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Despeckle filtering software toolbox for ultrasound imaging of the common carotid artery

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ABSTRACT

Ultrasound imaging of the common carotid artery (CCA) is a non-invasive tool used in medicine to assess the severity of atherosclerosis and monitor its progression through time. It is also used in border detection and texture characterization of the atherosclerotic carotid plaque in the CCA, the identification and measurement of the intima-media thickness (IMT) and the lumen diameter that all are very important in the assessment of cardiovascular disease (CVD). Visual perception, however, is hindered by speckle, a multiplicative noise, that degrades the quality of ultrasound B-mode imaging. Noise reduction is therefore essential for improving the visual observation quality or as a pre-processing step for further automated analysis, such as image segmentation of the IMT and the atherosclerotic carotid plaque in ultrasound images. In order to facilitate this preprocessing step, we have developed in MATLAB® a unified toolbox that integrates image despeckle filtering (IDF), texture analysis and image quality evaluation techniques to automate the pre-processing and complement the disease evaluation in ultrasound CCA images. The proposed software, is based on a graphical user interface (GUI) and incorporates image normalization, 10 different despeckle filtering techniques (DsFlsmv, DsFwiener, DsFlsminsc, DsFkuwahara, DsFgf, DsFmedian, DsFhmedian, DsFad, DsFnldif, DsFsrad), image intensity normalization, 65 texture features, 15 quantitative image quality metrics and objective image quality evaluation. The software is publicly available in an executable form, which can be downloaded from http://www.cs.ucy.ac.cy/medinfo/. It was validated on 100 ultrasound images of the CCA, by comparing its results with quantitative visual analysis performed by a medical expert. It was observed that the despeckle filters DsFlsmv, and DsFhmedian improved image quality perception (based on the expert's assessment and the image texture and quality metrics). It is anticipated that the system could help the physician in the assessment of cardiovascular image analysis.

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1. Introduction

In recent years significant technological advancements and progress in image processing have been achieved, however, still a number of factors in the visual quality of images, hinder the automated analysis [1], and disease evaluation [2]. These include imperfections of image acquisition instrumentations, natural phenomena, transmission errors, and coding artifacts, which all degrade the quality of image in the form of induced noise [3–5]. Ultrasound imaging is a powerful non-invasive diagnostic tool in medicine, but it is degraded by a form of multiplicative noise (speckle), which makes visual observation difficult [4,5]. Speckle is mainly found in echogenic areas of the image in the form of a granular appearance that affects texture of the image [1,6], which may carry important information about the shape of tissues and organs. Texture [2,7,8] and morphology [9] may provide additional quantitative information of the area under investigation, which may complement the human evaluation and provide additional diagnostic details. It is therefore of interest for the research community to investigate and apply new image despeckle filtering techniques that can increase the visual perception evaluation and further automate image analysis, thus improving the final diagnosis. These techniques are usually incorporated into integrated software for medical image processing applications. It should be however noted, that it is not always desirable to remove speckle noise from the images as it can be considered as a natural tissue effect which may provide additional information, especially in the areas of strain imaging and speckle tracking [10], and methods of ultrasound tissue characterization [11]. We propose in this study an integrated despeckle filtering (IDF) software toolbox (see also Fig. 1 and Fig. 2) for ultrasound image of the common carotid artery (CCA) for preprocessing ultrasound images for further analysis and assessment by the medical experts in cardiovascular imaging based diagnosis. The present work incorporates knowledge and results also presented in previous publications made by our group, where despeckle filtering [3–5], quality evaluation [12], segmentation of the intima-media complex (IMC) [13,14] and the atherosclerotic carotid plaque [15] from ultrasound images of the CCA were investigated. Recently, a video despeckle filtering (VDF) toolbox for medical ultrasound video has been proposed [16] and evaluated on 10 ultrasound videos of the CCA. The VDF toolbox builds up on previous work presented from our group [15,17–19].

In order to quantitatively evaluate the proposed IDF software system, we applied 10 different despeckle filtering techniques and evaluated their performance on 100 ultrasound images of the CCA. The IDF software toolbox was furthermore evaluated through 65 different texture features and 15 image quality metrics, which were extracted from the original and the despeckled images as well as through visual perception, performed by a neurovascular specialist, before and after despeckle filtering.

There are a number of studies reported in the literature, where ultrasound image medical software systems have been introduced. An overview of these systems is given in Table 1. The systems tabulated have been grouped under freeware, and other imaging systems. Loizou and Pattichis [4], presented a despeckle filtering study that was accompanied with a despeckle filtering toolbox software for ultrasound imaging of the CCA, based on MATLAB®, whereas, in this paper we extend and make the IDF software publicly available in an executable form, which can be downloaded from http://www.cs.ucy.ac.cy/medinfo/. The other imaging systems in Table 1 cover the despeckling of 2D or 3D ultrasound images, as well as the plaque texture characterization. For ultrasound image denoising, a number of systems are available in the market, such as those that are included in the widely known commercial ultrasound machines (Esaote S.p.A, Philips Electronic Ltd) as well as the ones that can be purchased as stand-alone software systems [20–25].

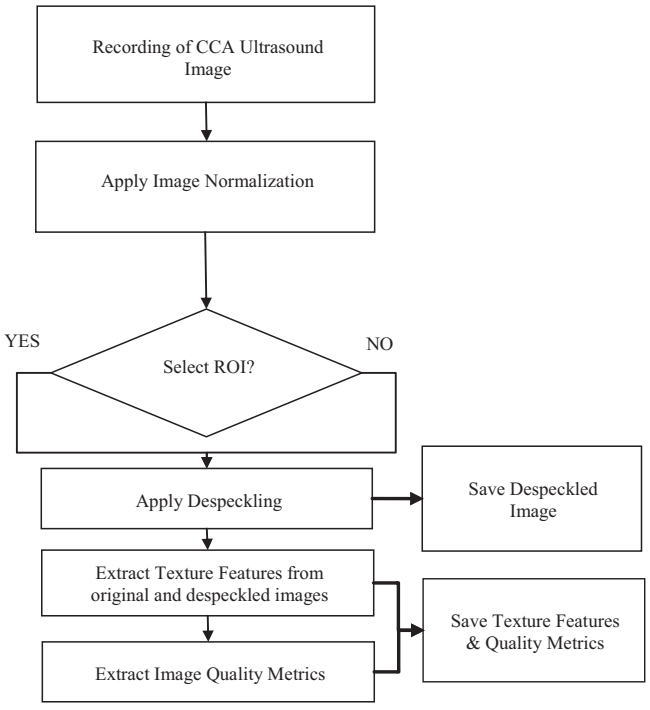

Fig. 1 – Flowchart analysis of the IDF toolbox for ultrasound image analysis.

The structure of the paper is as follows: In Section 2, the theoretical concepts of the proposed image despeckle filters are presented. In Section 3 we provide information on the materials and methods used in this study. The various results are presented in Section 4, followed by discussion (Section 5). Finally, Section 6 concludes the paper.

2. Image despeckle filters

In this section, theoretical background on 10 image despeckle filtering methods used in the proposed IDF software is presented as follows: (a) linear filter (DsFlsmv), (b) Wiener linear filter (DsFwiener), (c) linear filter (DsFlsminsc), (d) nonlinear filter (DsFkuwahara), (e) geometric filter (DsFgf), (f) median filter (DsFmedian), (g) hybrid median filter (DsFhmedian), (h) anisotropic diffusion filter (DsFad), (i) coherent nonlinear anisotropic diffusion filter (DsFnldif), and (j) speckle reducing anisotropic diffusion filter (DsFsrad).