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Review Article

Comparative assessment of texture features for the identification of cancer in ultrasound images: A review

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ABSTRACT

In this paper, we review the use of texture features for cancer detection in Ultrasound (US) images of breast, prostate, thyroid, ovaries and liver for Computer Aided Diagnosis (CAD) systems. This paper shows that texture features are a valuable tool to extract diagnostically relevant information from US images. This information helps practitioners to discriminate normal from abnormal tissues. A drawback of some classes of texture features comes from their sensitivity to both changes in image resolution and grayscale levels. These limitations pose a considerable challenge to CAD systems, because the information content of a specific texture feature depends on the US imaging system and its setup. Our review shows that single classes of texture features are insufficient, if considered alone, to create robust CAD systems, which can help to solve practical problems, such as cancer screening. Therefore, we recommend that the CAD system design involves testing a wide range of texture features along with features obtained with other image processing methods. Having such a competitive testing phase helps the designer to select the best feature combination for a particular problem. This approach will lead to practical US based cancer detection systems which deliver real benefits to patients by improving the diagnosis accuracy while reducing health care cost.

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1. Introduction

In 2015, heart diseases were the leading cause of death in the United States and cancer was the second leading cause of death. It is predicted that the order will reverse in the future [1]. Therefore, cancer is a big and growing public health problem [2]. Table 1 lists public health data from the American cancer society [3]. It shows both the estimated new cases and the estimated deaths for ovarian, liver, thyroid, breast and prostate cancers. These cancers contribute 34.64% of all the estimated new cancer cases and they are responsible for more than 18.48% of cancer related deaths. In terms of public health, the problem can be partitioned into cancer prevention, diagnosis and treatment. Cancer prevention is possible, because healthy lifestyle choices lower the risk for developing cancer. The link between lifestyle choices and cancer was discovered by studies which showed that cancer rates of migrants move towards the rate measured in the indigenous population [4,5]. Smoking, consumption of calorie dense food and reproductive behaviors are also known to increase the risk of getting cancer [4].

Table 1 – Estimation of the number of new cases and death for selected cancers in the United states, 2015 [3].

Cancer type	Estimated new cases	Estimated deaths
Ovarian	21,290	14,180
Liver and intrahepatic bile duct	35,660	24,550
Thyroid	62,450	1950
Breast	234,190	40,730
Prostate	220,800	27,540
All the cancer types from above together	574,390	108,950
All cancer types	1,658,370	589,430

Ultrasound (US) is a non-invasive, cost effective and safe[1] medical imaging modality which can be used to detect cancer [6,7]. Achieving a good diagnosis performance with this imaging technology requires an integrate interplay of fine motor skills (to operate the ultrasound transducer) and cognitive abilities for image interpretation [8]. Hence, practitioners require extensive initial training and continuous practice. A core problem of this human centric approach for disease diagnosis is the non-stationary diagnosis quality and inter- as well as intra-operator variability [9]. Non-stationary refers to the fact that the performance of human practitioners varies over time. These variations can be positive, such as gaining more experience over time as well as negative triggered by fatigue and other external factors. Overall, the beneficial properties of US technology outweigh these problems. Therefore, a vibrant research community explores a wide range of application areas for this imaging methodology. Initially, US was used only for application areas where tissue and bone formations led to sharp edges in the US images [10,11]. Unfortunately, a wide range of diseases cannot be diagnosed based on the edges within an US image alone [12,13]. Many of the new application areas target diseases whose symptoms and signs are changes in soft tissues [14]. A prominent example of that problem class is cancer diagnosis, because cancer cells are very similar to normal cells. Differentiating malignant from normal cells can be improved by interpreting image texture, since it contains information about the scanned tissues [15]. For a human practitioner, the changes in image texture, which indicate the presence of cancer, appear to be minute. Hence, human texture analysis is tiresome and error prone. As a consequence, a human centric approach leads to a low diagnostic accuracy.

Computer Aided Diagnosis (CAD) can help to overcome the problems of human texture analysis and thereby increase the diagnosis accuracy [16,17]. The challenge for such computer based texture analysis is twofold. First, we need to establish mathematical definitions for relevant image textures. These mathematical definitions lead to texture analysis algorithms which can be used in practical CAD systems [18]. The second problem is to detect the texture changes, which indicate malignant tissues. It turns out that these problems cannot be solved a priori; the texture interpretation can only be done a posteriori. In other words, it is impossible to know what type of texture analysis algorithm will be sensitive for the subtle differences between normal and cancer cells in US images. Therefore, empirical methods identify which texture methods work well for a specific problem [19]. As a consequence, it is necessary to test a wide range of algorithms and select the ones which show the best performance on known data. Another complicating factor, for computer based texture analysis, is that most of the known texture algorithms depend on the image resolution. Hence, specific texture results are not transferable between different US capturing machines.

Texture information can be extracted using various methods. In order to select the best algorithm, it is necessary to have a good understanding of the available methods. The current review provides an overview of the available texture algorithms and their applications. We review texture-based US image analysis in the areas of breast, prostate, liver, ovarian and thyroid cancer detection. This review shows that texture features are vital for achieving the diagnostic accuracy needed for practical CAD systems. Furthermore, we give an overview of texture algorithms. During the review, we found that only a few CAD systems are solely based on texture methods. Research work, that considers only texture algorithms, aims to improve the understanding of the relationship between human tissue formations and US images. Robust and therefore practical CAD systems must be based on a range of different feature extraction methods, preferably coming from different imaging methods. We recognize that texture-based image analysis is a useful and cost effective enhancement of the well-known US technology. For application areas, such as breast, liver, ovarian, prostate and thyroid cancer, US based texture features are vital for CAD.

To support our position, on texture analysis for medical US images, we have organized the article as follows. The next section provides pathological background on breast, prostate, liver, ovarian and thyroid cancer and their typical characteristics in ultrasound images. The material section contains a comprehensive review of texture algorithms and we introduce

[1] It uses no ionizing radiation.

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