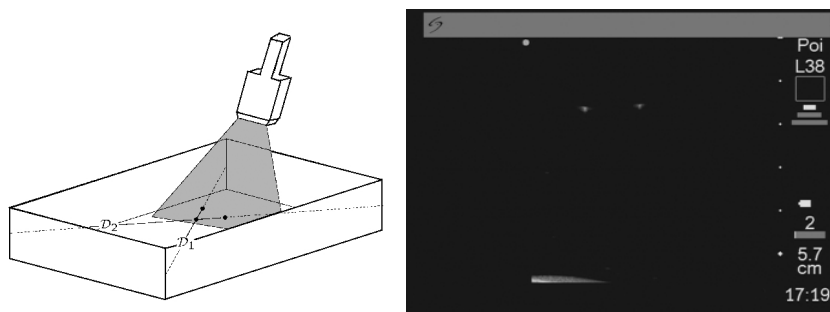


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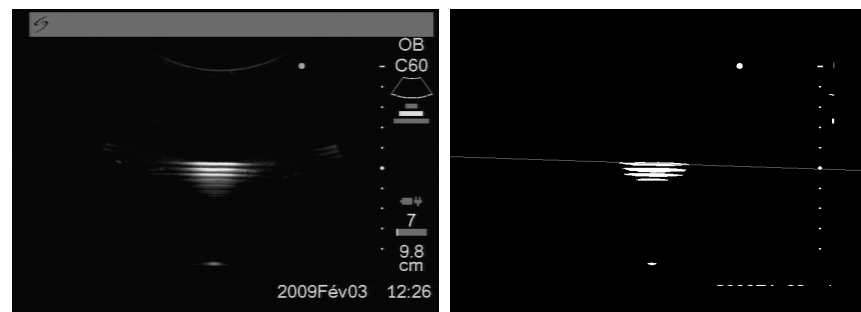
Phantom design

□ Cross wire phantoms



- Position the probe to see the intersection point in the US image
- Manual detection of the point
- Long calibration time

□ Wall phantoms



- Automatic detection of the bottom of the water tank
- Fast calibration
- Reflection
- Failure of the detection by Hough transform

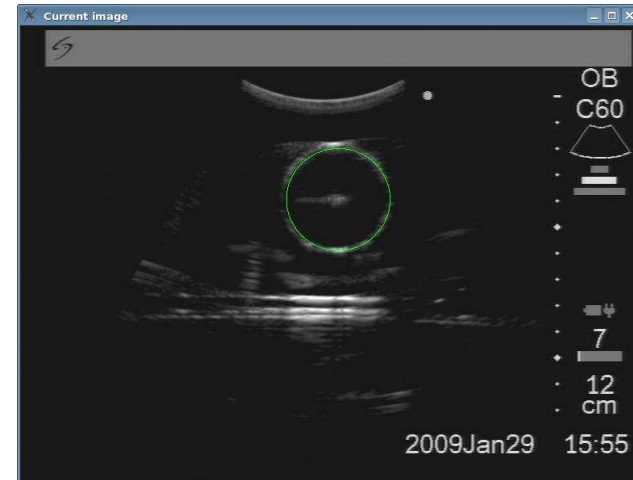
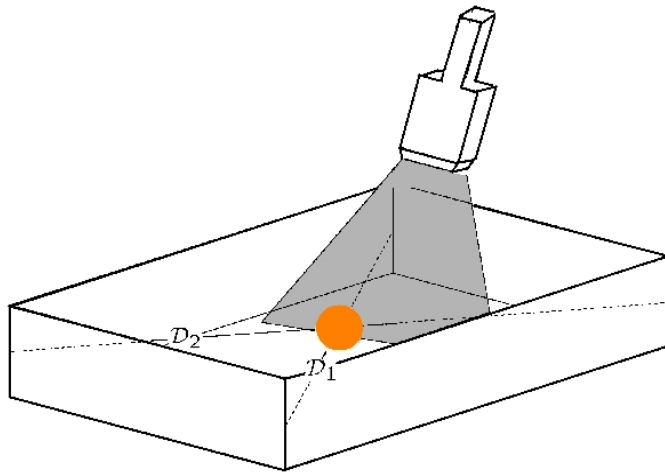


