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To cite this version:
Guillaume Lapouge, Jocelyne Troccaz, Philippe Poignet. Needle localization for needle steering under 3D ultrasound feedback. CSR: Continuum and Soft Robots, Oct 2018, Madrid, Spain. Continuum and Soft Robots (CSR) for Medical Interventions: Modelling, Fabrication, and Control - IROS Workshop, 2018. hal-01896975

HAL Id: hal-01896975
https://hal.archives-ouvertes.fr/hal-01896975
Submitted on 18 Oct 2018

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Needle localization for needle steering under 3D ultrasound feedback

Guillaume Lapouge(1) | Jocelyne Troccaz (1) | Philippe Poignet (2)
(1) Université Grenoble Alpes, CNRS, TIMC-IMAG, Grenoble, France, (2) Université Montpellier, CNRS, LIRMM, Montpellier, France.

Contact: guillaume.lapougeg@univ-grenoble-alpes.fr

Motivation and objectives

- In needle steering, estimating the needle pose is a critical problem.
- In 3D ultrasound volumes, fine needle localization is difficult and requires a combination of estimation and image processing to be successful. Indeed, 3D ultrasound imaging suffers from noise, artifacts and works at a low frequency.
- We propose a needle tip pose estimation method in the context of 3D robotic needle steering under 3D ultrasound feedback, based on multi-rate, multi-sensor fusion [1].
- This estimation feeds a segmentation algorithm for robust needle detection.

Pre-operative shear wave imaging (SWE)

- SWE estimates tissues Young’s modulus from their response to a shear wave US stimulation.
- The needle curvature is proportional to the tissue stiffness.

3D kinematic bicycle model

- The needle tip path is modeled by a bicycle kinematic model [3].
- \( \beta_{cut} \) is the cutting angle of the needle, as deduced from data fitting.

Multi-rate unscented Kalman filter

- The needle tip pose and curvature are estimated by a multi-rate unscented Kalman filter.
- All available measurements are taken into account asynchronously.
- The filter updates the estimation error covariance online to account for poor 3D US quality and expected changes of tissue stiffness.

References