Chapter XVII
Developments and Advances in Biomedical Functional Infrared Imaging

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ABSTRACT

This chapter presents an overview on recent developments in the field of clinical applications of the functional infrared imaging. The functional infrared imaging is a relatively recent imaging methodology introduced for the study of the functional properties and alterations of the human thermoregulatory system for biomedical purposes. The methodology is based on the modeling of the bio-heat exchange processes and the recording of thermal infrared data by means of advanced technology. Some innovative applications of functional infrared imaging to diagnostics, psychometrics, stress measurements and psycho-neurophysiology will be presented, with special emphasis to the potentialities and the capabilities that such technique may bring to biomedical investigations.

INTRODUCTION

Objects are characterized by a variety of physical parameters such as shape, weight, and size. However, one of the most frequently measured physical properties is temperature. Temperatures may be measured with either a contact or non-contact device. The thermal infrared imaging systems create electronic picture of the scene. Such non-contact systems allow the representation of the surface thermal distribution of an object by detecting the thermal infrared emission spontaneously emitted by the object itself. Early use of thermal infrared imaging in medicine dates back to early ‘60s. Several studies have been performed so far to assess the contribution that such information may provide to the clinicians. The physiological basis for using thermal infrared imaging in medicine is
the fact that the skin temperature distribution of the human body depends on the complex relationships defining the heat exchange processes between skin tissue, inner tissue, local vasculature, and metabolic activity. All of these processes are mediated and regulated by the sympathetic and parasympathetic activity to maintain the thermal homeostasis. The presence of a disease may affect both at a local or systemic level, the heat balance or exchange processes, resulting in an increase or a decrease of the skin temperature. Therefore, the detection of skin temperature abnormalities may provide diagnostic criteria for a variety of diseases interfering with the regular control of the skin temperature.

Unfortunately, such a simplistic approach, combined with early and not enough mature technology, did not provide adequate and effective results for supporting routinely use of thermal infrared imaging in diagnostics. Therefore, thermal infrared imaging has been substantially discarded as a diagnostic tool until the middle ‘90s.

At the beginning of ‘90s, the evolution of technological advances in infrared sensor technology, image processing, computer architecture, knowledge-based databases, and their overall system integration has resulted in new methods of research and use in medical infrared imaging. The development of infrared cameras with focal plane arrays added a new dimension to this imaging modality (Roganski, 2002). New detector materials with improved thermal sensitivity are now available and the production of high-density focal plane arrays (up to 640 x 480) has been achieved. Read-out circuitry using on-chip signal pre-processing is now in common use. These breakthroughs led to the availability of commercial and user-friendly camera systems with thermal sensitivity less than 30 mK (20 mK for nitrogen cooled cameras), as well as spatial resolution of 25-40 microns, given the appropriate optics. Furthermore, time resolution has been greatly improved, being now possible to acquire up to 100 full frame images per second (Bronzino, 2007).

The last-generation camera systems allow effective monitoring and studying the dynamics of the local control of the skin temperature and in which manner diseases or external stimuli may influence it (Diakides, 2002). This means that the characteristic parameters modeling the activity of the skin thermoregulatory system can be retrieved and used as quantitative and effective diagnostic parameters (Merla, 2002). Therefore, modeling the activity of the skin thermoregulatory system can provide specific parameters from which to infer diagnostic criteria (Merla, 2007).

As a consequence, there is an emerging interest in the development of smart image processing algorithms and bio-heat transfer models to enhance the interpretation of thermal signatures. In the clinical area, new researches are underway to achieve quantitative clinical data interpretation in standardized diagnostic procedures and protocols (Diakides, 2002).

In the past 10 years, significant progress has been made internationally by advancing a thrust for new initiatives worldwide for clinical quantification, international collaboration, and providing a forum for coordination, discussion, and publication. As a result of this process, three IEEE Engineering in Medicine and Biology Magazines, Special Issues dedicated to biomedical thermal imaging have been published (Diakides, 1998, 2000, 2002) in addition to a growing number of papers published on top international medical journals.

Developments of new quantitative approaches and methods in modern thermal infrared imaging have been proposed to re-visit classical applications of thermal imaging in medicine. The approaches so far proposed include among the others: quantitative active dynamic thermal-IR imaging (Novakowsky, 2007), dynamic thermal assessment (Anbar, 2007), advanced image processing (Wieck, 2007). Even early detection of breast cancer by means of thermal imaging based