Section: **Ultraschall und Intervention**

ID: 95

Abstract-Title:
FREEHAND CALIBRATION OF "3D ULTRASOUND NAVIGATION"

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Abstract-Text:
Introduction and problem
A major source of error in image guided surgery is tissue shift during the intervention (e.g. brain shift in neurosurgery). Therefore, intra-operative imaging like sonographic or MR images are commonly used in computer assisted surgery. Recently we developed in Leipzig an intraoperative "3D ultrasound navigation system" based on a navigation system and a conventional ultrasound system. A tracked ultrasound transducer can locate the 2D US images in 3D space and relate them to patient, devices, and pre-operative planning data (Fig. 1). Therefore, tracked ultrasound is an efficient tool for validity control of pre-operative planning, recognition of brain shift during the intervention, adjusting the operational path due to situational changes (iterative navigation), and finally, controlling of tumor removal. So far these systems are dedicated for one special application and are mostly developed as stand-alone devices. But the use of intraoperative ultrasound is generally accepted in different surgical disciplines like cardiovascular surgery or abdominal surgery. Furthermore, these systems lack appropriate interfaces and standards for vendor- and device-independent intercommunication. Components of the "3D ultrasound navigation system" like i.e. the sonography system cannot easily be exchanged with a system from another vendor, etc.
A simple calibration method for the application of arbitrary ultrasound probe with different parameters like sonography depth and frequencies was developed. This allows the use of arbitrary ultrasound devices. The tracker is mounted intra-operatively with an easy-locking mechanism to the ultrasound probe and the probe can be calibrated with a CUBE phantom and a CALIBRATION software.

Material and Methods
For calculating the transformation from the 2D ultrasound image to the 3D ultrasound slice we developed a calibration CUBE phantom (Fig. 2), which is filled with water. The calibration CUBE is a passive tracked plexiglas box with twisted nylon wires. The CUBE was digitized using a Faro Arm. Therefore the positions of the nylon wires in relation to the passive tracker markers are known. The wires were arranged in a special m-structure. Thus, the correct position of the segmented points in the 2D ultrasound image to the corresponding 3D points in the phantom can be calculated. Therefore the overall calibration transformation can be calculated.The CALIBRATION software automatically

segments the ultrasound points within the 2D US image in real-time. The program grabs the ultrasound image from an S-VHS connection, measures the ultrasound tracker coordinates as well as the phantom tracker coordinates and orientation, using an S-PACS interface client, for the tracking camera. The final transformation (Fig. 3) is calculated using a least square fitting algorithm based on 500 points.

Results

The aim of the study is on the evaluation of the accuracy of the transformation calculated by the calibration application. In this case an 8 MHz ultrasound probe was used. A box with a different pattern of wires was used for the validation. Then a scan of these cross wires and the corresponding transformation was performed using the calibrated 3D US navigation system. The accuracy was evaluated (Tab. 1).Conclusion

The results show that the proposed method for calibration of an ultrasound probe yields in sufficient accuracy. Further, the man-machine interface and handling was analysed. Surgeons claim an easy to use calibration method within 2 minutes. This allows easy re-calibration in the OR to address changes of parameters or US probes. The proposed calibration method enables the 3D-US system to be applied within different surgical disciplines. Nevertheless, better results may be expected with other CUBE configurations. Additionally, the depth of the CUBE is an important parameter for different ultrasound transducers. The calibration setup was developed within the S-PACS architecture of ICCAS and showed reasonable results as a first prototype: (1) the tracking system can be easily integrated in an dedicated navigation system (here 3D-US navigation system) (2) abstract interfaces for the tracking camera hide the hardware implementation details of the tracking system (3) the configuration and setup is simple and independent from the device and vendor (4) the system can be used across different surgical disciplines.

Bild 1/JPG

Depth [cm]	8	9	10	11	12
Mean [mm]	0.753	0.710	0.704	0.668	0.676
Std. Dev. [mm]	0.328	0.345	0.329	0.314	0.351

Table1: Accuracy of the calibration in relation to the ultrasound depth.

Bild 2/JPG

Fig. 1: System setup of the calibration system

Fig. 2: Plexiglas phantom for freehand ultrasound calibration

Bild 3/JPG

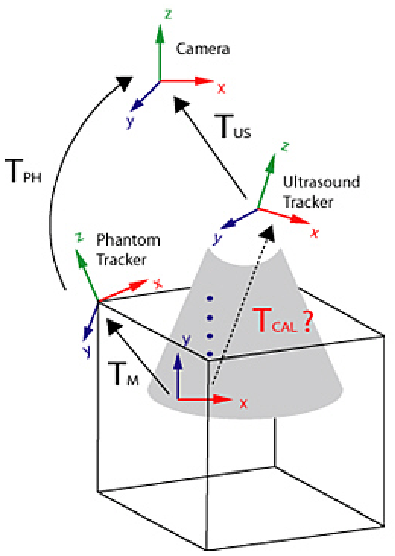

Fig. 3: Automatic computation of the transformation
$T_{CAL} = T_{US}^{-1} T_{PH} T_M$