Chapter 14

Advances in Ultrasound Despeckling:

An Overview

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ABSTRACT

The B-mode ultrasound images are corrupted due to the presence of speckle noise. Hence, the speckle removal in the ultrasound images is essential for proper clinical examination and quantitative assessments. The speckle pattern varies with several imaging parameters as well as the anatomical structure in the image. It is hard to avoid speckle by performing averaging and low noise system designs. An excessive speckle reduction diminishes the visibility of small anatomical structures and thereby makes the image understanding complicated. This chapter is intended to encapsulate various techniques for reducing speckle in medical ultrasound images and improving the image quality for visual inspection and/or computer-assisted diagnosis of ultrasound images. In addition, the chapter surveys the papers published between 2015 and 2018 to highlight the latest trends in the despeckling of ultrasound images. The chapter also presents the performance comparison of a few popular algorithms to despeckle medical ultrasound images.

INTRODUCTION

Ultrasound is a modern medical diagnostic instrument for imaging organs, muscles, and tissues or for obtaining measures that are good biomarkers in the clinical diagnosis and therapeutic procedures (Araki et al., 2016; Acharya et al., 2014; Loizou et al., 2005). It is preferred due to its merits such as economi-

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cal, real-time nature, safe and easy to use in practice. Ultrasound is useful in invasive and non-invasive medical applications (Suri, 2008; Saba et al., 2014; Del Cura et al., 2012; Christodoulou et al., 2002).

A conventional ultrasound system produces images using the principle of echo imaging. The use of echo localization for medical purposes has been initiated in the mid-1950s. In principle, the ultrasound system transmits acoustic (pressure) waves with frequencies that lie in the range from 1 to 20 MHz into the patient's body (Tole & Ostensen, 2005). When the acoustic wave hits the tissue barriers (scatters) exist in a specified size of medium (resolution cell), backscattering of the wave (echo) occurs. An ultrasonic probe detects the echoes and integrates to develop 1D acoustic line (A-line) signal. An envelope detector produces a low-frequency envelope signal from the high-frequency A-line signal. Then, the logarithmic compression and nonlinear processing of the envelope signal is performed. The procedure repeats for all the A lines usually arranged in a sequential order and interpolates to create a Cartesian image of the ultrasound B-scan (Sudeep et al., 2016).

Even though recent advances in technology have improved the functionality of ultrasound, it still possesses severe limitations in the following aspects: (i) Ultrasound scans of the brain, lungs and the abdominal region are limited due to the obstruction of sound waves by bone or air, (ii) it is difficult to produce clinically relevant images on patients with obesity, and (iii) its effectiveness heavily depends upon the expertise of the technician or physician conducting the examination (Patel, 2010).

In fact, the speckle generated by the intervention of back-scattered waves leads to quality degradation of ultrasound images. The granular pattern of speckle masks small anatomical structures in the image. Therefore, it complicates interpretations from the image. In (Goodman, 1975), speckle is modeled as the summation of many complex phasors, called a *complex random walk*. Among them, the phasors that possess destructive relationships interfere to form the speckle. Therefore, the relative phase between the back-scattered waves determines its degree of seriousness.

Based on the scatter number density (SND) per resolution cell, we can classify the speckle into 4 groups, which are (i) fully developed (ii) fully resolved (iii) partially developed and (iv) partially resolved (Seabra J. C. R., 2011). When SND is high, the envelope becomes Rayleigh distributed due to the contamination of *fully developed speckle* and it happens in blood regions. For the Gaussian distributed complex echo envelope with standard deviation σ and the absolute envelope amplitude u, the Rayleigh probability density function (PDF) is expressed as (Sudeep et al., 2016):

$$f\left(u,\sigma\right)=\frac{u}{\sigma^2}e^{-\frac{u^2}{2\sigma^2}} \tag{1}$$

If the random walk possesses an extra deterministic component, *fully resolved* speckle arises and the Rician distribution fits well with the envelope. Usually, it happens in regions of tremendous echolucent response like myocardium. The Rician distribution PDF is (Sudeep et al., 2016):

$$f\left(u\mid v,\sigma\right)=\frac{u}{\sigma^2}e^{-\frac{(u^2+v^2)}{2\sigma^2}}I_0\left(\frac{uv}{\sigma^2}\right) \tag{2}$$

where $I_0\left(\cdot\right)$ is the modified Bessel function of the first kind with order zero and v is the noise-free envelope magnitude value.

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