Automatic diagnosis of thermomammograms

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SUMMARY. In this work are presented the parameters we automatically obtained from a digitised thermomammography, their significance and the results obtained through the comparison between the computerized and medical diagnosis.

Key words: computerized thermography, thermomammograms.

INTRODUCTION

During the last few years a research project has been carried on at the « National Cancer Institute » of Milan regarding the development of a method to optimize and standardize a safe procedure for the early diagnosis of mammary cancer, in order to make mass screening and follow-up economically possible.

This research coordinated and partially financed by the C.N.R. (contract N. 76.00323. 86), is organized in the following sectors:

1) The study and selection of sensors which cover the infra red range, with a sensibility spectrum fitting the curve of thermic emission of the human skin, and with commutation frequencies which give an increase of detection of 1,5-2 points/millimeter, and therefore a better resolution of the thermographic image.

2) The improvement of the diagnostic information through the extraction from the thermomammograms of qualitatively more selective parameters [4, 5].

3) The study of the temperature variation on the surface of the breast, as a function of the thermofluid-dynamic condition of the mammary tissue and of the environment temperature.

4) The development of mathematical models for tissue, cysts, blood perfusion and tumoral structures.

5) The setting of a software package to create a file of maps of digitised thermomammographic signals on the mass memory of a computer [2]

6) Development of a program of statistical analysis for the management of the extracted information and for automatic diagnosis [1, 3, 6].

To summarize: the aim is to transform, exploiting its intrinsic potentiality, thermomammography from a useful but limited technique to an instrument of higher resolution, capable of increasing the information on the' tumoral pathology of the breast, and of improving the early individuation of the signals which characterize it.

Our work has been limited to points 2,5 and 6 because the medical competence and the available instrumentation made it difficult to consider the remaining ones.

The other sectors have been partially studied by the section of bioengineering of the Polytechnic of Milan and partiallv by the « Centre for the Study of Aerodynamics » of the Polytechnic of Naples.

PRESENTATION OF THE PROCEDURE

A first description of the algorithms for the creation of the file of the maps and for the pattern recognition of the breast appeared in « Acta Thermographica » [2]. To recall briefly the results we reproduce in Fig. 1 an example of the printout of a thermographic image memorized in the computer and in Fig. 2 the printout of the automatic recognition of the more important zones: mammary areas and the references of the neck and sternum.

Extraction of significant parametres for the diagnosis

At first we analised the thermic structures present in a thermomammogram and their

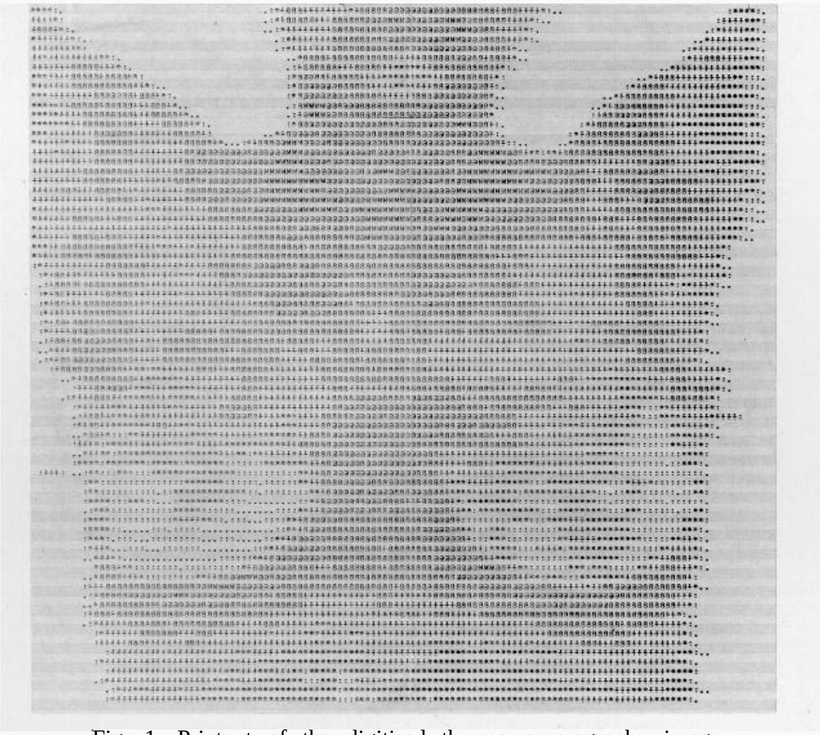

Fig. 1. Printout of the digitised thermomammography image.

