Improving N-Wire Phantom-based Freehand Ultrasound Calibration

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Purpose: Freehand tracked ultrasound (US) imaging is an inexpensive, safe, non-invasive technique used in several guided interventions. This technique requires spatial calibration between the tracker and the ultrasound beam. Several calibration devices (a.k.a. phantoms) use multiple parallel N-wires that are convenient for automatic calibration procedures. In these procedures, the segmentation of fiducials in the images and the localization of the middle wires are straightforward and can be performed in real time.

Calibration procedures reported in the literature use only the positions of the middle wires and disregard the information of the rest of the wires, 3D errors between the middle wires computed intersections and their respective segmented points in the image plane are the only terms in the cost function that is minimized for the calibration. We investigated if better results can be achieved if the information of all the wires is taken into account.

Methods: We considered a cost function based on the 2D errors between the intersection of the wires with the image plane and their respective segmented points in the image. This cost function was minimized in an iterative non-linear optimization starting from a seed computed with a closed-form strategy based on the middle wires.

Results: Calibration precision achieved with the N-wire phantom is at least comparable to that obtained with other methods traditionally considered more precise (cross-wire, stylus, plane phantom) but unlike the other calibration methods, calibration can be performed almost in real time and no user experience is required. Accuracy evaluation of the whole system is currently in progress.

Conclusions: Preliminary results suggest that US calibration using N-wires can be done more consistently and with a smaller range of probe movement (see figures) if a 2D cost function is used for all the wires instead of a 3D cost function for only the middle wire to optimize calibration parameters.

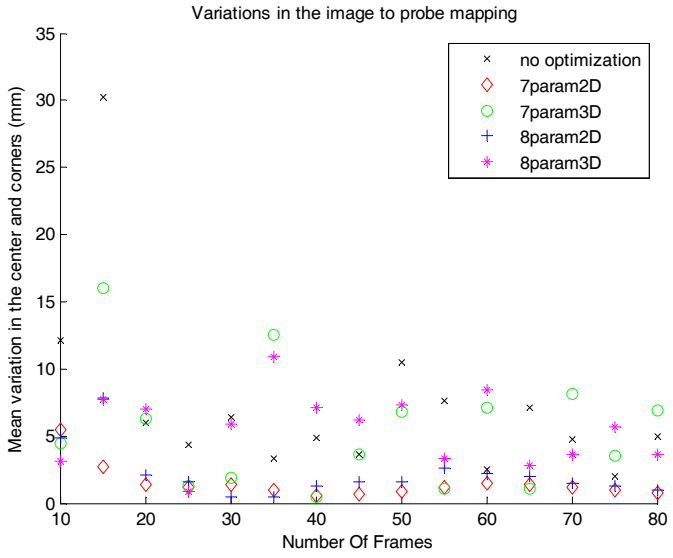

Fig1: Precision of different methods for curvilinear probe with 15 mm depth

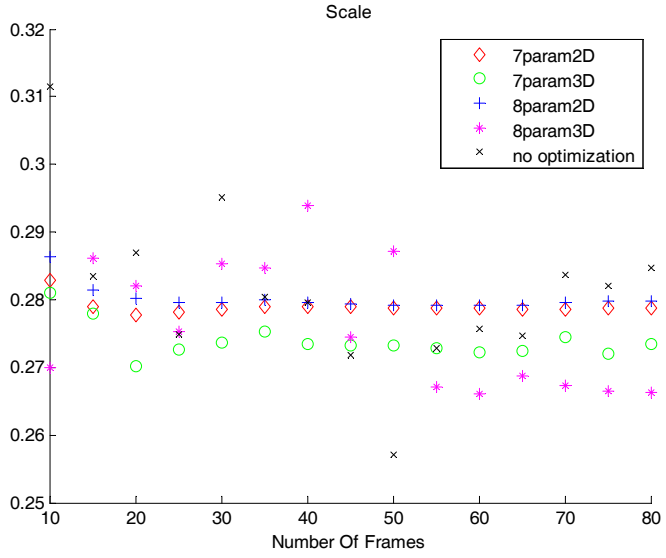

Fig2: Scale factor of calibration matrix is more consistent with fewer frames when 2D minimization is used

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