Termographical Methods To Determine The Breast Tumor Shapes

Oana Drosu[1)], Bogdan Cupceancu[2)], Florea I. Hantila[1)], *Member, IEEE*,
Mihai Vasiliu [1)], *Member, IEEE,* Cleante Mihai[1)]

Abstract - Nowadays, the medical practice is limited to exploring the thermal field on the breast surface, the infrared images being interpreted by specialist doctors with experience in this domain. The specialists succeed in the early detection of some abnormalities in the cell activity, that could represent the beginning of a malignant tumor development. Unfortunately, a procedure to determine the position and the dimensions of the tumor (a thermographical „radiography") has not been found yet.

I. INTRODUCTION

The diagnose of the breast cancer is usually performed using ecography, tomography (CAT) or mammography, the last procedure beeing an invasive one. The thermography, a total noninvasive technique, has the advantage of the early detection (before any other imagistic investigation) of any abnormal cell activity. Unfortunately, for the thermographical techniques the specialist experience and ability are needed. The disadvantage of the modern thermography is the limitation of proving the presence of the tumor, but not the exact location of it.

Eddie Y-K Ng and NM Sudharsan [1] consider, in their work, the possibility of extending the numerical modeling in the area of breast cancer detection in conjunction with medical thermography, as a factor of the physiological changes detection. This can be completed by the analysis of the anatomical changes detected by the mammography. The proposed framework suggested that it could reduce the occurrence of false-negative/positive cases. A numerical bioheat model of a female breast is developed and simulated. The results are compared with experimental results. The possibility of this method as an early detection tool is discussed. J. Koay and his team [2] develop within their work the segmentation of infrared images; asymmetry analysis, generating statistics that could be used as input parameters to an artificial neural network (ANN). A simple 1-1-1 network was trained and employed to predict clinical outcomes based on the difference statistics of mean temperature and standard deviation. Results are compared with actual clinical diagnosis. Ohashi and Uchida [4] investigate the major difficulty in the interpretation of breast thermography, which is the complexity of the vascular patterns, and the existence of cold tumors that give false indications. To overcome these difficulties, they investigated dynamic thermography after cold stress.

Cercetarile prezentate in lucrare au fost realizate in cadrul contractului CEEX/125/2006-INVTERM, finantat de MEC, prin INFOSOC .
[1)]Catedra de Electrotehnica, Universitatea Politehnica Bucuresti, Romania; e-mail: hantila@elth.pub.ro.
[2)]MEDIS, Campina, Romania.

When a breast is exposed to cold stress, the vascular pattern disappears, and after the stress is removed, the pattern gradually recovers.

The same authors [5] refer to clinical studies on 26 patients with nonpalpable breast cancer, which were examined by thermography. 15 patients (55%) were correctly diagnosed by thermography at steady state, 4 patients (14%) were correctly diagnosed by the aid of dynamic thermography and 3 patients (11%) were correctly diagnosed by the aid of μ-thermography. Background of diagnosis of small cancer by thermography at steady state as well as dynamic and μ-thermography was studied.

In Romania, there is the National Society of Thermography, whose president, dr. **Bogdan Cupceancu**, is the member of the research team of this project. He has three patents and many scientific papers, some of them being published in foreign journals [6, 7] in the area of senological thermography. Unfortunately, in Romania there is no result concerning thermographic methods for shape analysis of the breast tumours. This research direction started worldwide in the last 2 years, being performed by interdisciplinary teams containing medicine and engineering researchers. The published literature reports the possibility of the temperature computation on the breast surface via solving the temperature equation in the 3D breast structure.

