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Automatic detection of microcalcifications in mammography using a neuromimetic system based on retina

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Abstract

The incidence of breast cancer in France is roughly 26,000 and the annual number of deaths is 11,000. The mammography is the choice examination for the early identification of the tumours in an asymptomatic population. This is a simple, reliable, inexpensive examination, allowing to identify a grave and frequent pathology, but that can be the object of an effective treatment if early detected. Tthe recognition of the microcalcifications in the mammographies is the key for early detection of cancers. Automatic detection methods were already proposed, but they have a very weak specificity and a relatively low sensibility. Currently, the eyeof the expert still remains the better judge.

We propose a neuromimetic method to localize automatically the microcalcifications. In this method, we devise a network of formal neurones inspired from the mammal retina architecture. This model mimics one characteristic of the retina which is is a sensor that automatically adapts to the image characteristics to analyse and realize the outlines extraction and adaptative filtering of the pictures, based on its network properties. The results were tested using a public standardized data set (DDSM), which was designed to test the automatic detection methods. We show that our "retina" can extracts most of the microcalcifications that can be grouped together in clusters. While we achieve a 95% sensitivity, we must acknowledge a low specificity (22%). Current efforts will focus to enhance this latter parameter.

Keywords:

Breast cancer, mammography, neuromimetic method, retina, image processing.

1. Introduction

At the world-wide level, the breast cancer remains the major cause of the women deaths between 40 and 60 years. In France, it is the most frequent of the women cancers. According to a recent report from the ANAES [1], it has an incidence of about 26,000 new cases a year and is responsible of 11,000 deaths a year, with a 5 year survival rate of 71%. The mammography is the choice examination for the early identification of the tumors in an asymptomatic population. The recognition of the early signs (microcalcifications) in mammographies remains one of the difficult issue in the early detection of the cancers [2][3]. The earliest –then smallest– microcalcifications are difficult to visually detect. As effective preventive policies on a large scale would need to process huge number of mammographies, it would be interesting to have an automated method in which no suspect picture could pass unnoticed [4]. Automatic detection methods were already proposed [5]. Currently, the computer techniques were disappointing and the operator eye still remains the better judge. It could therefore be interesting to try a method based on neuromimetic technics mimicking the human eye to attempt to improve such a detection.

Since the end of the years 70, our team is interested by the information processing operated by the nervous structures. In this framework we worked on the modeling of the mammal retina to study the visual information processing by the retinal network [6][7]. We were able to show its ability to extract the outlines and to adapt automatically to the ambient conditions and therefore to automatically maintain the network in the optimum conditions. These properties are used here for the preprocessing of the mammography images and for the automated detection of the microcalcifications. Since the retina realizes a high pass filtering of the images, this is particularly interesting in this case. In fact, the retina is a sensor that automatically adapts to the image characteristics to treat and realizes the outlines extraction and adaptative filtering of the pictures, owing to its network property. We propose here a neuromimetic method inspired from the mammal retina preprocessing of visual information to localize automatically microcalcifications, by using a network of formal neurones inspired from the mammal retina architecture.

2. Material and methods

Material

The mammographies that we used to test the system are from the DDSM (Digital Database for Screening Mammography), a database created on the initiative of the Breast Cancer Research Program of the U.S. Army Medical Research and Material Command. This basis contains currently 2620 cases. The DDSM project is a collaborative effort implying the Massachussets General Hospital, the University of South Florida, and the National Sandia Laboratories [8][9]. It was developed to allow the comparison of the performances of the various methods developed by the researchers working on this problem. This database is accessible on Internet (ftp://figment.csee.usf.edu/pub/DDSM). Each mammography was digitized with a 600 dpi scanner and is a rectangular picture of 1411 to 5311 pixels wide and 3376 to 6871 pixels height. Each pixel is 12 bit depth (4096 levels of gray, from 0, the darkest to 4096, the clearest). A pixel corresponds to a square of 43.5 μm aside on the mammography.

Our case definition, in this study, is a cancer containing one cluster of visible unilateral microcalcifications on the cranio-caudal view. Our initial sample study includes 203 cases with 4 mammographies by case (left and right breasts, cranio-caudal and mediolateral-oblique incidences), i.e. 812 mammographies, 406 with microcalcifications and 406 of undamaged breasts. The set of the 812 mammographies was treated and analyzed. The statistical study of the whole data (not shown) demonstrated that results coming from the two views of a same breast (cranio-caudal and mediolateral-oblique) were highly correlated. Therefore, the final studies were realized on 406 mammographies using cranio-caudal view (203 with microcalcifications and 203 undamaged ones).

