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Multimodality Navigation Tool 'Navigator'

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Abstract – The presented work describes the Multimodality Navigation Tool project, developed by Esaote S.p.A and MedCom GmbH. The project goal is to enhance the image content of an Ultrasound Scanner by mean of combining the first modality with a second modality (like CT, MR) in realtime. The system consists of an US system (Technos MPX Esaote SpA) that provides the US scanning and a PC equipped with an electromagnetic tracking device enabling the realtime image fusion based on the geometry data and the content of the 2nd modality dataset The presented paper describes the system architecture, the user procedure and the testing result.

1. BASIC INFORMATION

The major benefit of medical ultrasound scanning lies in the real-time characteristics of the image, the easiness of use compared to a CT scanner and the low costs per image. However, ultrasound imaging is limited in its field of view and image quality which is often degraded by the physical and physiological conditions of the patient. Other methodologies, like computed tomography (CT) and magnetic resonance (MRI) offer a wider field of view, are rather patient-independent and often easier to interpret, but are inherently static in their presentation.

There is therefore an intrinsic difficulty in relating a target that has been identified in a CT or MRI image to the corresponding ultrasound image that only encompasses a limited portion of the anatomy. The possibility of combining the ultrasound exam with a reference modality and to fuse this data with the ultrasound scan improves the understanding of the current scan situation, particularly in difficult cases. The basic result is a speed up and increase of reliability of the hole procedure up to making a treatment just possible in the current situation. The "Navigator" is a system that has been jointly developed by ESAOTE and Medcom GmbH and that allows the real-time visualization of the ultrasound scan side by side with the corresponding virtual slices obtained from other modalities, that can be any one giving a 3D dataset of the desired anatomy. A prototype is shown in Fig 1.

Fig. 1. System Prototype

2. SYSTEM ARCHITECTURE

As shown in Fig.2, the system consists of an US scanner connected to the Navigation units. The two devices are connected by a video cable to grab the ultrasound screen and a network cable to query the current scan geometry of the US scanner. The US system provides the US image and its characteristics such as the spatial dimension, orientation and a probe fields of view. It is mandatory to have access to the ultrasound geometry in order to compute the correct size and orientation of the virtual slice out of the 2nd modality dataset. These data are provided by the US scanner by the network connection and automatically updated at every change on the console of the scanner. The US image is provided trough the video signals and digitalized by a standard frame grabber in order to be presented beside the virtual one.

An electromagnetic tracking system, composed by an transmitter and a small receiver (mounted on the US probe) provides the position and orientation of the US probe in relation to the transmitter, Fig,3.

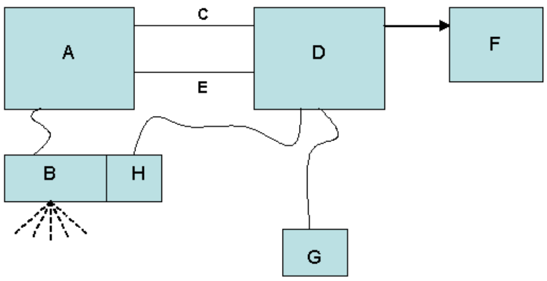

Fig. 2. System Architecture: A) US Scanner, B) US Probe, C) Network connection, D) Navigation Unit, E) Video connection, F) Monitor, G) Electromagnetic transmitter, H) Electromagnetic Receiver.

TABLE I. System specifications

Module	Description
US Scanner	Technos ^{MPX} Esaote S.p.A
US Probe	Convex array 6-2 MHz
Network connection	TCP/IP protocol
Navigation Unit	Pentium IV, 2.8 GHz, 1 Gigabyte RAM
Video connection	S-VHS signal
Monitor	LCD 17'' Touch-screen
Tracking system	PCIBirds (ASCENSION TECNOLOGY) Degrees of freedom: Six (position and orientation) Translation range, any direction: Standard transmitter = +/- 30 (76.2 cm) Angular range: All attitude Static accuracy standard sensor: .040 (1.0 mm) RMS position 0.15 degree RMS orientation

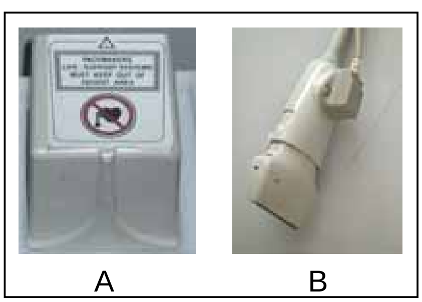

Fig. 3. A) Electromagnetic Transmitter, B) Electromagnetic receiver mounted on the US probe.

The Electromagnetic Tracker (compared to an optical system) works in a proper way in this kind of application because: the body district under examination does not required any special accuracy and the operative field of view is appropriate, it works even if a medical tool is located between the transmitter and the receiver and it is can be easily placed in any environment -- furthermore the cost is acceptable. All these points go pro to the Electromagnetic Tracker versus the Optical Tracker.

Of course the big disadvantage of the magnetic principle is the sensitivity concerning metallic objects close or near the receiver or transmitter. Thus, any metallic material that may interfere and disturb the magnetic field must be avoided between the transmitter and the receiver. Since neither the probe nor for instance the biopsy needle influences the accuracy, it has been found during the clinical tests that this requirement can be achieved without affecting the clinical routine in noticeable way.

