Biomed Tech 2013; 58 (Suppl. 1) © 2013 by Walter de Gruyter · Berlin · Boston. DOI 10.1515/bmt-2013-4291

Combined Modality for Ultrasound Imaging and Electromagnetic Tracking

A. M. Franz[1], K. März[1], A. Seitel[1,2], H. G. Kenngott[3], M. Wagner[3], A. Preukschas[3], H.-P. Meinzer[2], I. Wolf[2,4], L. Maier-Hein[1]

[1]Junior Group: Computer-Assisted Interventions, DKFZ Heidelberg, Germany
[2]Division of Medical and Biological Informatics , DKFZ Heidelberg, Germany
[3]Department of General, Abdominal and Transplantation Surgery, University of Heidelberg, Germany
[4]Mannheim University of Applied Sciences, Germany

a.franz@dkfz.de

Abstract: *Computer-assisted interventions (CAI) typically require localization (tracking) of surgical instruments and the patient. For ultrasound (US)-guided interventions, a new compact electromagnetic (EM) field generator enables construction of a combined modality which allows for both, EM tracking and US imaging with one handheld device. In this study, we present a research prototype of such a device and conduct accuracy assessments in a clinical US suite. The results show robust US imaging and EM tracking of the combined device, which emerges as a promising component for US-guided CAI systems.*

Keywords: *Computer Assisted Interventions, CAI, Electromagnetic Tracking, Compact FG, Ultrasound Imaging*

Introduction

For Computer-assisted Interventions (CAI), Ultrasound (US) offers clear benefits over other imaging modalities: It acquires images in real-time and at low costs, is widely available and does not expose the patient or the physician to radiation. However, most CAI concepts require exact localization (tracking) of instruments and patient. Whenever image-based tracking is not feasible, external tracking systems are a common alternative. Electromagnetic (EM) tracking is a technique which enables the localization of small sensors in an EM field without the need of a line of sight.[1] However, an additional device, the EM field generator (FG) needs to be placed near to the patient. This complicates the integration of such systems into the clinical workflow and hinders wide clinical application.

Due to its compact and lightweight design, a new mobile FG from NDI (Northern Digital Inc., Waterloo, Canada), herein referred to as *Compact FG*, offers the possibility to be attached to small medical devices like US probes. With such a combined device, no additional hardware needs to be placed close to the patient and the FG is located in an ideal position near the region of interest (ROI), as it moves together with the US probe. In a recent study, we showed that distortions caused by interference with commercial US probes the *Compact FG* is attached to can be neglected.[2] However, for further research with the new combined modality, a fully integrated prototype which enables simultaneous access to US and tracking data in real time is necessary. Furthermore, this data must be accurate and reliable when acquired in real clinical environments.

In this study, we present a research prototype which enables full access to real-time US raw data and EM tracking data on one PC, based on commercially available components and open source software. The prototype is evaluated in regard to possible distortions of EM tracking and US imaging in a clinical US suite.

Materials and Methods

As shown in Figure 1, the prototype of the combined modality consists of the following components:

US probe with attached field generator: A Telemed (TELEMED Ltd., Vilnius, Lithuania) US probe, Type C4.5/50/128Z was combined with a NDI *Compact FG*. The FG enables EM tracking in a dome shaped volume with a radius of 18.5 cm, covering the imaging plane of the US probe and a 3D volume around it. The modality weighs about 200g (the FG contributes 100g) and can be used with one hand like any conventional US probe.

Telemed Logicscan 128 US device: Connected via USB, this devices acts as an interface to US probes for a PC. The US functionality is accessible by a software interface.

Aurora EM tracking system: This system, sold by NDI, enables tracking of up to 8 sensors in the EM field created by the FG.[1] It is connected via USB or a serial port.

Notebook/PC: A common Notebook/PC may be used as hardware platform for the new modality. In our setup we used a Core i7 2.5 GHz system with 16 GB of memory. The open source Medical Imaging Interaction Toolkit (MITK, www.mitk.org)[3] serves as software framework. Tracking and US imaging as part of image guided therapy (IGT) applications are supported by the software modules MITK-IGT and MITK-US.

The modality was evaluated in a clinical US suite of the German Cancer Research Center (DKFZ), as shown in Figure 2. The evaluation consisted of two experiments: (1) accuracy assessment of the EM tracking concerning distortions caused by the Telemed US probe and/or by the clinical environment and (2) assessment of possible distortions of US imaging caused by the Compact FG.

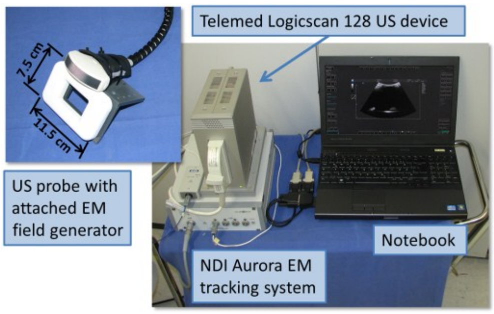

Figure 1: Prototype of the combined modality.

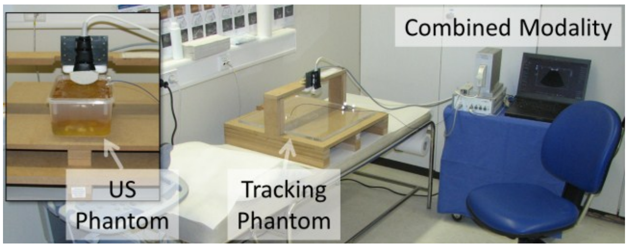

Figure 2: Experimental setup concerning (1) EM tracking accuracy and (2) US imaging errors in a clinical US suite.

