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SYNERGIC USE OF X-RAY STEREOTAXIS AND SCINTIGRAPHIC IMAGE TO REDUCE THE POSITIONING UNCERTAINTY OF THE BIOPSY NEEDLE

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Abstract – The present paper describes the advantages of the combined use of morphologic and functional diagnostic images for improving the accuracy in pathology localization. The main goal of the position uncertainty reduction is to carefully select the area of interest for the biopsy.

The paper describes the new diagnostic technique based on the synergic use of morphologic and functional diagnostic images and shows examples images obtained during breast stereotactic biopsy on some patients.

Keywords: Image fusion, scintigraphy, biopsy

1. INTRODUCTION

The goal of the paper is to present a new technique for accurately detecting the position where to put the bioptic needle for core biopsy. The proposed use of the gamma camera is due to the fact that the widely used X-ray stereotactic test is based on a morphologic approach: i.e. the change in tissue density is detected. An analysis based on functional instead of morphologic approach would be much more reliable (insensible to presence of scars from previous biopsy, but able to detect eventual X-ray occult cancers).

Scintimammography might be a valuable alternative to current methods of patients diagnosis but current cameras are not optimised for lesion detection in small areas, such as breast (see [6]). For that reason a mini gamma camera was adopted in this research. Since mini gamma camera is characterised by a small view field it can be only used as a tool for refining the suspected lesion position and not for a first screening. For this reason the mini gamma camera is used in the present research in conjunction with the X-ray stereotactic test.

2. THE CLASSIC APPROACH

Core biopsy is the most widely accepted method to get diagnosis of breast cancer because of its almost absolute specificity. Sensitivity depends upon accuracy of bioptic needle driving to suspicious tissue. The most accepted and validated guide is stereotactic digital X-ray mammography: bioptic needle is semi automatically directed toward opacity, whose deepness is previously calculated by a computer on the basis of two-projection digital mammography (the 3D vision is based on the analysis of stereo images taken at two positions 30° apart, see for example [1], [2] and [3]). Limits of stereotactic biopsy are the presence of X-ray occult cancers, occurrence of multiple opacities, scars from previous biopsies.

The whole procedure is controlled by a calculator where the X-ray images are shown so that the doctor can choose the biopsy position through a mouse click on both the projections. A dedicated PC is able to extract the 3D coordinates of the suspects lesion by means of a triangulation, starting from the 2D coordinates selected by the doctor on the two projections. The three-dimensional coordinates of the disease are then sent to the bioptical device that is able to automatically position the X and Y coordinates of the needle, allowing the doctor to select the Z coordinate only (representing the drawing depth).

The needle draws a portion of tissue with 3 mm diameter and 19 mm length.

The described procedure is performed through a bioptic device named "Mammotone" combined with Fischer Imaging System, this device is able to execute the stereotassic mammography and the core biopsy.

3. THE SYNERGIC USE OF X-RAY AND SCINTIGRAPHY

The new procedure requires, together with the classic X-ray device, the use of a gamma camera as a further diagnostic tool, with the goal of measuring the emission due to a specific radioactive tracer (^{99m}Tc-Sestamibi (MIBI)). The tracer concentration is higher in the area of interest of the tissue. The main advantage of the use of the gamma camera is that the imaging probe produces diagnostic images that are directly related to the pathologic activity and not to the morphologic signs, such as tissue density changes.

For this reason some Authors combined X-ray with scintimammography in order to obtain clinical data on the reliability of scintimammography in predicting the malignancy of suspected breast lesions [4]. In the present paper, however, through digital image processing, the gamma-camera information are used in order to reduce the bioptic needle position uncertainty for core biopsy.

The scintillation camera is a small, transportable prototype of high resolution gamma camera (patented) for radioguided surgery: the Imaging Probe (IP). The Field Of View (FOV) is 22 x 22 mm and 0.8 kg weight. The camera is based upon the compact Hamamatsu R7600-00-C12

Position Sensitive Photomultiplier Tube (PSPMT), coupled to scintillating arrays. The PSPMT can be arranged as array when larger FOV is needed.

The external dimensions of the gamma camera is 40 x 40 x 120 mm and it can then be handled as a surgical scintigraphic device (even if heavier, because of the lead and tungsten shields). Because of the relatively small field of view the scintillation camera must be used as a refinement tool after the gross positioning obtained with the X-ray test.

4. CALIBRATION OF THE GAMMA CAMERA

Scintigraphic and digital X-ray image shave different dimensions and geometrical references. In order to fuse these images IP was previously calibrated using scintigraphic and digital X-ray images obtained from a simple 5 parallel holes lead phantom (fig.1). Holes were 7.5 mm apart. The phantom consisted of:

1) a 100 mm diameter Perspex base with a reference mask to reproduce the IP positioning,
2) a lead cylinder made of two parts with 5 coaxial holes, one collimator 15 mm thick with 1.4 mm diameter holes, and a source holder 35 mm thick with 2.4 mm diameter holes.

