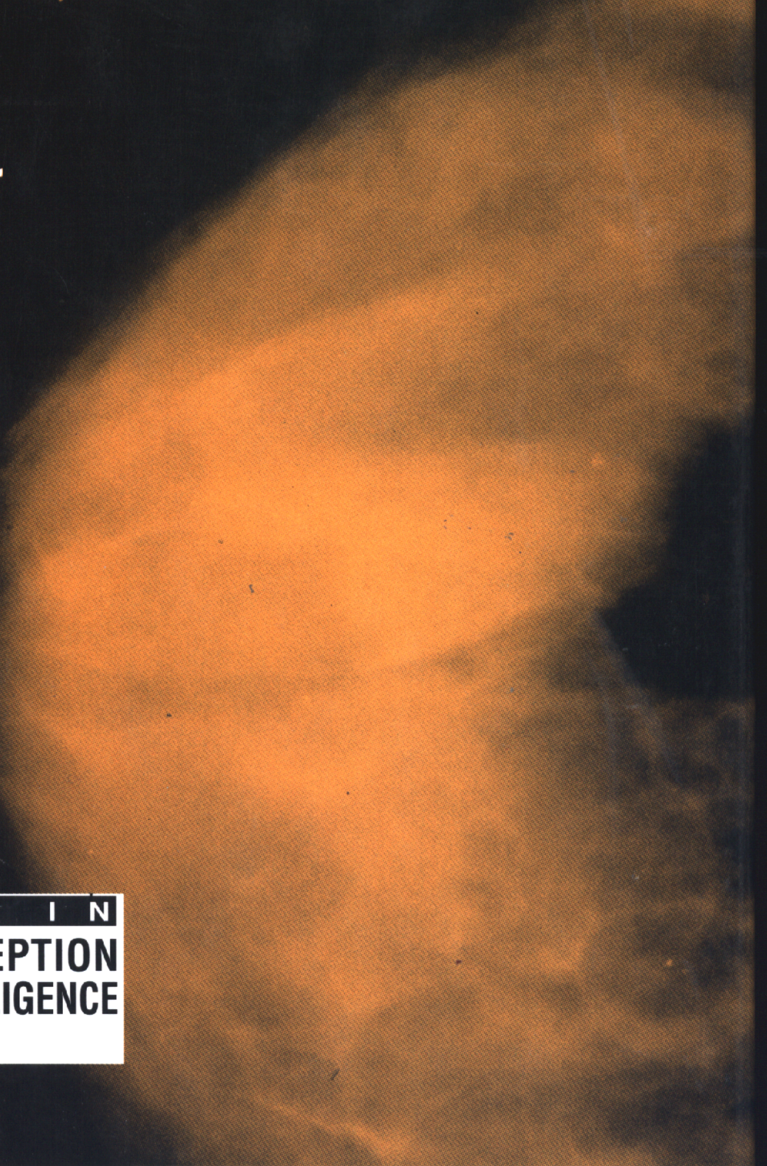
STATE OF THE ART IN

DIGITAL MAMMOGRAPHIC IMAGE ANALYSIS

Edited by

K W Bowyer
S Astley



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DIGITAL MAMMOGRAPHIC IMAGE ANALYSIS

SERIES IN MACHINE PERCEPTION AND ARTIFICIAL INTELLIGENCE

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EDITOR'S INTRODUCTION

The interpretation of medical images is one of the most technically challenging applications of computer vision, largely because of the high degree of variability associated with both normal and abnormal appearances. This special issue focuses on one particularly important problem; the detection of breast cancer in X-ray mammograms. Throughout the western world, where around one in twelve women suffer from breast cancer at some time in their lives, screening programmes based on mammography have been instituted. (Unlike our western Europe counterparts, the U.S.A. does not yet have any national screening program – KB.) Such programmes aim to increase the effectiveness of treatment by identifying sufferers before any tumour becomes palpable. When detected late, the disease carries a high risk of mortality.