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Spherical phantom

- Ping-pong ball in a water tank



- Robust detection of the circle in US images
 - Active contour (snake) with $h=1$
 - Tracking in images set
- Extracted features
 - Circle centre (u_C, v_C)
 - Circle radius (r_C)



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Simulation results

Probe poses all around the ball

- 6 poses
- 120 images acquired at each pose

Calibration initialization

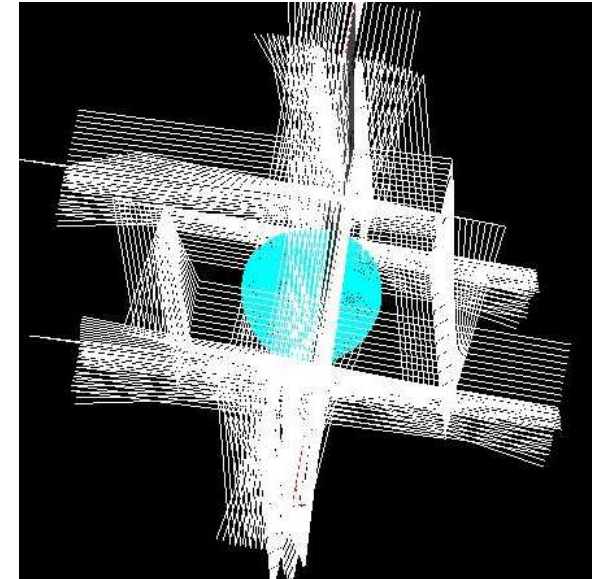
$$T(\text{cm}) = (0 ; 10 ; 0) \quad ; \quad R(^{\circ}) = (10 ; 180 ; 30)$$

Real parameters

$$T(\text{cm}) = (5 ; 15 ; 0.2) \quad ; \quad R(^{\circ}) = (0 ; 180 ; 0)$$

Calibration results

- 11 parameters
- Computation time : 5087ms
- $T = (5.0 ; 15.0 ; -0.1) \quad ; \quad R = (0.1 ; 182.9 ; -2.187)$



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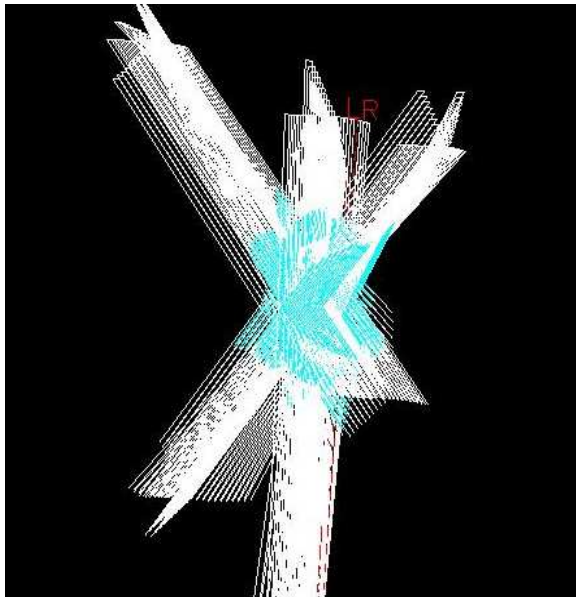
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Simulation results