Eddie Y-K Ng, S.C Fok and col. [8] studied the computerized detection of breast cancer with artificial intelligence and thermograms. This paper shows the concurrent use of thermography and artificial neural networks (ANN) for the early diagnosis of breast cancer. It has been reported that breast thermography itself could detect breast cancer up to 10 years earlier than the conventional methods such as mammography, in particular in the younger patient. However, the accuracy of thermography is dependent on many factors such as the symmetry of the breasts' temperature and temperature stability, the physiological state and the microclimate of the investigation room. This paper examines the use of ANN to complement the infrared heat radiating from the surface of the body with other physiological data. Four backpropagation neural networks were developed and trained using the results from the Singapore General Hospital patients' physiological data and thermographs. Owing to the inaccuracies found in thermography and the low population size gathered for this project, the networks developed could only accurately diagnose about 61.54% of the breast cancer cases. Nevertheless, the basic neural network framework has been established and it has great potential for future development of an intelligent breast cancer diagnosis system. This would be especially useful to

the teenagers and young adults who are unsuitable for mammography at a young age. An intelligent breast thermography-neural network will be able to give an accurate diagnosis of breast cancer and can make a positive impact on breast disease detection.

II. ACQUISITION OF THE TEMPERATURES ON THE BREAST SURFACE

The formation of the data files concerning the temperature distribution on the breast surface is a problem that has been studied from the theoretical and practical viewpoint, whose principle is illustrated in Fig.1.

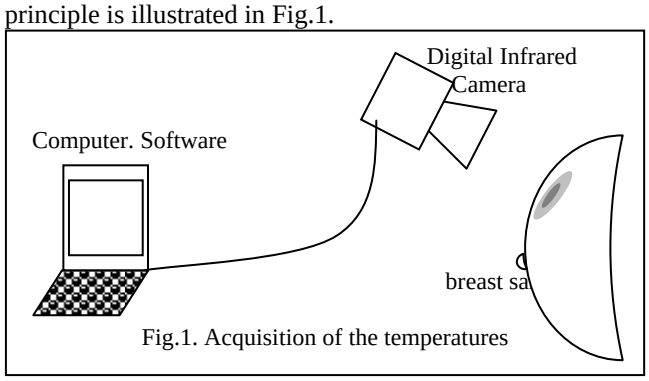


Fig.1. Acquisition of the temperatures

Unfortunately, the data acquisition necessary to define the breast geometry is a high-cost procedure and does not represent the purpose of the study. For the beginning, some solutions will be adopted in order to approximate the breast geometry using simple shapes like an elliptical surfaces. The axis of the ellipsoids and their position can be chosen using the breast dimensions measurements. Several complicated numerical procedures for the geometry modelling can be developed.

III. THE SOLUTION OF THE DIRECT PROBLEM FOR THE THERMIC FIELD

A. Finite Element Method

Fourier Equation for the thermal field in the steady state is:

$$-\nabla(\lambda \nabla T) = p \tag{1}$$

where λ is the termical conductibility and p is the volume density of the power that results from the tissue metabolism. The boundary condition is :

$$-\lambda \frac{\partial T}{\partial n} = \alpha (T - T_e) \tag{2}$$

where α is the thermal convection coefficient and T_e is the temperature out of the domain. In order to solve numerically the equation (1) the Galerkin technique with 1st order nodal elements can be chosen. We define a tetrahedral mesh of the domain and we associate for each node I a function:

$$\varphi_k = 1 - \frac{\mathbf{S}_{k,i}}{3V_i}\mathbf{r} \tag{3}$$

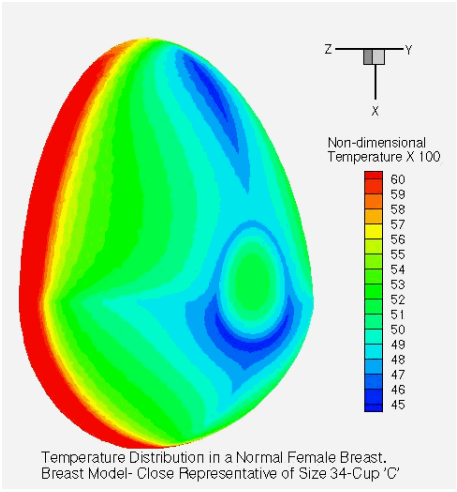
where $\mathbf{S}_{k,i}$ is the surface of the opposite face of the node k in tetrahedron i, outward oriented, and V_i is the volume of the tetrahedron i. We write the temperature as:

$$T = \sum_{j=1}^{n} a_j \varphi_j \tag{4}$$

and we project the equation (1) on the test functions φ_k :

$$\sum_{j=1}^{n} a_j \left(\int_{\partial\Omega} \alpha \varphi_k \varphi_j dA + \int_{\Omega} \lambda grad\varphi_k grad\varphi_j dv \right) - \int_{\partial\Omega} \varphi_k T_e dA - \int_{\Omega} p\varphi_k dv = 0, \quad k=1,2,\ldots,n \tag{5}$$

where Ω is the domain and $\partial\Omega$ is its boundary. In Fig.2 is shown the tetrahedral mesh and the temperature distribution on the breast surface, obtained in [1]



