# Augmented reality guided radio-frequency tumor ablation

S. Nicolau[1], A. Garcia[1], X. Pennec[2], L. Soler[1], N. Ayache[2].
[1] IRCAD, 1 Place de l'Hôpital, 67091, Strasbourg, France.
[2] INRIA, Projet Epidaure, 2004 Route des Lucioles, 06902, Sophia Antipolis, France.
{stephane.nicolau, luc.soler}@ircad.u-strasbg.fr
**Keywords** : augmented reality, radio-frequency ablation, 3D/2D registration, needle tracking.

## Introduction

The treatment of liver tumors by radio-frequency ablation (RFA) is an evolving technology using coagulative necrosis to treat patients with unresectable primary or metastatic hepatic cancers [McGa]. However, the guidance procedure to reach the tumors with the needle is usually performed visually using intraoperative two dimensional (2D) cross-sections of the patient obtained with either ultrasound (US) or computed tomography (CT) studies. Because of the difficulty to locate the tumor's center in three dimensions (3D), it usually requires many trials to put the tip of the needle in the proper position to perform tumor coagulation. Then, the targeting procedure is often very time consuming.

Real-time superimposition of images reconstructed in 3D from CT studies onto a real patient, so-called Augmented Reality (AR), may improve the accuracy and decrease complications in interventions such as RFA needle placement. One purpose of this project was to build an AR system that could superimpose 3D reconstructions of the liver and its tumors onto a video image associated with a real-time tracking system of the needle. In such a system, the overall margin of error has to be less than 5 mm to provide a meaningful and safe result. We present in this paper our preliminary experiments made on a human abdomen phantom.

## 1. Registration of the 3D reconstructed model
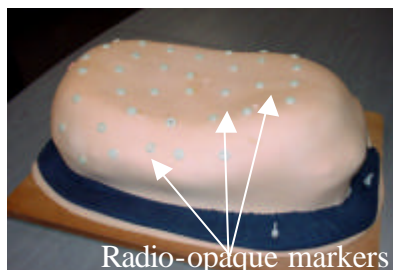
### Model reconstruction


**Fig. 1 : Human abdomen phantom**


**Fig. 2 : Phantom 3D reconstruction**

Twenty five radio-opaque markers are stick on the skin phantom (fig.1), which is afterward scanned (slice thickness of 1mm). A 3D reconstruction (skin, liver and markers) is performed with a specific software [Sol] (fig. 2).

### Model superimposition

Two cameras jointly calibrated [Zh] are oriented toward the phantom from two different points of view. To superimpose the 3D reconstruction in the video images, we need to match the markers localized on the reconstruction on those visible in the video images. For this purpose we use the 3D/2D registration criterion described in [Nico] . An experimental study realized with this phantom [Nico] proved that the superimposition accuracy for target in the liver was about 2 mm.

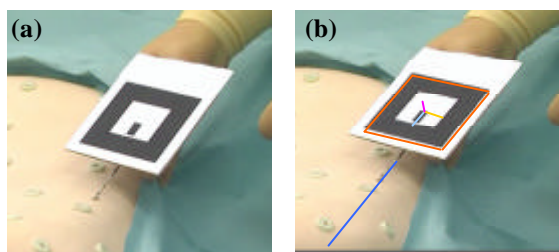## 2. Superimposition of the virtual needle on the real one


**Fig. 3 : Video image from one camera : before (a) and after (b) superimposition of the virtual needle.**

As the needle is no more visible as soon as the radiologist introduces it under the skin, its virtual model needs to be superimposed in real-time onto the video images (fig. 3). Then, it has to be tracked by the cameras. This tracking is performed by an automatic detection followed by a stereoscopic reconstruction of a square pattern [HIL], that is rigidly fixed to the needle.
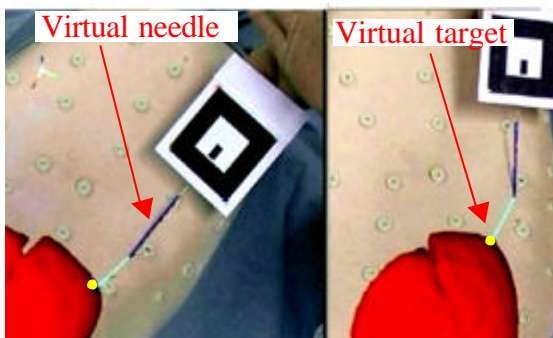
## 3. Experimental results



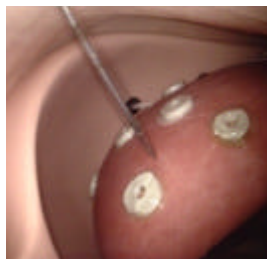**Fig. 4 : The augmented view: the light blue line indicates the distance between the needle tip and the target.**

The targets are modeled with radio-opaque markers stick on the fake liver inside the phantom. To reach one target, the augmented view provides the virtual position of the target and the needle in the 2 video images (fig. 4). The needle orientation is guided by the color target that changes when the needle points the right direction. Moreover, the distance between the top needle and the virtual target is indicated.

Two participants (a computer (CP) scientist and a surgeon) each performed 50 consecutive needle targetings of the model tumor using the augmented view. After each trial, the accuracy of the hit was verified by an independent observer using an endoscopic camera (fig. 5). Results are shown in Table 1.



|  | Total | CP | Surgeon |
|---|---|---|---|
| Average real distance (mm) | 2.79 ± 1.41 | 3.6 ± 1.03 | 1.98 ± 1.27 |
| Average time (sec) | 46.57 ± 24.64 | 38.5 ± 21.78 | 54.64 ± 24.88 |

**Fig. 5 : The endoscopic view**

**Table 1 :targeting results (average value ± standard deviation).**

## Conclusion

This system of AR guidance based on 3D reconstruction, 3D/2D registration and real-time tracking with only stereoscopic external video acquisition is not only feasible, but highly precise as well (mean of 2.8 mm). It offers the possibility to locate hidden targets quickly (less than one minute on average), whereas a standard percutaneous intervention takes generally more than 5 min. The system is also easy to use, and yields reproducible results: an untrained surgeon, not involved with the initial development of the system was able to use it with repeated precision. One major advantage of this system is the simple material needed, indeed, only a PC, a video acquisition card, two cameras and a printed square are required.

In the future, we planned experiments on alive porcine in order to take into account the organs mobility induced by breathing. Indeed, as we cannot simulate the organs shift due to breathing, we need an additional study to quantify its impact on the targeting accuracy. A breathing cycle monitoring is likely to be the employed strategy to limit inaccuracies.

## Bibliography

[Sol] Soler L.,Delingette H., Malandain G., Montagnat J., Ayache N., Koehl C., et al. Fully automatic anatomical, pathological, and functional segmentation from CT scans for hepatic surgery. Computer Aided Surgery 2001;6(3):131—142.

[Zh] Zhang Z. A flexible new technique for camera calibration. Technical report; Microsoft Research; 1998 December

[Nico] Nicolau S., Pennec X, Soler L., Ayache N. Evaluation of a new 3D/2D registration criterion for liver radio-frequencies guided by augmented reality. In IS4TM LNCS 2673; 2003 France;p.274—287.

[HIT] Human Interface Technology Library:
www.hitl.washington.edu/research/shared_space/download/

[McGa] McGahan JP., Dodd GD. Radiofrequency ablation of the liver: current status. AJR Am J Roentgnol 2001;176(1):3—16.