3. CLINICAL PROCEDURE

In order to start a multimodality exam, it is necessary to scan the patient, with the reference modality, applying at least three skin markers on the interesting area, Fig 4.

Fig. 4. Marker location

The slices will be imported in the Navigation unity in DICOM format through PACS or data CD. The Navigation system processes every slice and by taking into account the slice to slice distance and dimension, generates a surface volume, as shown in Fig.5..

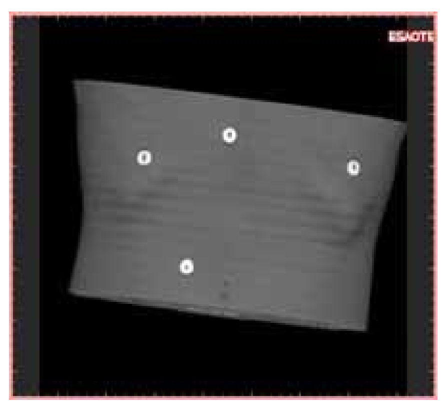

Fig. 5. Reference modality volume with skin marker

Once the patient is located on the treatment couch and the transmitter is fixed in a suitable position it is necessary to start the registration phase, Fig 6. The registration procedure combines the patient co-coordinate system, the probe position and the 3D dataset in a known and fixed co-cordinate system which is mandatory to compute a correct virtual slice at the current probe position. To this aim it is necessary to select the same markers in the volume as well as on the patient skin and to register the marker position with the tracking device. During this registration step and also during the following treatment procedure it is important to keep the patient and the transmitter in a fixed position.

Fig. 5. Patient Marker registration

Once all markers have been registered a registration matrix is be computed by the software in order to correlate the probe spatial position with the reference modality volume that, after this procedure, fit with the patient body. For any probe position and of course for any US image the system gives the related reference modality slice obtained by virtually cutting the volume according to the probe spatial coordinates. As shown in Fig 6.

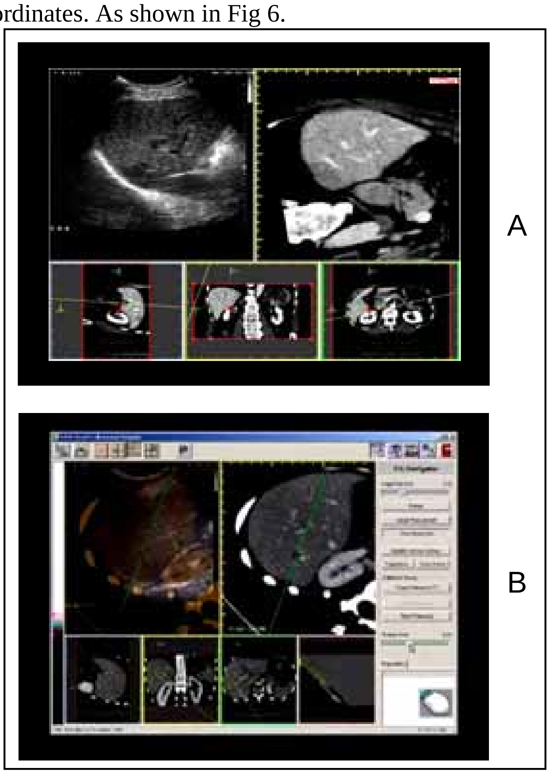

Fig. 6. A) Patient Navigation exam B) with CT/US overlap

4. TEST RESULT

The system have been tested with success in laboratory condition using a CIRS phantom Model 57(Fig.7). The estimated accuracy is better than 3 mm.

Fig.7. A)Phantom CIRS, B) CT Phantom surface rendering

In clinical trials 167 patient with lesion dimension from 0.8 cm to 1.8 cm have been examined. In the 94% lesion are properly targeted.

Fig.8 Phantom Navigation exam

4. CONCLUSION

During the clinical trial the system has shown the real advantage coming from the merging of a real-time modality like ecography with a static modality like CT or MRI that provides a whole organ scan. The major benefit comes from the easiness in the lesion localization that are better targetable in the reference modality and even sometimes are only detectable in the 2nd modality. The US system gives the benefit coming from a the real-time analysis that together with the introduction of contrast media application is used to localize and characterize the lesions. In patients with cirrhosis with suspect of primitive tumour (HCC) or in patients with tumour with suspect of secondary liver tumour, especially in Europe, the use of echography with contrast media permits to improve the diagnosis of the lesion, localization and characterization. The use of US system in combination with thermo-ablation apparatus is became a standard procedure for treatment of liver tumour or metastasis. The help coming from the Navigator system may permits to increase the precision in the target lesion where the US image is not clear. A volumetric reference modality dataset permits to analyze different planes respect to the US scan giving the possibility to better understand the morphology of the target lesion or the anatomical structures that are surrounding the target.

5. REFERENCES

[1] PATENT - Ref. MEDPT0327EP - European Patent Application 03008448.7 - Keyword: Combining first and second image data of an object