Probe poses above the ball

3 poses reachable with the US probe in the water tank

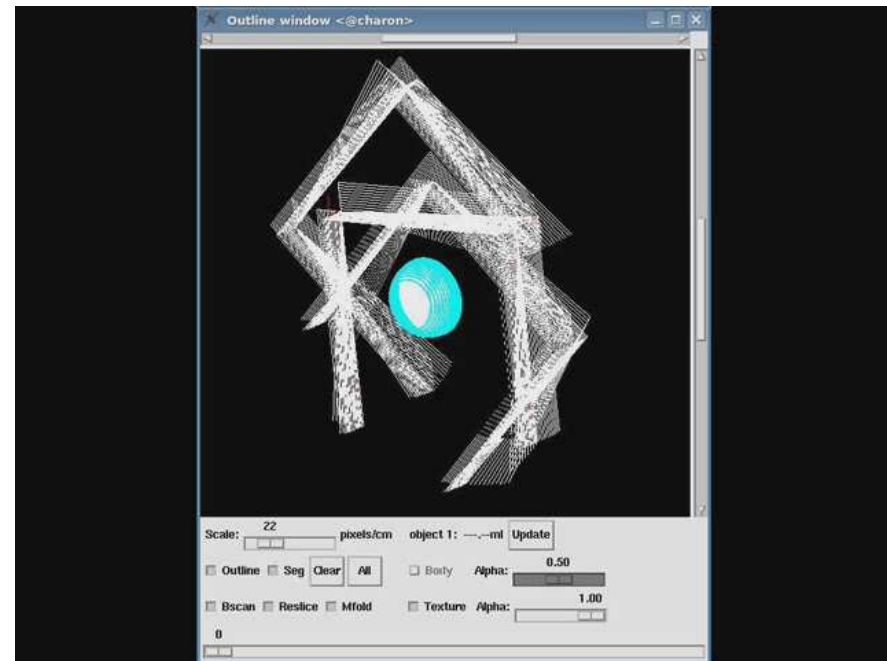
□ 11 parameters optimisation



□ Previous computation of scale factors

- Translational motion of the probe
- Detection of the maximal radius (pixel)
- Ball radius : $R = 20$ mm

□ 9 parameters optimisation



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Thank you for your attention !

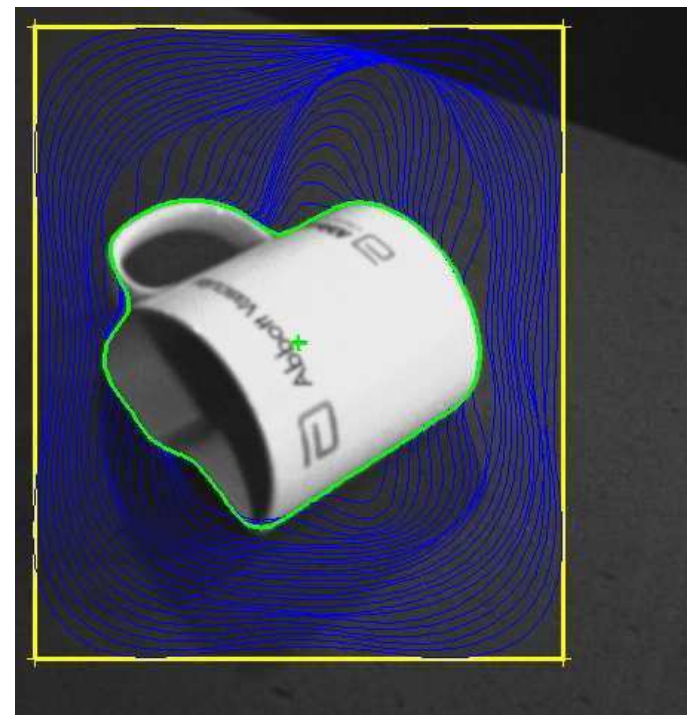
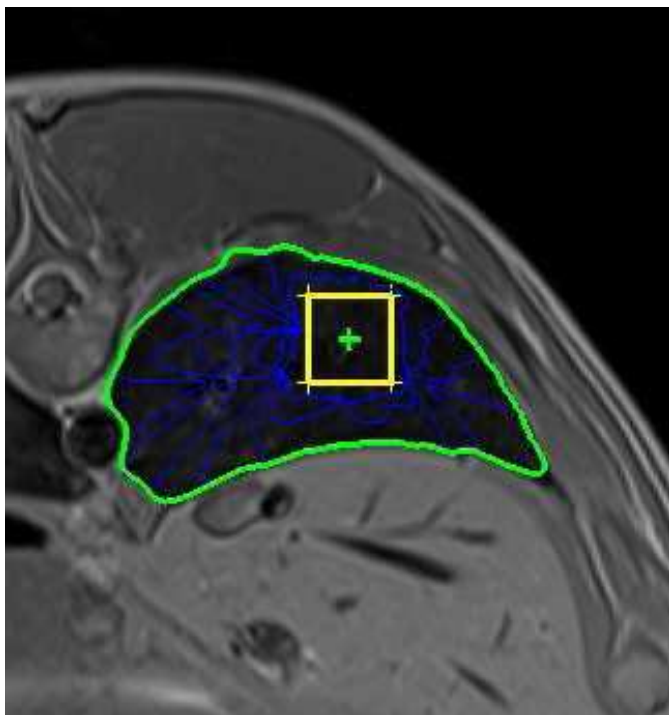