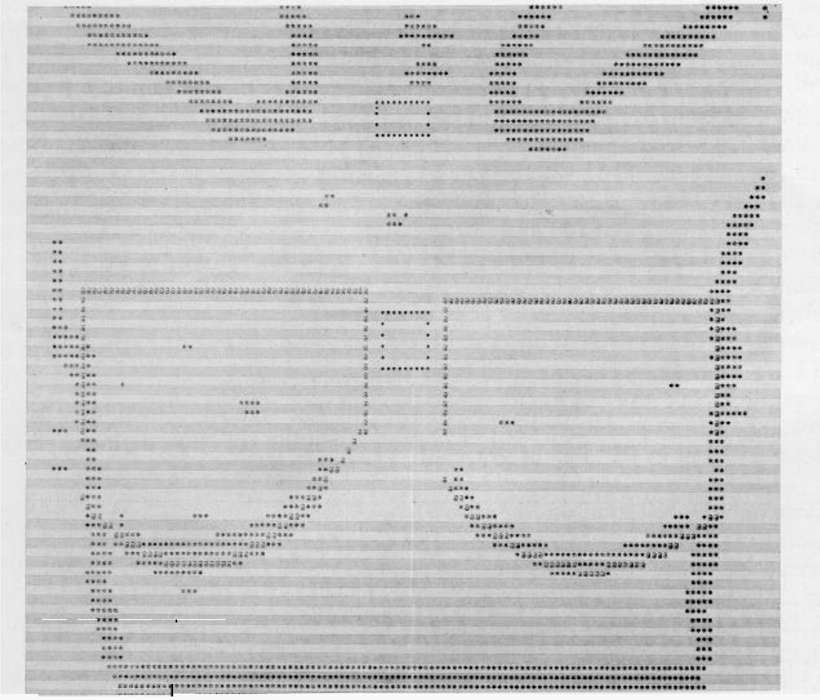

Fig. 2. Automatic pattern recognition of the breast, neck and sternum.

Fig. 3. Vascular network of the original image.

correlation to the presence of neoplasms. As a result of the analysis we tried to define the same kind of information used by the human operator in his visual analysis expressed in the form of suitable parameters. In addition, statistical measures were defined, which, as distinct from the previous ones, are quantified with difficulty by the human eye and therefore can usefully integrate the normal parameters of evaluation.

As a result, three « sets » of measures according to different needs of evaluation and interpretation have been formed.

The first set consists of those elements which give us a measure of the statistical distribution of the temperature level in the area of greatest interest.

This information is collected in the following parameters:

1) The average temperature and its standard deviation in each desired area.

2) Computation of the center of mass and of the polar moment (a measure of dispersion of the hot spots with respect to the center of mass) in the same areas as in point 1.

This data is utilized for multiple comparison. For example: to compare the average temperature of any controlateral areas, and to verify, (through the standard deviation and the polar moments) these values derived from similar distributions of the hot spots.

The second set is formed by the parameters which describe the shape.

Those under consideration are:

1) The number of parts (connected sets) each isotherm surface is composed of;

2) The perimeter and the area of each isothermic surface;

3) The gradient map obtained through a convolution of the digitised original image with a « gradient operator ».

We can calculate with these data a « form index » in each examined area and for each temperature level, as a ratio between the square of the perimeter and the area of each isothermic region. In areas of high temperature gradient this form index can be used to calculate the probability as to whether such a gradient depends on the venous distribution

	Average temperature								*Standard deviation*	*Center of mass*		*Polar moment*
MAP	4.23	2.97	7.64	15.62	29.41	28.11	13.61	2.64	0.0	0.0	0.0	0.0
PSIN	4.28	3.51	7.07	13.14	29.87	29.56	14.09	2.76	0.0	0.0	0.0	0.0
PDES	4.19	2.42	8.23	18.14	28.93	26.64	13.12	2.52	0.0	0.0	0.0	0.0
STER	5.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COLL	5.81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSIN	3.60	7.441	17.15	19.88	25.11	24.36	5.84	0.23	0.10	9.00	28.00	259.00
MDES	3.60	0.91	18.12	25.25	34.42	18.04	3.26	0.0	0.13	15.00	39.00	79.00
S1S	4.16	0.77	2.56	18.72	42.05	29.23	6.67	0.0	0.16	4.00	3.00	18.00
S1D	3.71	0.27	10.93	25.33	44.27	19.20	0.0	0.0	0.17	34.00	120.00	0.0
S2S	4.62	0.0	0.0	6.40	34.67	49.07	9.87	0.0	0.20	8.00	16.00	103.00
S2D	4.53	0.0	0.0	0.28	54.17	37.50	8.06	0.0	0.22	10.00	19.00	30.00
S3S	2.40	15.66	40.66	36.45	3.92	2.11	0.60	0.60	0.17	14.00	23.00	1.00
S3D	2.83	3.44	38.44	39.37	12.19	3.75	2.81	0.0	0.17	13.00	19.00	11.00
S4S	2.68	19.46	36.65	19.91	10.86	7.24	5.43	0.45	0.12	3.00	16.00	46.00
S4D	3.12	0.0	28.41	42.05	20.45	7.20	1.89	0 0	0.16	6.00	19.00	10.00

Fig. 4. First table of the extracted parameters.