(1) Assessment of EM Tracking: We used a standardized assessment protocol proposed by Hummel *et al.* [4] to perform 36 positional measurements in a known grid with 5 cm distances on three levels relatively to the FG. Orientation of the 5 degrees of freedom EM sensor was assessed by 32 rotational measurements. Reference data of similar experiments with other US probes in a lab environment is available from a previous study which also includes a detailed description of the protocol [2].

(2) Assessment of US Imaging: Possible US imaging distortions were assessed by constant sonographic acquisition of a gelatine phantom including artificial targets, as shown in Figure 2 and 4. To obtain an averaged base image of this scene, we recorded ten images (grey values, range: 0..255) with detached FG and calculated the mean intensity image (IMG_{Base}). Ten independent images were captured as reference ($IMG_{Ref,n}$ [n=1..10]). Subsequently, the FG was attached carefully such that the pose of the US probe relative to the phantom remained constant. With the combined modality, ten images were recorded ($IMG_{Mod,n}$ [n=1..10]) while EM tracking was activated. For analysis of this data, IMG_{Base} was subtracted from each $IMG_{Ref|Mod,n}$ resulting in the error images $IMG_{ErrorRef,n}$ and $IMG_{ErrorMod,n}$ [n=1..10] respectively. The error values of each pixel of the images were then compared in regard to mean value (μ), standard deviation (σ) and maximum value. $IMG_{ErrorRef}$ shows the regular noise including speckle[5] of US imaging while $IMG_{ErrorMod}$ shows additional errors/noise introduced by the *Compact FG*. The experiment was repeated three times with different scenes (*Test Series 1-3*).

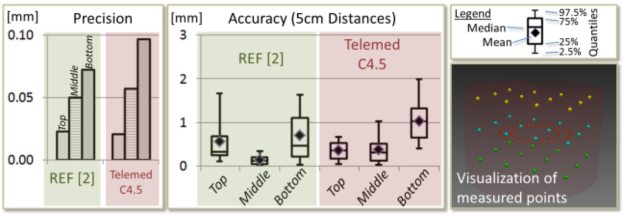

Figure 3: Results of the EM tracking assessment. The reference values (REF) are taken from [2].

Results

Mean positional accuracy and precision of EM tracking in the US suite with attached Telemed C4.5 probe were below 1.0 mm and 0.1 mm respectively, as shown in Figure 3. Compared to the reference data without probe in a lab environment the decrease is 24% and 20% respectively. The rotational error was 0.4±0.9° (ROT1, n=16, 180°) and 1.6±2.5° (ROT2, n=16, 180°). The assessment of US imaging shows a mean intensity error of 0.65, which is an increase of 0.16 / 31% compared to the reference measurement, as shown in Figure 4.

Discussion

The measured errors are relatively small, as can be seen in Figure 3 and 4b) showing no visual EM field distortions or US imaging artefacts. Known robustness problems for EM-Tracking in clinical environments [6] have not been observed for the combined modality which may be attributed to the placement of the FG near the ROI[1]. The slightly increased error of the US images, as shown in Figure 4a) may be caused by several reasons, e.g. slight unintended movements of the phantom or due to the added weight of the FG. The latter might cause the US probe to press slightly harder onto the phantom and result in an increased contrast. However, it should be noted that the averaged increase of these errors is very small: 0.1-0.2 for a value range of 0 to 255.

a)

Test Series	Error REF μ±σ	Error REF max	Error MOD μ±σ	Error MOD max
1	0.52±1.27	30	0.63±1.73	50
2	0.50±1.20	29	0.65±1.76	58
3	0.46±1.20	41	0.67±1.83	69

b)

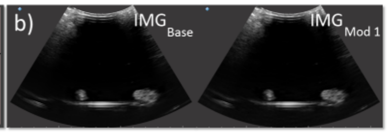

Figure 4: Results of the US imaging assessment. a) Errors of grey values (range 0..255) averaged over ~5 million pixels of ten US images. b) Example US images of Test Series 2.

Future work includes further improvements of the combined modality. In this study we mounted the probe to the side of the FG because of technical constraints[2] resulting in a quite bulky setup. For better handling we aim at central mount of the FG in a joint housing for US probe and Compact FG.
In conclusion, the results show robust US imaging and EM tracking of the combined device, which emerges as a promising component for US-guided CAI systems.

Acknowledgement

This study was conducted with support of the Research Training Group 1126: "Intelligent Surgery" funded by the German Research Foundation (DFG).

Bibliography

[1] T. Peters and K. Cleary, *Image-Guided Interventions: Technology and Applications*, Berlin: Springer, 2008

[2] A. M. Franz *et al.*, *Electromagnetic tracking for US-guided interventions: standardized assessment of a new compact field generator*, Int J CARS, vol. 7(6), pp. 813–818, 2012

[3] M. Nolden *et al.*, *The Medical Imaging Interaction Toolkit: challenges and advances : 10 years of open-source development*, Int J CARS, vol. 8(4), pp. 607-620, 2013

[4] J. B. Hummel *et al.*, Design and application of an assessment protocol for electromagnetic tracking systems, Med Phys, vol. 32(7), pp. 2371–2379, 2005

[5] R. F. Wagner et al., *Statistics of Speckle in Ultrasound B-Scans*, IEEE Trans. on Sonics and Ultrasonics, Vol. 30(3), pp.156–163, 1983

[6] Z. Yaniv *et al.*, *Electromagnetic tracking in the clinical environment*, Med Phys, vol. 36, pp. 876–892, 2009