Methods

Definitions

In this paper, "event" is a pixel for which one the level value of grey surpasses a given threshold, after the preprocessing realized by the detection systems. "4-related" objects are objects whose 4 sides connect similar objects. "Spot" is a grouping of 4-related events, or an event remained isolated after the determination of the spots. "Alert" is a spot surviving the selection process described below. The "***r***-cluster center" is the pixel at the center of a disc of radius ***r*** (defined below) having a not null intersection with at least ***n*** alerts (***n*** is a parameter of the detection algorithm, see below). We define a "cluster" as a 4-related body of the union of the dilated (by a circle of radius ***r***) centers of clusters. A "DDSM-cluster" is the region delimited by the DDSM as containing one or more groups of microcalcifications.

Finally a "mammography with lesion" is a mammography presenting at least a DDSM-cluster. A "healthy mammography" is a mammography not presenting any DDSM-cluster.

Detection of microcalcifications

The retina model : The microcalcifications detector is composed of five types of cells that form two distinct pathways, inspired from the ON pathway of the mammal retina. The first pathway corresponds to the direct pathway: each pixel from the original image is the input to the "bipolar cell", itself directly connected to the "ganglion cell", the output of the retina. The second pathway corresponds to the indirect pathway, with the "horizontal" and "amacrines" cells. Each horizontal cell receives from several (for example 625 (25x25)) neighbour pixels and inhibits the corresponding bipolar cell (this one here realizes therefore the subtraction between the value of the pixel and the average of the 625 pixels being close to, and adapts therefore to the local average luminosity). Every amacrine cell receives the absolute value of the output of the numerous (for example 32761 (181x181)) bipolar units being close to and inhibits the corresponding ganglion cell (this one realizes therefore an adaptation to the level of local average noise). The horizontal cells calculate the local average of the luminosity, it is a matter of a fuzzy low pass filter. The bipolar cells compute the difference between the value sent back by the horizontal cells and the real luminosity. The whole set generates a high pass filter.

The amacrine and ganglion cells realize the adaptation to the local level of the noise as the horizontal cells calculate the local average of the luminosity. They compute the average of the absolute values of the output of the bipolar cells (on a radius a lot bigger than one of the horizontal cells, but using the same principle). The ganglion cells divide the output of the bipolar cells by the one of the amacrines cells. They allow the system to adapt itself at the local level of noise. The output of the ganglion cells is thresholded, and allows to select the "events" on which subsequent processing will be done, in order to determine the "spots", the "alerts" and finally the "clusters", that are in fact the important elements for the diagnosis.

Event detection: The grey level threshold above which a pixel is considered being an event was determined by a preliminary parametric analysis (see infra). Events were grouped together according to specified rules, allowing obtaining spots. At this point, some isolated events without significance, (for example due to noise) can still persist. In order to eliminate such events, an opening with an element more or less large is realized. This operation is realized after the thresholding and realizes again a low pass filter. Then, 4-related events are grouped in "spots", some of them become "alerts" if they are preserved after the selection operations aiming to conclude that a spot is or no a microcalcification. This selection is based on the computation of the fractal dimension of the local image and on the diameter of the spots. By their nature little noisy and strongly contrasted, non biological artefacts as the edges and eventually the labels or the instrumentations (clips, needles) could cause false alarms and when these are close toghether, they can falsely appear as clusters. Fractal dimension are computed for an 11×11 pixels area from the surrounding 33×33 pixels area to eliminate all spots with a fractal dimension lower than 2, since we determined from our data that they represent non biological structures. Elimination of the spots by their average diameter is based on the fact that the diameter of a microcalcification ranges between 100 μm to 1 mm [10]. Consequently, only the spots with an average diameter between 2.3 pixels (100 μm) and 23 pixels (1 mm) are kept. This preselection reduces the quantity of information, improves their quality and reduce the computation time.