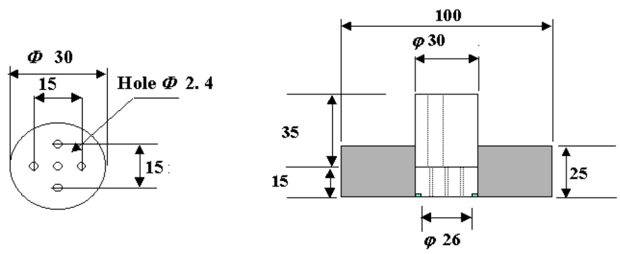

Fig. 1: The phantom

The breast compressor shows a 50x50 mm^2 window about, on its centre. The phantom was mounted in the compressor (in the position reserved to breast) with its axis centered in the window (see Fig. 2).

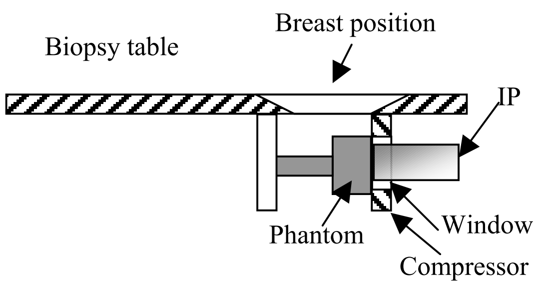

Fig. 2: Experimental setup with the Image Probe mounted on the bioptic needle support on Mammotone

The described phantom was designed in order to produce nominally identical images using both X-ray and scintigraphy: lead is in fact X-ray opaque and produce an image where the 5 holes are clearly visible; mounting five ^{141}Ce radioscopic sources into the holes, the scintigraphic images show the same hole positions on the X-ray images, allowing for system calibration.

IP was put in the appropriate support that we especially made to firmly link it to the Mammotone guide, so that the IP was coaxial to biopsy field and to the lead phantom. Five ^{141}Ce radioisotopic sources (145 keV) were mounted into the source holders. Each source was 2.3 mm diameter, 25 mm height and 500 μCi (18,500 kBq) activity. The scintigraphic image was acquired irradiating the IP with this phantom obtaining five 1.4 mm diameter collimated spots (corresponding to the 1.4 mm diameter phantom collimator holes).

Since the scintigraphic images are low-resolution (8x8), the detection of the phantom position is affected by a high uncertainty ad it is then difficult to obtain accurate data for the system calibration. Uncertainty is also due to the fact that photons emerging from phantom holes could impact more than only one elements of the gamma-camera, producing a multiple spot. In Fig. 3 an example of gamma camera acquired phantom image is shown: the pixel intensities are proportional to the number of photons received by each IP crystal during the exam.

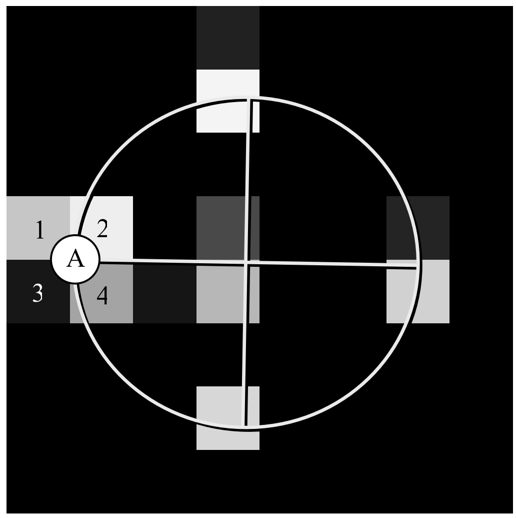

Fig. 3: The image of the phantom obtained by the gamma-camera

In order to obtain the linear transformation parameters (X and Y shift, rotation and zoom) for the gamma camera calibration, two steps must be followed:

1. using the gamma camera obtained image, estimate each phantom source position appraising the centre of mass coordinates (X_G Y_G) of the surrounding pixel intensities;
   i.e. calculating the X and Y coordinates of the source A (see Fig. 3) applying the following equation to pixels i=1 to 4, where p_i is the intensity value of the ith pixel of coordinates x_i and y_i

$$X_G = \frac{\sum_i x_i \cdot p_i}{\sum_i p_i} \qquad Y_G = \frac{\sum_i y_i \cdot p_i}{\sum_i p_i}$$

2. calculate the coordinates of the five phantom generated spots on the X–ray image
3. apply a linear transformation to the five gamma camera points, obtained at the step 1 and considered as a tracker image, in order to minimize the mean square distance between each scintigraphic point and the corresponding X-ray one.

