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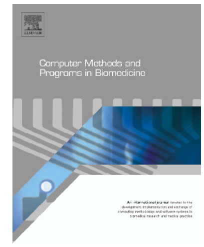

Hybrid analysis for indicating patients with breast cancer using temperature time series

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ABSTRACT

Breast cancer is the most common cancer among women worldwide. Diagnosis and treatment in early stages increase cure chances. The temperature of cancerous tissue is generally higher than that of healthy surrounding tissues, making thermography an option to be considered in screening strategies of this cancer type. This paper proposes a hybrid methodology for analyzing dynamic infrared thermography in order to indicate patients with risk of breast cancer, using unsupervised and supervised machine learning techniques, which characterizes the methodology as hybrid. The dynamic infrared thermography monitors or quantitatively measures temperature changes on the examined surface, after a thermal stress. In the dynamic infrared thermography execution, a sequence of breast thermograms is generated. In the proposed methodology, this sequence is processed and analyzed by several techniques. First, the region of the breasts is segmented and the thermograms of the sequence are registered. Then, temperature time series are built and the k-means algorithm is applied on these series using various values of k. Clustering formed by k-means algorithm, for each k value, is evaluated using clustering validation indices, generating values treated as features in the classification model construction step. A data mining tool was used to solve the combined algorithm selection and hyperparameter optimization (CASH) problem in classification tasks. Besides the classification algorithm recommended by the data mining tool, classifiers based on Bayesian networks, neural networks, decision rules and decision tree were executed on the data set used for evaluation. Test results support that the proposed analysis methodology is able to indicate patients with breast cancer. Among 39 tested classification algorithms, K-Star and Bayes Net presented 100% classification accuracy. Furthermore, among the Bayes Net, multi-layer perceptron, decision table and random forest classification algorithms, an average accuracy of 95.38% was obtained.

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1. Introduction

Breast cancer has become one of the most horrifying experiences in women's health nowadays. It is the most common cancer among women worldwide accounting for about 30% of all cases. However, when identified and treated in early stages, this cancer type has relatively good prognosis. Screening is a strategy adopted by health authorities in order to identify women who are at initial stages of this breast disease. However, all types of examinations, including mammography, considered the gold standard for cancer detection, have limitations such as high false positive classification rate, insufficient effectiveness in dense breasts and using ionizing radiation. Since cancerous tissue temperature is generally higher than healthy surrounding tissues, thermography has been considered a promising screening method for breast cancer detection, by generating images that reveal the heat distribution on the skin surface [1–3].

The temperature time series analyzed in this work are generated from dynamic infrared thermography (DIT), which is a method for monitoring the dynamic response of the skin temperature after thermal stress. The most common thermal stress type is cooling using an electric fan, where air flow is directed to the skin [4]. The cooling of the breasts, theoretically, improves the thermal contrast between healthy and unhealthy tissues, because blood vessels promoted by cancerous tumors do not have muscular layer and neither neural regulation like embryological vessels [5]. These vessels are only endothelial tubes and therefore they do not contract in response to sympathetic stimulation. Because of this, the temperature in the tumor region remains almost unchanged, whereas the temperature in healthy regions is significantly modified when thermal stress is applied [5]. When compared to static infrared thermography (SIT), DIT is faster and more robust. SIT requires rigid environmental conditions and significantly long time for acclimatization of the patient to examining room conditions. On the other hand, DIT is much less dependent on the condition and temperature of the examining room [6].

We propose in this paper a new hybrid breast DIT analysis methodology in order to indicate patients with risk of breast cancer, using unsupervised and supervised machine learning techniques, which characterizes the methodology as hybrid. Examination systems based on this methodology could assist in breast cancer screening programs, without replacing currently existing tests. Patients with any abnormality in the breast detected by the proposed methodology, would be forwarded to other tests for a more careful investigation. This could help in the rational use of mammography, especially in developing countries, where access to mammography is not fully available to the poor population.

Thermal images of patients of the Antonio Pedro University Hospital (HUAP), available at the Database for Mastology Research with Infrared Image – DMR-IR [7], were used to evaluate the proposed methodology. The image sequence generated by DIT is processed in order to generate the temperature time series of both breasts, which are then clustered by k-means algorithm [8]. The formed clusters of temperature time series are evaluated by clustering validation indices, such as Silhouette [9], Davies–Bouldin [10] and Calinski–Harabasz [11]. The values generated by calculating these indices are treated as features and submitted to a feature selection step. Lastly, the patient is classified between sick or healthy, having the selected features as input. In the proposed methodology, the detection of a suspicious region (or more) is independent of its location in the breast. The main goal of the methodology is just indicate if the patient has risk of having cancer or not.

In the evaluation of the proposed methodology, the Auto-WEKA [12] data mining tool was used to solve the combined algorithm selection and hyperparameter optimization (CASH) problem in classification tasks [12]. Beyond the classification algorithm recommended by the data mining tool, classifiers based on Bayesian networks, neural networks, decision rules and decision tree were executed on the data set used for evaluation. Test results support that the proposed hybrid analysis methodology is able to indicate patients with breast cancer. Among 39 tested classification algorithms, K-Star and Bayes Net showed 100% classification accuracy. Furthermore, among the Bayes Net, multi-layer perceptron, decision table and random forest classification algorithms, an average accuracy of 95.38% was obtained.

The remainder of the paper is organized as follows. In Section 2, some important related works are discussed. The methodology proposed in this work is detailed in the third section. In Section 4, tests and results are presented and discussed. Conclusions are the subject of the last section.

2. Related work

An updated survey on general breast thermography, as well as its classification, is presented in Borchartt et al. [4]. In [3] Etehadtavakol and Ng discuss recent research achievements in medical thermography with concerns about the possibility of early breast cancer detection. Other interesting and recent works are described in [13–15]. However these works analyze images generated by SIT. Thus, we present here a review of works that analyze only images generated by DIT. The works reported in this section are in chronological order, highlighting the evolution of this examination type over the years.

In Ohashi and Uchida's works [16,17], in 1997 and 2000, respectively, a thermogram sequence is captured with interval of 15 seconds between images. A breast is cancerous if it presents, what the authors defined as a decision criterion, a positive heating pattern in the thermogram sequence. However, this criterion lacks details in the text. Apparently, the image analysis is performed visually, because no computational method is reported. The tests were conducted with images collected between 1989 and 1994 of 728 patients. The true positive rate exceeds 80%, but the false positive rate exceeds 40%.

Anbar et al. [18], in 2000, stated that is possible to locate areas on the surface of breast exhibiting abnormal low temperature modulation. The skin surface area of the breast is divided into small regions (2×2 pixels). The temperature of each of these region is accompanied in the 2024 thermograms acquired in sequence, yielding the time series. The spatial distribution of the temperature modulation amplitudes of each of these regions is represented on a map of multicolored bits.