Mammographic Image Analysis

Computational Imaging and Vision

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PREFACE

Breast cancer is a major health problem in the Western world, where it is the most common cancer among women. Approximately 1 in 12 women will develop breast cancer during the course of their lives. Over the past twenty years there have been a series of major advances in the management of women with breast cancer, ranging from novel chemotherapy and radiotherapy treatments to conservative surgery. The next twenty years are likely to see computerized image analysis playing an increasingly important role in patient management.

As applications of image analysis go, medical applications are tough in general, and breast cancer image analysis is one of the toughest. There are many reasons for this: highly variable and irregular shapes of the objects of interest, changing imaging conditions, and the densely textured nature of the images. Add to this the increasing need for quantitative information, precision, and reliability (very few false positives), and the image processing challenge becomes quite daunting, in fact it pushes image analysis techniques right to their limits.

There are many stakeholders in the search for better ways to detect tumours and manage patient care. Most important are the teams of clinicians, typically comprising a radiologist, a surgeon, and a pathologist. They, in turn, rely on medical technicians and radiographers, medical physicists, and, increasingly, medical image analysts. Future developments mostly come from researchers and students (who first have to learn the basics of the subject effectively). Finally, women act as subjects and volunteers, and more and more want to be informed about the nature of their disease and the decision making process that concerns their well-being. Though we are image analysts, we have tried to write this monograph so that the ideas can be accessed by the widest possible range of stakeholders. To this end, we have tried to keep mathematical detail in boxes independent of the text and put in plenty of examples. So, if the going gets tough occasionally, please don't give up!

Many of the ideas described in the monograph originally appeared in journal articles written over a period of nine years, though we have discovered a lot of new material during the course of writing this monograph. We embarked on the roller-coaster ride that is writing a monograph because we

wanted to promote two themes that underpin all of our work and which can only be described episodically in any single article. First, we believe that the high levels of reliability demanded of mammographic image analysis inevitably imply the development of techniques that are specific to mammography, irrespective of whether it is based on x-ray, magnetic resonance imagery (MRI), ultrasound, nuclear medicine, or any other imaging modality. We interpret this as meaning that it is necessary to base our algorithms on a set of detailed, explicit models: of image formation, of contrast agent take-up, of anatomy, and of pathology. Part I of the monograph develops such a model-based approach to x-ray mammography, Part II shows how it can be exploited, while Part III develops a model and exploits it for contrast-enhanced MRI mammography.

Second, the key contribution of our approach to x-ray mammographic image analysis is the development of a representation of the non-fatty compressed breast tissue that we show can be derived from a single mammogram. The importance of the representation, which we call h_{int}, is that it removes all those those changes in the image that are due only to the particular imaging conditions (for example, the film speed or exposure time), leaving just the non-fatty "**int**eresting" tissue. Normalising images in this way enables us to enhance them, match them, and classify regions in them more reliably, because unnecessary, distracting variations have been eliminated. We show how the h_{int} representation can be developed in Part I, then put it to work on a range of clinically-important tasks in Part II.

This monograph has had a long gestation period, partly because we have made numerous discoveries while writing it, and partly because the subject is in a period of rapid development. One of the more pleasant tasks for the authors is to thank publicly the many people who have helped us realise this monograph and the ideas that it promotes. First, the UK Engineering and Physical Sciences Research Council funded RPH as a doctoral student and subsequently as a post-doctoral researcher, and awarded JMB a Senior Research Fellowship for five years and funded his major project on mammography. Max Viergever encouraged us to write the monograph and remained patient long after our estimated finish date. RPH thanks Philips Laboratories for the six month sabbatical he spent there, and in particular Charles Carman. JMB thanks Nicholas Ayache, the members of Project Epidaure and INRIA for hosting two stays on the Côte d'Azur that changed his life in many ways. We thank the staff of the Breast Care Unit at the Churchill Hospital, Oxford for their continuing support over many years, particularly Basil Shepstone, Ruth English, Yvonne Swainston, Wendy Hills, Hazel Bailey, Sue McDougal, June Pickvance, Coral James, Jane Cobb, Janet Green, Liz Robinson, Lorriane Tucker, Christine Cherry, Jan Lougher, Betty Harvey, Lettice Bowen, Geraldine Ashworth,

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Finally, JMB dedicates this monograph to the memory of his wonderful mother-in-law, Dr. Irene Friedlander, whose untimely death from breast cancer was the spur for his research in mammography.