The linear transformation parameters are the calibration constants of the system.

In order to show the calibration capabilities, the X-ray and scintigraphic images are overlapped; before doing that the gamma camera image was processed with the goal of fictitiously reduce the pixel size: the energy associated to each pixel is concentrated in a small area in the centre of the pixel. This procedure has been done for graphic purposes only: in this way the overlapping of scintigraphic and X–ray images give rise to better visible images.

In Fig. 4 an example image is shown where the points obtained by the gamma camera are overlapped on the X-ray image, after the calibration. The arrow marked points are the X-ray ones, while the others are the calibrated gamma camera ones.

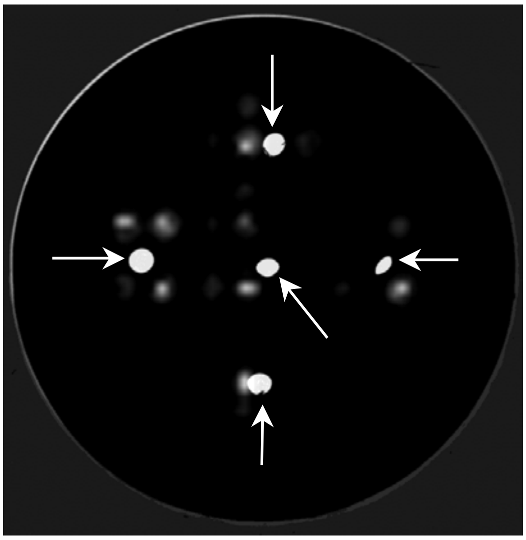

Fig. 4: Calibration image of the phantom: X-ray (arrow marked) and gamma camera images overlapped

The results can be considered satisfactory, even if the leftmost point produces three clearly visible points (i.e. the photons emerging from that source impact on more gamma camera crystals); this is not a problem because, thanks to the procedure described above, the centre of mass of the spots can be calculated and the actual source position can be estimated.

Once the calibration is performed the images obtained with the gamma camera can be compared with the X-ray ones and the coordinates obtained with the IP probe used for biopsy needle guide.

5. OPERATING PROCEDURE

The calibrated gamma camera is used in order to refine the biopsy position; the operating procedure is briefly described in the following lines in order to clarify the proposed techniques.

Once the X-ray stereotactic test has done, the core biopsy needle support is mounted on the biopsy bed and the gamma camera is then mounted on this support using an adapter. This robotized support allows for a gamma camera positioning so that the centre of the gamma camera field of view is equal to the X and Y coordinates of the pathology centre obtained with the X-ray test.

Using the manual control along the Z axis the gamma camera is then leant against the patient’s skin and a scintigraphics image is acquired.

The image is in fact a matrix where each element of the matrix is proportional to the number of charges received by the gamma camera sensing elements. Through the analysis of the image, the coordinates of the core biopsy position are obtained: in order to reduce the uncertainty of the lesion position estimation, an algorithm able to perform a sub-pixel analysis of the gamma camera image is applied.

The coordinates of the maximum emission point are extracted trough a two step procedure: first of all the algorithm finds the sensing element characterized by the highest number of measured charges. The second step is based on the use of a sub-pixel algorithm [5], in order to identify the maximum emission point with an uncertainty level lower than the pixel side (this kind of analysis is necessary since the image is discretized). Starting from the element selected in the first step, the sub pixel algorithm analyses the image in four directions: vertical, horizontal and ±45°; for each of these directions the curve interpolating the pixel intensities is calculated; the coordinates of the maximum of each curve can then be analytically calculated. At this point four x-y pairs of the maximum emission point coordinates are available: the average x and y values represent the best estimation of the lesion position; in this point the core biopsy will be done.

At this point the surgeon mounts the robotized bioptic needle instead of the gamma camera and the automatic control places it in the new calculated biopsy point. Since the biopsy sample is 19 mm long (in Z direction) an accurate positioning along this coordinate is not needed. For this reason the resolution given by the X-ray stereotactic is, in this direction, sufficient.

It must be underlined that the need of the biopsy coordinates refinement is not mainly due to X-ray uncertainty, but, above all, to the scintigraphic test capability of locate functional instead of morphologic lesions.

6. EXPERIMENTAL RESULTS

Although carried out on a restricted number of patients (3 patients), the experimentation lead to the conclusion that using a gamma camera improve significantly the accuracy of the coordinates measurement of the pathology.

As it is shown in the Fig. 5, the location of the pathology measured with morphological observations (X-ray, on the left, shows only one spot) doesn't match with the functional one (gamma camera and X-ray images overlapped, right) that shows three spots: the main one close to the morphologic lesion. Note that the image obtained using scintillation camera was interpolated and re-sampled using a commercial image analysis tool in order to make the greyscale smoother.