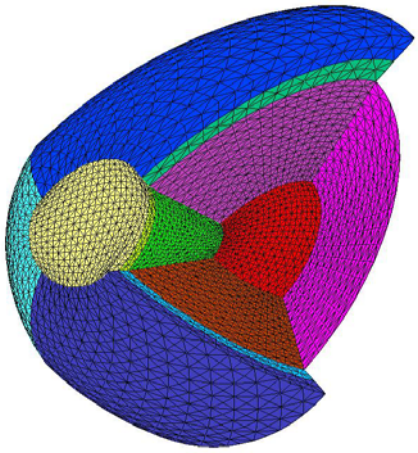


Fig.2. Thetraedral mesh and thermic field on the breast surface

3.2. Boundary Element Method

We divide the domain in m subdomains ω_k. We can demonstrate that, on the subdomain boundaries, the following relations are valid (Fig.3):

$$\frac{1}{\lambda_k} \int_{\omega_k} \frac{p(\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|} dv' + \oint_{\partial\omega_k} \frac{1}{|\mathbf{r}-\mathbf{r}'|} \frac{\partial T(\mathbf{r}')}{\partial n} dS'$$

$$-\oint_{\partial\omega_k} T(\mathbf{r}')\frac{(\mathbf{r}-\mathbf{r}')\cdot\cdot\mathbf{n}'}{|\mathbf{r}-\mathbf{r}'|^3}dS' = \alpha T(\mathbf{r}) \ , k=1,2,\ldots,m \quad (6)$$

where α is the solid angle under which a small vicinity ω_k of the domain is seen from the observation point **r**'. On the surface between the subdomains ω_k and ω_j the continuity conditions are valid:

$$T_k = T_j \text{ si } \lambda_k \frac{\partial T_k}{\partial n_k} = \lambda_j \frac{\partial T_j}{\partial n_j} \quad (7)$$

and on the boundary $\partial\Omega$ of the whole domain the condition (2) is verified.

Contrary to the system (5), the system (6), (7), (2) has a smaller number of unknowns , but it has a full matrix.

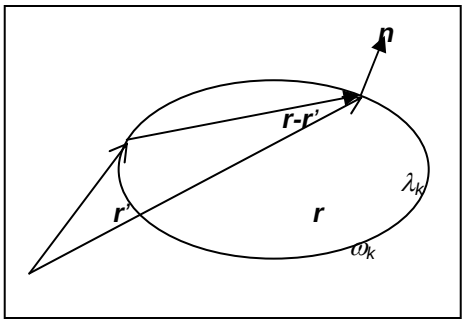


Fig.3. Subdomain

IV. SOLVING THE INVERSE THERMAL FIELD PROBLEM

The malignant tumor leads to a change of the volume distribution of the losses inside the breast tissue. By this way a power density which is not the normal one is created which leads to a temperature modification on the breast surface. The idea of detecting the shape of the defect with the aid of the thermal field consists in measuring the temperature on the body surface, using, for instance, an infrared camera. Then the measured values are compared with those calculated through the direct problem of thermal field. A square functional of the difference between the measured and the calculated values is defined for a supposed tumour and this functional is minimized through a gradient procedure. Unfortunately, it is not convex and some parasitic solutions could appear.