Determination of clusters

Clusters are groupings of microcalcifications, and are predictor of breast cancer. Isolated microcalcifications have no signification. The DDSM labels therefore only clusters, no

individual microcalcifications. We consider that there is a significant grouping around a point if the number of alerts to a distance less than a given radius (***r***) of this point is greater than a given number ***n*** (the two parameters, ***n*** and ***r***, can vary). All the alerts are expanded by a circle of radius ***r*** in order to show the other alarms participating in the detection of the "candidate cluster". The surface delimited by the set of circles of radius r containing at least n alerts is considered as a cluster. This surface is compared to the zone declared as being a cluster by the DDSM. One considers that there has corroborating detection between the DDSM and our system when these two zones have a not null intersection.

Evaluation of results

To evaluate the performances of the detection method of clusters of microcalcifications in the mammographies, sensitivity and specificity were calculated. We used as gold standard the cluster definition of the DDSM: a true positive (TP) is a mammography with lesion in which at least one cluster is detected. One considers as false positive (FP) a healthy mammography in which at least one cluster was detected and as true negative (TN) a healthy mammography in which no cluster was detected.

The sensibility is the percentage of TP in comparison with the number of mammographies with cancer (K for cancer) (Se=TP/K), and the specificity is the percentage of TN in comparison with the number of healthy mammographies (N for normal) (Sp=TN/N). From these values, ROC curves were established for all combinations of parameters of the detection algorithm..

Technical

Implementation of the algorithms was written in C language on PCs running Linux. Breast tissue detouring was performed manually using The GIMP. ROC curves were computed using Scilab.

3. Results

Figure 1 shows a mammography (fig. 1-A), on which the DDSM cluster was correctly detected by the neuromimetic method (fig. 1-D). Moreover, it shows also the different steps of the image processing. It appears clearly from this figure that the "retina" allows to wipe out the noisy background and make the microcalcifications visible, thanks to the horizontal cells, that make contour extraction (fig. 1-B), and to the amacrine cells that perform a local adaptation to the local luminosity that equalizes the background colour (fig. 1-C).

This detection system is based on several parameters (thresholds, number ***n***, radius ***r***, spread of horizontal or amacrine influence) which can be adequately tuned. To guide this tuning, sensibility and specificity can be systematically assessed. A parametric study was performed to determine the best parameter choice. From these values ROC curves representing the joint evolution of specificity and sensibility according to the evolution of a given parameter were systemically built.

Currently, the best results we have obtained indicate a sensibility Se = 94.6% and a specificity Sp = 21.7% (fig. 2). Compared to a currently commercial system (Second Look of CADX Medical Systems), that delivers a sensibility Se = 89% and a specificity Sp = 14% [11], our system presents an improvement. The results presented here are nevertheless preliminary, because the specificity is still too low..

4. Conclusion

Alaylioglu and Aghdasi [12][13] noticed that all the detection systems have the same structures basis. They always begin by a high pass filtering followed by an adaptive

