Accepted Manuscript

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PII: S0923-5965(17)30158-3
DOI: https://doi.org/10.1016/j.image.2017.09.005
Reference: IMAGE 15278

To appear in: *Signal Processing: Image Communication*

Received date : 28 January 2016
Revised date : 5 June 2017
Accepted date : 11 September 2017

Please cite this article as: A. Khvostikov, A. Krylov, J. Kamalov, A. Megroyan, Ultrasound despeckling by anisotropic diffusion and total variation methods for liver fibrosis diagnostics, *Signal Processing: Image Communication* (2017), https://doi.org/10.1016/j.image.2017.09.005

Ultrasound despeckling by anisotropic diffusion and total variation methods for liver fibrosis diagnostics

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Abstract

Anisotropic diffusion method and a total variation method for B-mode ultrasound image speckle filtering were compared for the problem of liver fibrosis diagnostics. An effective stopping criterion to control the strength of image filtering with the anisotropic diffusion algorithm and the regularization parameter estimation method for the proposed total variation algorithm were introduced. The comparison of two speckle filtering techniques demonstrated the advantage of anisotropic diffusion algorithm. Liver fibrosis diagnostics was performed using image texture analysis based on 10-20 textural characteristics. Siemens ACUSON S2000 ultrasound images of liver for 60 patients were used to determine the fibrosis according to the METAVIR score. A two-step algorithm includes elastography based F4 stage detection and F0 – (F1,F2,F3) separation using ultrasound texture analysis. The classification was performed with Random Forest classifier. A comparison with deep convolutional neural networks was also performed. It was found that speckle filtering procedure in some cases enhances the texture-based classification and increases the total accuracy value up to 5% and makes the classification more robust and independent from the train–test set selection.

Keywords: Liver fibrosis, B-mode ultrasound images, Speckle filtering, Anisotropic diffusion, Total variation, Texture analysis, Classification algorithms.

1. Introduction

One of the main problems of ultrasound imaging is the presence of speckle noise. It considerably complicates texture image analysis and affects the classification results. There are several methods for image despeckling. The most advanced are methods, based on nonlinear anisotropic diffusion [1, 2] and methods, based on total variation [3].

Speckle filtering is a nontrivial problem and the effectiveness of despeckling techniques strongly varies for different medical applications. At the same time, the influence of speckle reduction on the liver texture analysis has not attracted much attention. The first work on this problem [4] analyzed the influence of anisotropic diffusion speckle filtering on the liver fibrosis classification. In this paper we continue the work in this area.

Liver fibrosis is one of the most common diffuse liver diseases, which due to the chronic inflammation causes gradual overgrowth or thickening of the liver conjunctive tissue. Fibrosis leads to serious consequences: violation of exchange processes between blood and liver cells, blood shunting, progression of chronic liver disease into cirrhosis, reduction of spectrum and effectiveness of therapeutic measures. Therefore, the early diagnosis and assessment of the fibrosis stage is an important problem, which has recently become the subject of many studies. The most popular non-invasive method of diffuse disease diagnostics is an ultrasound examination. All major techniques of current interest can be divided into three main groups:

- methods based on the analysis of the entire ultrasound image[5] involve the allocation of large image area and analyzing some specially designed characteristics after preliminary filtering. These methods are extremely simple, but do not provide the desired accuracy.
- methods based on texture analysis. Small image regions of interest are described using characteristics of Laws' energy masks [6], co-occurrence matrices [7], gray level run-length matrices [8] and wavelet transform [7, 9]. These methods are very common and provide the most accurate diagnostics.
- methods based on the analysis of elastography data (ARFI) [10] demonstrate the high accuracy of cirrhosis detection. However their applicability in the task of fibrosis grading seems to be rather poor.

We propose a comprehensive texture-based algorithm for fibrosis diagnostics using B-mode ultrasound images

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