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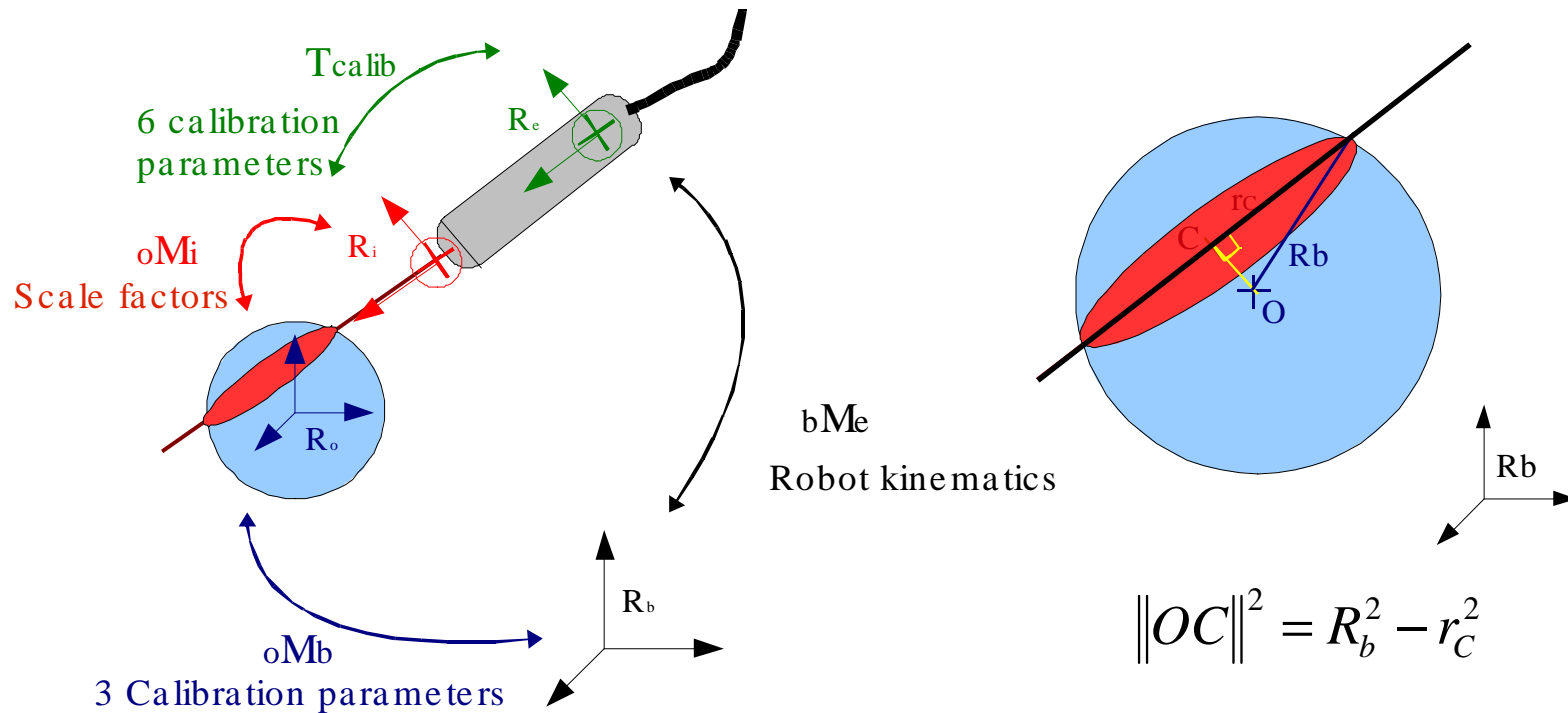
Snakes [Collewet09]



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Spherical phantom : equation minimization



Cost function :

$$f = ({}^b x_C - {}^b x_O)^2 + ({}^b y_C - {}^b y_O)^2 + ({}^b z_C - {}^b z_O)^2 - R_b^2 + r_C^2$$



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