For the numerical calculations, we divide the area that is supposed to contain the tumour in small subdomains. We can suppose that the unknowns have the values 0 or 1, associated to the subdomains occupied by the tumour. We can also suppose that the tumour has the volume density of the losses p_T, contrary to the rest of the tissue where we have p. If we have $\boldsymbol{m}$ subdomains, the detection of the tumour means 2^m searches, that imposes a huge computational effort. If the modelling of the losses is not binary performed, but it is made using the q base, than we have q^m searches. It is obvious that the elaboration of the search-accelerating algorithms is obligatory. The neural networks for the problem solution canwill be developed. They have the disadvantage of the solution blockage for a local minimum. The genetic algorithms can avoid this trouble, but they need a lot of computations. If we admit the superposition of the sources (tumours), we can use an original semideterministic procedure, that will be developed within the project, maybe combined with neural networks and genetic algorithms.

Let $T \in R^M$ be the temperature vector for the M measurement locations and let $F \in Z_2^N$ be the vector of the tumoral sources, where $Z_2 = \{0,1\}$. We have:

$$T=AF \quad (8)$$

where the coefficient a_{ij} of the matrix A is the temperature of the boundary node i produced by the tumoral source from the subdomain j. This coefficient is obtained using the direct method for the thermal field computation. Obviously, the relation (15) is valid only if we admit the superposition. For a given temperature vector T, we use a Gauss pivoting technique to determine a submatrix A' that is well-enough conditioned. It corresponds to a set of tumoral subdomains F'. For the rest of the subdomains F", we try the values 0 or 1; in each case we have to calculate the values F'. Thus, the relation(15) can be partitioned:

$$\begin{pmatrix} T' \\ T_u \end{pmatrix} = \begin{pmatrix} A' & A'' \\ A'_u & A''_u \end{pmatrix} \begin{pmatrix} F' \\ F'' \end{pmatrix} \quad (9)$$

and we have

$$F' = A'^{-1}(T - A''F'') \quad (10)$$

The inverse matrix A'^{-1} must be calculated once. If we have N" unknowns F", then the relation (17) is used $2^{N'}$ times. The deviation of the values F' with respect to the numbers 0 or 1 is calculated.:

$$deviation = \sum_k^{N'} \left| F'_{kcalculated} - (1 or\ 0) \right| < \varepsilon N \quad (11)$$

V REFERENCES

[1] Y-K Ng Eddie and N.M. Sudharsan, "Computer, simulation in conjunction with medical thermography as an adjunct tool for early detection of breast cancer" *BMC Cancer* 2004, vol 4, pp 17;

[2] J. Koay, C. Herry, and M. Frize, "Analysis of breast thermography with an artificial neural network", *Engineering in Medicine and Biology Society,* 2004. EMBC 2004. Conference Proceedings, Vol 1, 2004 pp 1159 – 1162;

[3] D.N. Popov, E.V. Vavilova, "Using infrared thermography in the diagnostics of breast and lung oncological pathologies**"**, *MTT 2001, Proceedings of the 7th International Scientific and Practical Conference of Students, Post-graduates and Young Scientists,* 2001, pp.148 - 151;

[4] Y. Ohashi, and I. Uchida, "Applying dynamic thermography in the diagnosis of breast cancer", *Engineering in Medicine and Biology Magazine, IEEE* Vol. 19, Issue 3, May-June 2000, pp.:42 – 51;

[5] Y. Ohashi, and I. Uchida, "Some considerations on the diagnosis of breast cancer by thermography in patients with nonpalpable breast cancer", *Engineering in Medicine and Biology society, Proceedings of the 19th Annual International Conference of the IEEE,* Vol. 2, 30 Oct.-2 Nov. 1997 pp.670 – 672;

[6] B. Cupceancu and I. Mogos. “The multiparameter analysis concept in computerized contact breast thermography”, *Endocrinologie,* 1987 Apr-Jun; vol. 25(2), pp.121-124;

[7] B. Cupceancu, I. Mogos.C., and C. Cotruta, “Tamoxifen responders selection by computerized contact thermography in benign breast disease”, *Endocrinologie*, 1986 Apr-Jun;vol. 24(2), pp.115-112;

[8] E.Y. Ng, S.C. Fok, Y.C. Peh, F.C. Ng, and L.S. Sim, “Computerized detection of breast cancer with artificial intelligence and thermograms”, *J Med Eng Technol*. 2002 Jul-Aug;26(4), pp. 152-157;