Real-time Quality Control in Ultrasound Navigation

The overwhelming majority of intra-operative hazard situations in ultrasound (US) navigation systems are attributed to failure of registration between the US system and the frame of reference with respect to which surgical tools are navigated. Researchers at the CISST ERC have developed a break-through methodology for real-time in-vivo quality control (QC) of tracked US systems, in order to capture failures during the interventions.

Typically, US navigation is achieved by rigidly attaching 3D localizers to the US probe, where the spatial transformation between the US image pixels and the 3D localizers on the probe requires calibration. From our experience, the wide majority of intra-operative hazard situations manifest in miscalibration. The most typical form of errors is false reading of the tracker that occurs quite often in electromagnetic tracking systems due to invisible field distortions caused by metal objects or electromagnetic noise. Another typical problem related to tracking is deformation or physical damage of the tracking body attached to the probe, causing a latent misreading of pose. *What makes these problems exceedingly dangerous is that they occur without apparent warning*. Among human operator errors, inadvertent changes of lateral image polarity occur quite frequently and always transparently to the clinician.

In effect, we dynamically recalibrate the tracked US system for rotation, scale factor, and in-plane position offset up to a scale factor. We detect any unexpected change in these parameters through capturing discrepancies in the resulting calibration matrix, thereby assuring quality (accuracy and consistency) of the tracked system. No phantom is used for the recalibration. We perform the task of calibration and quality control in the background, transparently to the clinician user while the patient is being scanned.

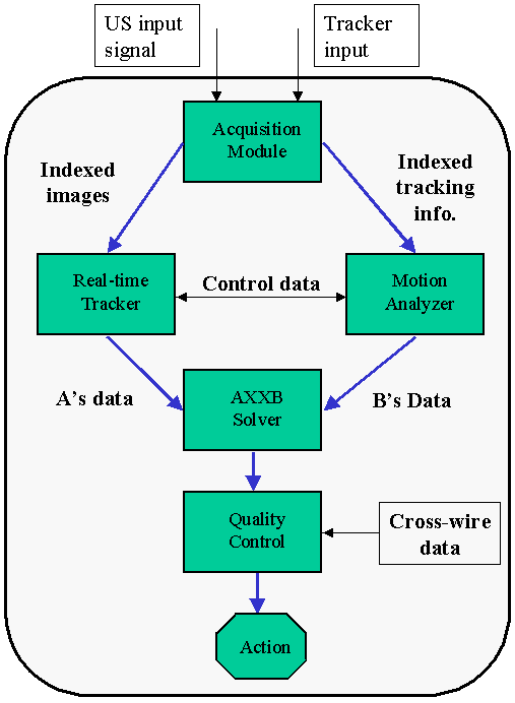

Fig. 1: The in-vivo quality control workflow

The workflow in the real-time QC procedure is described in Fig 1. The *Acquisition Module* receives US video signal and tracker reading, from which it prepares synchronized indexed sequences of images and tracking information. The *Motion Analyzer* sorts out the types of motions in these sequences and sends control signal for the *Real-time Tracker*, which recovers the *A* matrices. Finally, the novel *AX=XB* real-time solver recovers the *X* calibration matrix. The *Quality Control* unit analyzes the new calibration and compares it with previous runs. In case of suspected discrepancy, an appropriate *Action* is initiated to deal with the hazard condition. The action could range from generating a warning message to demanding to halt the procedure and fully recalibrate the system. It must be noted that a full recalibration is necessary only if a scale factor is found to be at fault, because the partial calibration recovers all other parameters during the QC process.