Mammographic images are notoriously difficult to interpret. The human breast varies considerably in composition, giving mammographic appearances ranging from relative uniformity to complex patterns of bright streaks or blobs. In screening programmes, the vast majority of images are unequivocally normal, but each image must be carefully searched for any sign of abnormality. Significant features may be small or subtle; malignant microcalcifications, for example, can be detected when they are only a tenth of a millimetre across. There is a considerable body of evidence to suggest that radiologists find the task of interpretation difficult; indeed, in many centers films are studied by two radiologists in an attempt to reduce error rates. Computers could be used to aid the process in a variety of ways, from detecting and prompting specific signs of abnormality to distinguishing between benign and malignant tumours. In recent years there has been rapid progress in computer-aided mammography, with the widespread and serious nature of the problem providing a powerful motivation for those engaged in the research. This progress is reflected in the variety and high standard of the papers in this volume.

This book is the end result of the efforts and considerations of many people. Dmitry Goldgof and Raj Archarya, the co-chairs of the *1993 SPIE Biomedical Image Processing Conference*, were kind enough to allow a substantial portion of the program of their meeting to be filled with papers related to mammographic image analysis. This portion of the meeting informally became the *First International Workshop on Mammographic Image Analysis*, with a total of 28 papers contributed by 25 different research groups in seven different countries around the world. Following the indulgence shown by Dmitry Goldgof and Raj Acharya, Horst Bunke was kind enough to allow a special issue of the International Journal of Pattern Recognition and Artificial Intelligence devoted to selected papers from this meeting. A total of sixteen papers were initially submitted for possible publication in the special issue. The reviewing of most of these papers was handled jointly by Sue Astley in the U.K. and Kevin Bowyer in the U.S. (The reviewing of papers from the University of Manchester group was handled by Prof. Bowyer in the U.S. and the reviewing of papers from the University of South Florida group was handled by Prof. Astley in the U.K.) Based on the reviewers' comments, nine contributed papers were eventually selected to appear in the IJPRAI special issue. Limitations on the space available forced us to omit some papers which merited wider dissemination. Thus the publisher agreed to bring out this book. The book contains an additional five papers not in the special issue, including some which were not originally submitted to the special issue but were solicited by the editors after the presentations at the *1993 SPIE Biomedical Image Processing Conference.*

The papers in this book touch on a variety of different subtopics in mammographic image analysis.

The paper by Astley and co-workers describes a number of experiments performed in Manchester with the aim of identifying the problems, tools, and methods of presenting results that will be of the most value to the radiologist. Results are summarized for detection of microcalcifications, masses, spiculated (stellate) lesions and asymmetry. A comparison is given of radiologist performance (ROC curves) working with and without the benefit of prompting by automated image analysis.

The paper by Magnin and co-workers concentrates on data compression techniques for use in creating a mammography database. The basic method is *Discrete Cosine Transform* (DCT) of block subimages followed by Huffman encoding of the DCT coefficients. The claim is that compression ratios of up to 30 can be achieved without the radiologist being able to discriminate between the original and the compressed/reconstructed image. This paper also describes "SENOBASE", a database available on CD that contains 400 commented digitized mammograms.

The paper by Aghdasi and co-workers deals with deconvolution and image smoothing filters for mammograms images. The authors point out that the literature specific to mammogram images has generally just considered smoothing and enhancement techniques and not also deconvolution techniques.

The paper by Hajnal and co-workers deals with a proposed procedure to automatically separate the flow of images through a screening program into "fatty" and "dense" categories, with the motivation being that the more difficult images to read could be given to a more experienced reader or allocated more time.

The paper by Nishikawa and co-workers gives an overview of the work done by the University of Chicago group, which has an established history of pioneering work in mammographic image analysis. This paper discusses approaches to detection of clustered microcalcifications, detection of breast masses and classification of breast masses. Performance results are presented as ROC curves.

The paper by Barman, Granlund and Haglund proposes a framework for *wavelets* oriented analysis of mammograms. (Several papers related to the use of wavelets techniques were presented at the workshop.) The authors explain the wavelets approach and present some results for detection of clusters of microcalcifications. Results are given as performance points; that is, Receiver Operating Characteristic (ROC) curves are not generated for the technique.

