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A parametric imaging approach for the segmentation of ultrasound data

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Abstract

When an ultrasonic examination is performed, a segmentation tool would often be very useful, either for the detection of pathologies, the early diagnosis of cancer or the follow-up of the lesions. Such a tool must be both reliable and accurate. However, because of the relatively reduced quality of ultrasound images due to the speckled texture, the segmentation of ultrasound data is a difficult task. We have previously proposed to tackle the problem using a multiresolution Bayesian region-based algorithm. For computation time purposes, a multiresolution version has been implemented. In order to improve the quality of the segmentation, we propose to perform the segmentation not only from the envelope image but to combine more information about the properties of the tissues in the segmentation process. Several acoustical parameters have thus been computed, either directly from the images or from the radio-frequency (RF) signal.

In a previous study, two parametric images were involved in the segmentation process. The parameter represented the integrated backscatter (IBS) and the mean central frequency (MCF), which is a measurement related to the attenuation of ultrasound waves in the media. In this study, parameters representative of the scattering conditions in the tissue are evaluated in the multiparametric segmentation process. They are extracted from the *K*-distribution (α,b) and the Nakagami distribution (m,Ω) and are related to the local density of scatterers (α,m), the size of the scatterers (b) and the backscattering properties of the medium (Ω).

The acoustical features are calculated locally on a sliding window. This procedure allows to built parametric mapping representing the particular characteristics of the medium. To test the influence of the acoustical parameters in the segmentation process, a set of numerical phantoms has been computed using the Field software developed by J.A. Jensen. Each phantom consists in two regions with two different acoustical properties: the density of scatterers and the scattering amplitude. From both the simulated RF signals and envelope images, the parameters have been computed; their relevance to represent a particular characteristic of the medium is evaluated. The segmentation has been processed for each phantom. The ability of each parameter to improve the segmentation results is validated. A agar–gel phantom has also been created, in order to test the accuracy of the parameters in conditions closer to the in vivo ultrasound imaging. This phantom contains four inclusions with different concentrations of silica. A B&K ultrasound device provides the RF data. The quantification of the segmentation quality is based on the rate of correctly classified pixels and it has been computed for all the parameters either from the field images or the phantom images. The large improvement in the segmentation results obtained reveals that the multiparametric segmentation scheme proposed in this study can be a reliable tool for the processing of noisy ultrasound data.

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1. Introduction

Ultrasound images are of common use in medical imaging for the diagnosis of many diseases. The probe can be positioned freely by the clinician and the short acquisition time enables the possibility of getting real time data. The segmentation of these data is a very important step toward an automatic analysis and/or quantitative measurements. For example, quantitative volume parameters recovery is a unique mean of making objective reproducible and operator independent diagnosis. Thus, it is all the more important to perform a successful segmentation. Several attempts have been developed to segment ultrasound data from the echographic images: for instance, the cavities of the heart [1], liver or prostate tumours [2,3]. As ultrasound data lead to very noisy images with low contrasted regions and blurred boundaries, the conventional edge-based segmentation methods such as Canny edge detection [4] or Prewitt operators [5] are not suited to find the boundaries between tissues. For these reasons, we have focused our research on one hand on region-based segmentation methods and on the other hand on a multiparametric approach.

The different tissues on an image (representing different organs or pathological and healthy tissues) are characterised by their acoustic impedances, which reflect differences in the structural organisation of the scatterers [6–9].

We have previously proposed and evaluated a multiparametric implementation of a segmentation algorithm [10,11]. The multiparametric approach consists in calculating local features from the ultrasonic data that yield to images which are maps of the feature. Then, to ensure the robustness of the method, the segmentation is not performed from the envelope image only, but from several images. This method has been completed in this study by adding acoustical parameters to the segmentation process. These parameters are representative of the scattering conditions in the tissue. They are extracted from the *K*-distribution (α,b) and the Nakagami distribution (m,Ω). These four parameters are fully described in Section 2. So, for each parameter, the computed map shows the variations of the parameter throughout the investigated area. Local measurements are thus needed for this mapping, so we must find a trade-off between the size of the local measurement window and the resolution of the parametric image. The window (either 1D or 2D) must be large enough to exhibit stationary statistics, representative of the local specificity of the tissue.

Most of the parametric measurement methods implemented in the frame of this study provide qualitative measurements. Because the purpose is image segmentation, our application does not need accurate quantitative measurements but reliable relative estimations that clearly emphasise the differences between various tissues.

The implemented method for the segmentation of the multiparametric data is based on a Bayesian approach using a multiresolution Markov random field. The several parameters are computed from the image or from the radio-frequency (RF) signals. The multiparametric approach is implemented to obtain a more robust segmentation and the multiresolution approach is interesting to improve simultaneously the robustness of the segmentation and the speed of the algorithm.

This paper proposes to investigate the relevance of several parameters for the segmentation of ultrasonic data. It is organised as follows. Section 2 describes the parametric images calculated from the ultrasonic data and the segmentation algorithm used. Section 3 presents on one hand the segmentation results on numerical ultrasound phantoms and, on the other hand the segmentation results on an gelatine–agar phantom. The results are discussed in Section 4 and the conclusions drawn from this study are finally summarised in Section 5.

2. Method

2.1. Acoustical parameters

The conventional image used by the radiologist during an ultrasonic examination is the B-mode image computed from the envelope of the RF signal. The envelope signal contains information related to amplitude, but the frequency and phase information, related to the attenuation and to the spatial distribution of individual scatterers, is lost irretrievably by the envelope extraction operation.

Several studies have proposed various methods for extracting information about the characteristics of the tissues in order to characterise the tissues and detect pathologies. Some measurements are closely related to the acoustical properties of the tissues [12], some others, like textural parameters, are not [13].

Acoustical parameters are often extracted from the RF signal and are representative of the scatterers properties within the tissues. Those parameters can provide two kinds of information. On one hand, integrated backscatter coefficients [14] and attenuation estimators [15] measure the echogenicity properties of the scatterers. On the other hand, parameters such as scatterers density, scatterers size or mean scatterer spacing (MSS) estimators characterise the spatial organisation of the scatterers [16]. Some methods propose to derive acoustical parameters from the envelope image. They are based on the numerous studies which try to link the particularities of a tissue with a specific intensity distribution on the envelope image [17].

The methods implemented in this study for the tissue characterisation are described hereafter. They lead to