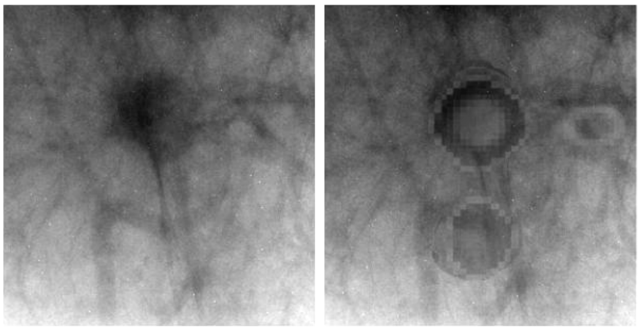

Fig. 5: 6 mm X-ray suspected breast cancer (left) and overlap with scintigraphic image (right)

The system reliability is proved by the comparison of the two images in Fig. 6 showing a scintigraphic image of the lesion before and after the core biopsy: note how the bioptic sample dramatically reduces the pathology emission (Fig. 6 on the right side). This fact confirms that the sample was taken in the proper position and consequently the istological analysis will be run on a tissue that actually belongs to the pathology.

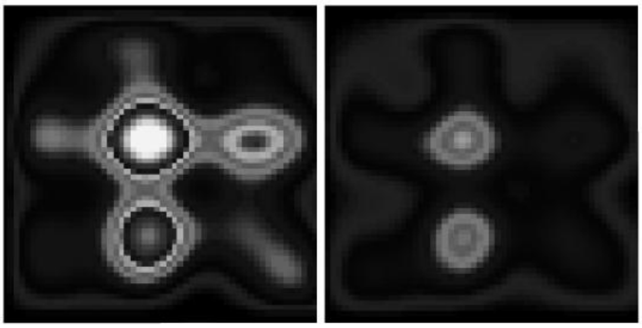

Fig. 6. Scintigraphic image before (left) and after (right) the core biopsy

Although the scintigraphic image is discretized, as can be easily seen in Fig. 3, and then intrinsically characterized by a resolution worse than the X-ray images, the uncertainty associated with the lesion position detection is less in case of scintigraphic image thanks to the scintillation camera ability to produce functional and not morphologic images coupled with the gamma camera uncertainty reduction due to the sub pixel algorithm application.

7. CONCLUSIONS

The experimentation leads to the conclusion that the combined use of traditional morphological diagnostic and functional analysis of scintigraphics images allows to obtain the following results:

- a better reliability and a reduced uncertainty on the 3D coordinates location of the pathology
- a check of the sample effectiveness that can be obtained indirectly thanks to the reduction of the pathology emission or, better, checking the emission of the sample.

The Imaging Probe looks attractive because it is ready for clinical tests in the field of application where simple counters are currently used. Moreover new radio-pharmaceuticals, able to create higher tumour to background ratio, will possibly enhance IP usefulness.

The main development of what was shown in this article consists on the lymph node mapping using the imaging probe [7]. This procedure has the main advantage in the fact that is not invasive and it is more reliable in comparison with the standard procedures.

REFERENCES

[1] R. Horaud, O. Monga "Vision par ordinateur: outils fondamentaux" Hermes, Paris, 1993T.

[2] O.D. Faugeras and G. Toscani "The calibration problem for stereo" *Proc. Computer Vision And Pattern Recognition*, pages 15-20, Miami Beach, Florida, USA, June 1986

[3] R.Y.Tsai "A Versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off-the-shelf TV Cameras and Lenses" *IEEE Journal of Robotics and Automation*, RA-3(4):323-344, august 1987

[4] A.G. Weisenberger F. Barbosa, T.D. Gree, R. Hoefer, C. Keppel, B. Kross, S. Majewski, V. Popov, R. Wojcik and D.C. Wymer "A combined Scintimammography / Stereotactic Core Biopsy Digital X-ray System" *IEEE Nuclear Science Symposium and Medical Imaging Conference,* Lyon, France; October 15-20, 2000

[5] A. Clarke, X. Wang "Extracting high precision infromation from CCD images" *Proc. ImechE Conf., Optical methods and data processing for heat and fluid flow*, London 1998

[6] D. Steinbach, A. Goode, F. Farzanpay S Majewski, D. Weisenberger, M. . Williams and R. Wojcik "Developement of a small field of view scindmammography camera: measurements and simulations" JLAB-PHY-97-04

[7] A. Soluri, R. Scafè, F. Scopinaro, R. Bruschi, V. Casasanta, R. Latini, G. Stringola, A. Tatì, R. Pellegrini, G. De Vincentis, R. Paini "Radionuclides for Limph Node Mapping – Current status and Future Aspects" *Mediterra Publiscers* 1999 p.67

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