The paper by Karssemeijer brings together and updates his various previous results in the area of mammographic image analysis. One element of his approach is an algorithm to rescale mammogram images so that noise levels are equal at all intensities. Another part is a *Markov random field* model applied to detect clusters of microcalcifications. Results are given as FROC curves, using a test set of 40 images and a training set of 25 images.

The paper by Chitre, Dhawan and Moskowitz describes a method for classifying microcalcifications into benign and malignant categories. The approach does not require image segmentation; an already (hand) segmented cluster of microcalcifications is classified as either benign or malignant. *Second-order histogram* statistics are extracted and used for classification by a neural network.

Shen, Rangayyan and Desautels have also tackled the detection and classification of microcalcifications. In their paper they describe a detection method based on *multi-tolerance region growing.* A variety of shape measures are computed, and a neural network is employed for classification of detected microcalcifications into benign and malignant categories. Classification rates are presented for a range of different classifiers.

The detection of microcalcifications has also been addressed by Woods and co-workers. Candidate microcalcifications are segmented on the basis of local brightness, and classified into microcalcification and non-calcification categories. Several features were evaluated, and the most powerful were used to compare classifiers both for the detection of individual microcalcifications and for the detection of clusters. Results are given as ROC curves for linear and quadratic classifiers, a binary decision tree, several different neural networks and a k nearest neighbor method.

The paper by Brzakovic and Neskovic develops an approach to mammographic image analysis called *fuzzy pyramid linking*. The technique can be applied to the detection of both microcalcifications and masses. The "pyramid" data structure reflects an explicit multiresolution analysis of the image. The "fuzzy" part indicates that classification is done by carrying through a "degree of membership" until a final step when the result is "crispened" and a decision made. The linking in the pyramid gives some adaptive local flavor to the processing. Performance is given as point results (no ROC curves).

The paper by Parker and co-workers concentrates on development of a classifier to distinguish between comedo and non-comedo *Ductal Carcinoma In Situ*. Calcifications are hand-labelled in a set of images. A large number of possible features are considered for use with a general k nearest neighbor classifier. Results are given in the form of ROC curves.

Miller and Astley present results of a method to detect abnormalities by assessing the degree of asymmetry between left and right breasts. They first segment the breast images on the basis of texture to identify non-fat regions, and then compare shape, grey-level and topological properties of these regions to identify potential abnormalities. Results of the segmentation procedure (ROC curves), and of classification of mammogram pairs both into normal and abnormal categories and into specific abnormality groups, are shown.

The paper by Kegelmeyer focuses on development of an approach for automated detection of stellate lesions. Rather than segmenting regions of the image and then computing properties of the segmented regions, as the other papers do, Kegelmeyer computes properties for a window around every pixel to find "stellate-ness" for each pixel and then groups pixels with high stellateness. The features used to measure stellate-ness are *Laws' texture energy measures* and the *analysis of locally oriented edges* (ALOE) measure developed by Kegelmeyer. A binary decision tree is used as the classifier and results are presented as ROC curves.

Lastly, the paper by Etta Pisano and Faina Shtern is a special treat. Doctors Pisano and Shtern give us a perspective on this field of research from the point of view of the practicing M.D. who reads mammogram studies in a clinical setting. We are fortunate that they have been willing to take the time to consider the work in this area and give us the benefit of their experience and insight.

We would like to extend our sincere thanks to all of the people who contributed to making this special issue happen. We hope that the readers will find the papers interesting and that some readers will even be stimulated to begin research work in this very important area.

Finally, we are pleased to announce the *Second International Workshop on Mammographic Image Analysis*, which will be held at the Royal York Hotel in York, England, from 10th to 12th July 1994. Further information can be obtained from Prof. Alastair Gale, the Applied Vision Research Unit, University of Derby, Derby DE3 5GX; Fax: +44 332 514323; email: a.gale@uk.ac.derby.

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