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# Synopsis

## Biomedical Imaging

Biomedical imaging, in one form or another, pervades virtually all of clinical medicine. One may define biomedical imaging as the process of acquiring and/or processing a picture of some part of a biological entity. The field is intimately connected with a variety of sophisticated technologies because it is via these technologies that many of the biomedical images that we take for granted are acquired. Some of the most widely applied technologies include ultrasound (commonly used for example in fetal assessment), xray (the standard tool for the initial assessment of musculoskeletal trauma), computed tomography (CT – widely regarded as the workhorse imaging system in many hospitals) and magnetic resonance imaging (MRI – typically slower than CT, but can often provide more image detail in certain organs). Other newer technologies can also be considered to be part of the biomedical imaging field, for example magnetoencephalograghy, which gives a "picture" of the currents within the brain, and even gene microarray analysis, which gives a "picture" of a persons' genetic makeup. Biomedical imaging (in contrast to the narrower field of medical imaging) also includes such procedures as confocal microscopy, electrical mapping and immunofluroescence. Depending on how broadly one interprets the meaning of the word "picture" or "image" the standard electrocardiogram (ECG) can also be regarded as one form of biomedical imaging, since it yields an image of the electrical activity of the heart, albeit it a highly filtered and low spatial resolution image.

The field of biomedical imaging dates back more than 100 years. In 1895, Wilhelm Conrad Roentgen (1845-1923) was experimenting with cathode rays. In particular he was trying to determine what objects such rays could travel through (at the time he postulated that he was dealing with some unknown type of radiation, hence his naming them x-rays). In his now famous experiment, he directed the rays at his wife's hand on top of a photographic plate (exposing it for a total of 15 minutes), and obtained the well known image of the bones of Bertha Roentgen's hand, complete with an outline of her ring. Roentgen's work in this field led to him being awarded the first Nobel prize in physics in 1901. Xray machines began appearing in hospitals in the early 1900s with one of the main uses of these first generation machines and images being in the early detection of tuberculosis.

The parallel development of ultrasound technology can arguably trace its roots back to Pierre Curie who introduced simple echo sounding methods in 1880, which led to the discovery of Sonar. However, it was not until after World War II that modern ultrasound was developed. A period of rapid development of this type of imaging occurred in the 1960s, with the first fetal ultrasounds scans being performed late that decade. Today ultrasound is routinely used throughout the world, and has found widespread use in, for instance, the field of cardiology.

The principles of magnetic resonance were first investigated in 1950s. This followed the first successful nuclear magnetic resonance (NMR) experiments in 1946, which were conducted independently by two people in the US (Felix Bloch and Edward Purcell – who were both awarded the Nobel prize for physics in 1952). The first clinical MR imaging machines were tested in 1980, and in 1984 the US Federal and Drug Administration gave approval for the clinical use of MRI, opening the way for the widespread introduction of the technology in the USA. The awarding of the 2003 Nobel prize in physiology or medicine to Paul Larterbur and Sir Peter Mansfield "for their discoveries concerning magnetic resonance imaging" and the 2003 Nobel prize in physics to A.A.Abrikosov, V.L.Ginzburg and A.J.Leggett for pioneering contributions to the theory of superfluids and superconductors (which are for example used in magnetic resonance imaging) reinforces the widespread impact and importance of MRI. The other common clinical imaging modality routinely used for examining soft tissue, namely CT, was invented in 1972 by Godfrey Hounsfield who also received a Nobel prize for his work.

The fast, frequent and widespread acquisition of images via these various technologies mentioned above has led to new medical specialisations. While the extraction and interpretation of some features of the images are relatively straightforward (e.g. is the bone broken?) others can be much more challenging. With the continual improvement in spatial and temporal resolution, it is appropriate in many situations to consider investigating the temporal dynamics of volumetric features included within image sets, and to seek to determine the normality or otherwise of these features. This can be an extremely difficult task - automatic image segmentation and specialist feature extraction methodologies are often required. To reinforce this, the three papers chosen for this section all involve some aspect of automatic segmentation and/or classification of MR images. To maintain perspective on this issue one should note the following quote of McInerney et al [1]: “completely automatic analysis of all data sets may be an unrealistic goal, even in the long term”. Rather, the short to mid-term goal should be highly automated processing of various image sets allowing for varying degrees of human intervention.