	Perimeter of the isothermic surface							*Number of parts each isothermic surface is composed of*						
MAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PSIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PDES	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STER	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COLL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MSIN	85	192	210	249	217	60	3	8	15	14	20	9	9	1
MDES	12	170	256	305	206	40	0	9	7	16	17	16	6	0
S1S	3	10	68	132	82	18	0	0	0	0	0	0	0	0
S1D	1	23	74	125	53	0	0	0	0	0	0	0	0	0
S2S	0	0	21	80	114	31	0	0	0	0	0	0	0	0
S2D	0	0	1	98	122	26	0	0	0	0	0	0	0	0
S3S	49	111	79	13	7	2	2	0	0	0	0	0	0	0
S3D	11	83	90	36	12	9	0	0	0	0	0	0	0	0
S4S	33	71	42	24	14	9	1	0	0	0	0	0	0	0
S4D	0	64	91	46	19	5	0	0	0	0	0	0	0	0

Fig. 5. Second table of the extracted parameters.

List of symbols (Figs. 4, 5). MAP: Total image — PSIN: Left area with respect to symmetry axis - PDES: Right area with respect to symmetry axis - STER: Sternal area - COLL: Neck area - MSIN: Left breast - MDES: Right breast - SlS; First quarter of left breast - S2S; Second quarter of left breast - S3S; Third quarter of left breast - SIS; Fourth quarter of left breast - SlD; First quarter of right breast - S2D; Second quarter of right breast - S3D; Third quarter of right breast - S4D; Fourth quarter of right breast.

or whether it is a hot spot due to an underlying neoplastic process.

The third set is finally composed by those parameters the combination of which allows us to classify each thermogram as one of the principle « thermic patterns » conventionally adopted (avascular uniform, vascular linear, vascular irregular, avascular mottled).

For this purpose we use two qualitatively very different algorithms:

1) The first one, makes use of a convolution grid corrisponding to the « laplacian operator » for a digitised spazial function, and transforms the original image into another one where only the vascular network is brought to evidence (Fig. 3).

On this new map we can operate in different ways: a) extracting form descriptors of the kind mentioned above, to classify them in one of the standard thermic pattern; *b)* to verify the symmetry of the venous network; c) to remove from the original image the thermic contribution due to the veins, in order to better identify the iperthermies due to possible neoplastic processes.

2) The second algorithm computes the average dimension of the mammary thermic structures: for example in an « avascular uniform » pattern the thermic structure has infrequent variations of temperature level, therefore the average dimension of the isothermic regions will be slightly lower than those of the breast. A « vascular network » pattern is instead characterized by many variations of temperature level and the average dimension of the isothermic areas will be much lower than those of the breast.

It is possible, by an adequate statistical calculation, to point out these differences evaluating the size of the more frequent structures.

CONCLUSIONS

It is clear, from our description, that our aim is to describe the degree of thermomammographic pathology evaluating the statistical behaviour of a certain set of well defined suitable parameters. Therefore tables have been made, (Fig. 4 and 5), to carry out an initial critical examination of the present approach, to construct an algorithm capable of evaluating the whole set of parameters and to diagnose a case as negative, positive or uncertain.

These tables give us an immediate comparison of the values of the parameters extracted from the controlateral symmetric zones, making easy the assessment of discrepancies.

Due to a lack of instruments and to technical difficulties we have applied this procedute only to sixteen digitised maps.

We realize that the reliability of such data is not sufficient to give us definitive results.

Preliminary result of the cases we have processed indicate a good correlation between positive diagnosis expressed by a specialist and the presence of anomalous asymmetries among the elements in the tables.

These preliminary results seem to give a positive indication of the possibility of building a useful automatic system for the early detection of breast cancer.

REFERENCES

1. **Dwyer S. J., McLaren R. W., Harlow C. A.:** ***Computer-aided diagnosis of breast cancer from thermography.*** Congress on pattern recognition and artificial intelligence. New York, **1976.**
2. **Fava G.,** Leonardi G., Pietroiusti M., **Vi**ganotti G., Zonca G.: Breast thermography: an approach to pattern recognition. ***Acta Thermographica,* 1, *183-184,* 1976.**
3. **OOI** H., **MIKI Y.:** Computer analysis of breast cancer thermograms. ***Jap. J. Med. Electron. & Biol Eng. (Japan),* 14, 111-117, 1976.**
4. **Von** Fournier **D.,** Kuttig H., Curland **S., Poser H.:** Auswertung von Thermogrammen mit dem Computer in der Mammarkarzinom Diagnostik. ***Sfrahlentherapie,* 145, 406-414, 1973.**
5. Winter J., Stein M. A.: Computer image processing techniques for automade breast thermogram interpretation. ***Comput. Biomed. Res., 6, 522-529, 1973.***
6. Ziskin M. C., Negin M., Piner C., Lapayowker M. S.: Computer diagnosis of breast thermograms. ***Radiology* 115, *341-347, 1975.***