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Theoretical Assessment of Electro-Thermal Imaging: A New Technique for Medical Diagnosis

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Abstract—**Breast cancer is one of the most crucial cancer types. To improve the diagnosis performance, a hybrid system is proposed through simultaneous utilization of thermal and electrical impedance imaging methods. The innovation of the approach relies on the frequency dependence of the tissue's electrical impedance which facilitates the acquisition of multiple thermal images with currents at different frequencies injected to the region of the body under inspection. The applied current and the resulting heating at the body surface are distributed based on the frequency dependent conductivity distribution. The electrical currents increase the thermal contrast on the body surface depending on the electrical properties of the tissues at the operation frequency. The technique also provides frequency dependent conductivity distribution data through thermal imaging which can be used as a basis for the detection of the breast carcinoma. Based on our findings, the contrast resolution between the healthy and cancerous tissue is increased, improving the depth-dependent imaging performance from 3 mm to 9 mm for a 1.5 mm tumor. The sensitivity of the technique can be further increased by an infrared camera with dual band imaging capability. Consequently, the proposed approach has a potential to improve the sensitivity and accuracy of medical imaging over the standard thermography.**

***Index Terms*—medical diagnostic imaging, thermal imaging, active thermography, breast cancer detection.**

I. Introduction

Mammography, ultrasound imaging and magnetic resonance imaging (MRI) are imaging modalities that are used for the diagnosis of breast carcinoma [1]. However, these techniques have some limitations. While alternative imaging modalities, like electrical impedance tomography (EIT) and infrared thermography have been investigated for this purpose [2-3], their performances in breast carcinoma diagnosis are also limited [4-5]. In order to improve the diagnostic performance, we propose a hybrid imaging modality through simultaneous utilization of these two alternative techniques. We call this modality *Electro-Thermal Imaging*. In this paper, we first discuss the basic limitations of the existing modalities, and then provide a theoretical assessment of the potential of the proposed hybrid technique.

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Mammography has accuracy problems especially for small tumors, and it is not comfortable for patients [6]. Statistical studies show that there is 4-34 % false negative ratio in mammography [7]. Furthermore, exposure of the patient to ionizing radiation (X-ray) is potentially harmful for the human tissue [7]. Ultrasound is another important imaging method that is used to screen the breast [1]. However, this technique has poor performance in detecting micro formations and monitoring deep regions of the breast [8]. Magnetic resonance imaging (MRI) is also used for imaging breast tissues; but it is usually employed as a complementary tool instead of being utilized as a sole screening method [9]. Although MRI is more sensitive than mammography, it has potential for a high false-positive rate which may result in unnecessary biopsies [9]. In addition, this technique may not be the first choice by the patients due to the relatively long data acquisition time. Consequently, there is no gold standard in detecting cancerous tissue in the breast. In order to minimize errors in diagnosis, multi-modal techniques are proposed that employ more than one technique complementing each other [10].

In applied current EIT, the electrical properties of the tissues are used for diagnosis [3]. The current applied on the surface of the tissue has the highest intensity beneath the current drive electrodes, and focusing on the desired body location is relatively difficult. Consequently, the desired amount of signal cannot be provided from the inner regions of the body [4]. In addition, the number of measurements is limited by the number of current drive electrodes resulting in low-resolution images [3].

Infrared (IR) imaging is another technique that may be used for breast cancer diagnosis [8]. In IR imaging, the radiation (self-emission) from the body is sensed by an infrared camera to display the temperature distribution [11]. Several studies report infrared imaging as an important risk marker [2], [12]. IR imaging gives information about metabolic activity and tumor induced angiogenesis instead of structural knowledge such as the size of the tumor and micro calcifications [11]. It may also show indications before the development of breast cancer, unlike other imaging modalities. A conventional thermogram denotes the vascular or minimally vascular temperature distributions without localized heat abnormalities. Abnormal mammograms have significantly localized vascular patterns and cause 3 °C temperature elevation above the surrounding tissue temperature [13]. Abnormal breast thermogram due to vascular, neuronal or systemic disorders shows a significant risk indicator for the breast cancer. Tumor tissue usually includes a highly vascularized structure causing apparently higher local skin temperature that may be several degrees hotter than the background tissue [14]. Thermal image