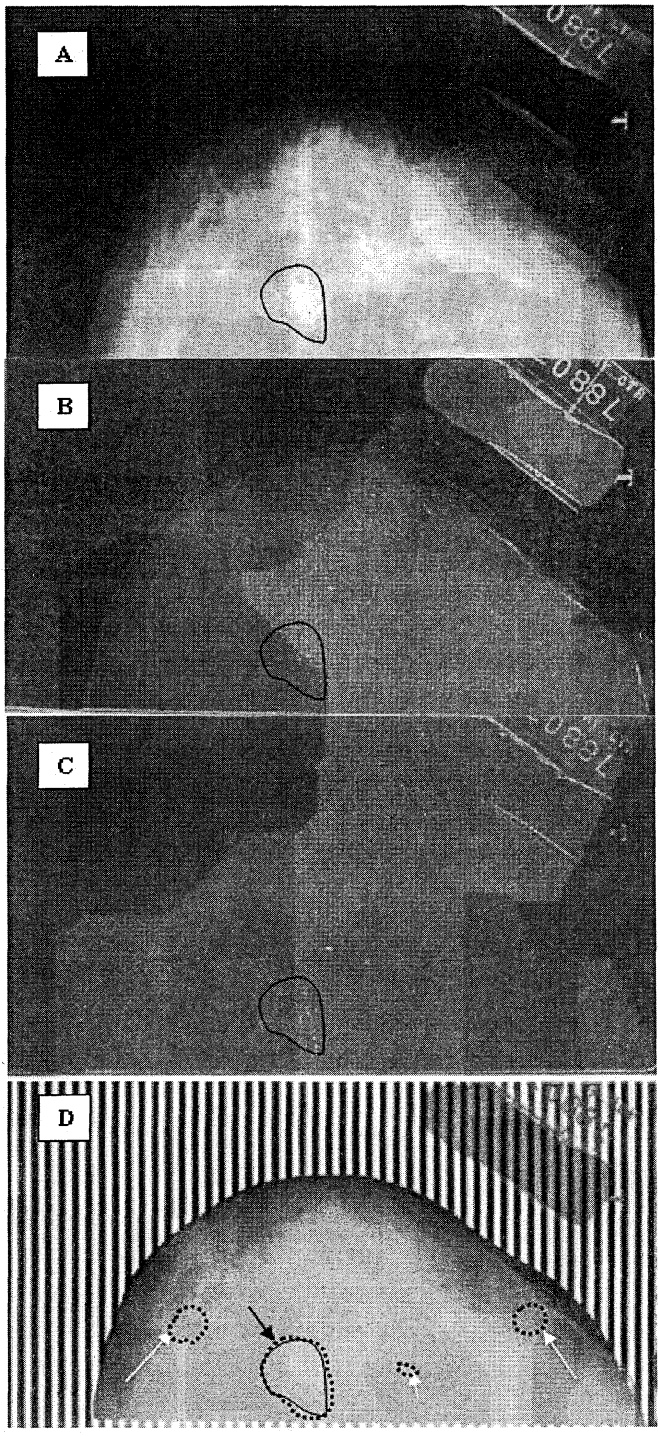

***Figure 1**: The different steps of the automatic processing of a mammography (case A_1578 of DDSM, left breast, cranio-caudal incidence) by the retina. The closed curve indicates the localization of a cluster of microcalcifications as stated by DDSM. It has been reported on all images.*

***A**: original mammographie. Microcalcifications are difficult to dissociate from the very dense background.*

***B**: image obtained at the bipolar level. Microcalcifications are more visible, as well as other lighter images in the breast. Nevertheless it still exists many residual trabeculations.*

***C**: image obtained at the level of the ganglion cells. The background is now not different from the zones outside o the breast, and microcalcifications are now easily visible, thanks to the amacrine units.*

***D**: Automatic detection of clusters, represented by the double pink concentric closed curves. Microcalcifications are small grey dots that we have delimited inside dotted lines. Areas eliminated by the fractal dimensions are dots outside dotted lines. Detection algorithm is performed in the breast, out of the stripped area (manually delimited). Note that the DDSM cluster was correctly detected (black arrow). However 3 other zones (white arrows) among them a very small one (small white arrow) led to false positive.*

thresholding to the local noise and finishes by a clusterization. Optional steps can be added such as a selection of the alarms after the thresholding, a selection of the clusters or a low pass filter before or after the high pass filter to generate a passe band filter that is less

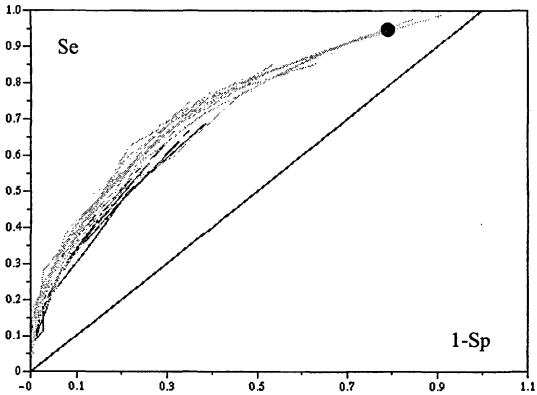

*Figure 2: ROC curves family showing the evolution of sensibility and specificity when the number of microcalcifications **n** varies, for 5 diameters (∅) of influence of Amacrine cells (10 to 50) and 5 diameters of influence of Horizontal cells (2 to 6). The black dot represents the chosen set of parameter (n = 3, ∅H = 6, ∅A = 11).*

sensitive to the noise of digitizing. The developed system during the course of this project does not breach to these rules, but exploits the neuromimetic approach to perform all this work in fewer steps.

5. Acknowledgements

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