Before commenting on each paper, it is worth noting here that despite the fact that the various imaging modalities mentioned above use very different technologies to obtain their respective image sets, once the images have been obtained, the issues involved with segmenting them and extracting appropriate features are fairly generic. Thus, although the papers of this section all deal with MRI data sets, the work described in these papers has much wider applicability.

The paper of Frangi et al [2] deals with the problem of constructing three dimensional shape models from a series of MR images. The particular application chosen was that of determining an average cardiac shape from a set of images taken from a range of apparently normal individuals. The heart is a particularly difficult organ to attempt to use for this application. When constructing and comparing shape models between individuals, the use of consistent landmarks are vital for appropriate comparisons. There are relatively few anatomical landmarks that can be used for such purposes on the ventricles of the heart, so the authors have developed a set of pseudo-landmarks. The process described in the paper uses manual segmentation of a given patients’ short axis MR images, and automatically landmarks these images. This allows an average model of the 14 individual hearts to be created from which one can examine the 3D shape variability. The paper provides a proof of concept for using such a process on the heart. The important implications are not only that such statistical shape models can be a useful aid in improving image segmentation, but also that given a good statistical shape model one can perhaps infer the likelihood of a given set of MR images being from a “normal” heart. The surface shape models and their set of pseudo landmarks also open up the possibility of inferring internal myocardial deformations, hence local strains. Such features may be useful clinically in determining for instance the regional performance of heart tissue.

The paper of McInernery et al [1] provides a new approach to the automatic image segmentation problem. It introduces the concept of a “deformable organism”, which possesses both a deformable body and a set of distributed sensors. The authors’ aim is to use both local and global features of an image set to aid in the segmentation. Thus, local features of the image, for instance grey scale intensity of the pixels, can be used to determine immediate boundaries between different structures, while high level features incorporating for example pre-stored anatomical knowledge of the regions of interest, provide higher level control of the organism. The performance of this organism concept is demonstrated using the corpus callosum in a variety of 2D mid-sagittal MR brain images. This particular part of the brain serves as the primary means of communication between the two cerebral hemispheres and morphological differences in this region have been implicated in schizophrenia, amongst a number of other disorders. The progressive growth and deformation of a “corpus callosum deformable organism” is excellently illustrated in several figures of [1]. The results show that such an approach could be a useful aid in image segmentation.

The third paper in this section focuses on the clinical application of 3D shape models to MR images of the brain. In particular, the authors focus on the amygdala-hippocampal region of the brain, and use 3D shape models to examine inter- and intra-patient volume and shape variability in patients diagnosed with schizophrenia and normal comparison subjects. In contrast to the previous two papers, where the focus was on procedural and algorithmic development, the major focus of this paper is the use of shape models to provide clinically relevant differentiations between normal and schizophrenic patients. The datasets used for this study are relatively old – the MR images having being obtained on or before 1992. These image sets have been analyzed previously, but are now being subjected to further analysis; in particular, attention is being focused on shape variations. The findings are very promising – combining both shape and volumetric features allows 87% of the cases considered to be correctly classified, whereas using volumetric features alone provides only 70% accuracy. Without using some sort of model constructed from the images, it is virtually impossible for medical personnel to give an objective diagnosis using such features as shape and volume, particularly if the changes are subtle. This paper thus provides a valuable illustration of the sort of potentially useful information contained in existing image sets that can still be usefully extracted and utilised.

The papers reviewed in this synopsis represent just a very small subset of those published in the biomedical imaging area. Despite the massive technological developments occurring in the field of biomedical imaging, and the accolades that those responsible for such developments are receiving, it is perhaps appropriate that the papers in this section all deal with image segmentation and feature extraction. Without developments in these areas to rival the technological developments in image acquisition, much of the useful clinical information contained within high resolution dynamic imaging sets may not be realized.

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