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Despeckle Filtering for Ultrasound Imaging and Video

Volume II: Selected Applications

Second Edition

Christos P. Loizou
Constantinos S. Pattichis

Synthesis Lectures on Algorithms and Software in Engineering

Andreas Spanias, *Series Editor*

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ABSTRACT

In ultrasound imaging and video visual perception is hindered by speckle multiplicative noise that degrades the quality. Noise reduction is therefore essential for improving the visual observation quality or as a pre-processing step for further automated analysis, such as image/video segmentation, texture analysis and encoding in ultrasound imaging and video. The goal of the first book (book 1 of 2 books) was to introduce the problem of speckle in ultrasound image and video as well as the theoretical background, algorithmic steps, and the Matlab™ code for the following group of despeckle filters: linear despeckle filtering, non-linear despeckle filtering, diffusion despeckle filtering, and wavelet despeckle filtering. The goal of this book (book 2 of 2 books) is to demonstrate the use of a comparative evaluation framework based on these despeckle filters (introduced on book 1) on cardiovascular ultrasound image and video processing and analysis. More specifically, the despeckle filtering evaluation framework is based on texture analysis, image quality evaluation metrics, and visual evaluation by experts. This framework is applied in cardiovascular ultrasound image/video processing on the tasks of segmentation and structural measurements, texture analysis for differentiating between two classes (i.e. normal vs disease) and for efficient encoding for mobile applications. It is shown that despeckle noise reduction improved segmentation and measurement (of tissue structure investigated), increased the texture feature distance between normal and abnormal tissue, improved image/video quality evaluation and perception and produced significantly lower bitrates in video encoding. Furthermore, in order to facilitate further applications we have developed in MATLAB^{TM} two different toolboxes that integrate image (IDF) and video (VDF) despeckle filtering, texture analysis, and image and video quality evaluation metrics. The code for these toolsets is open source and these are available to download complementary to the two monographs.

KEYWORDS

speckle, despeckle, noise filtering, ultrasound, ultrasound imaging, ultrasound video, cardiovascular imaging and video, texture, image and video quality, video encoding, mobile health, carotid artery

To my Family, and
in memory of my father Panayiotis and my mother Eleni
Christos P. Loizou

To my mother, and
in memory of my father Stephanos, and my sister Revecka
Constantinos S. Pattichis

"This is the way we should see Christ. He is our friend, our brother; He is whatever is good and beautiful. He is everything. Yet, He is still a friend and He shouts it out, "You're my friends, don't you understand that? We're brothers. I'm not...I don't hold hell in my hands. I am not threatening you. I love you. I want you to enjoy life together with me."

"Love Christ and put nothing before His Love. He is joy, He is life, He is light. Christ is Everything. He is the ultimate desire, He is everything. Everything beautiful is in Christ."

"The life of the parents is the only thing that makes good children. Parents should be very patient and 'saintlike' to their children. They should truly love their children. And the children will share this love! For the bad attitude of the children, says father Porphyrios, the ones who are usually responsible for it are their parents themselves. The parents don't help their children by lecturing them and repeating to them 'advices', or by making them obeying strict rules in order to impose discipline. If the parents do not become 'saints' and truly love their children and if they don't struggle for it, then they make a huge mistake. With their wrong and/or negative attitude the parents convey to their children their negative feelings. Then their children become reactive and insecure not only to their home, but to the society as well."

Saint Porphyrios (Bairaktaris) the Kapsokalyvite

Source: Wikipedia

Contents

Preface

Speckle is a multiplicative noise that degrades image quality and the visual evaluation in ultrasound and SAR imaging. This necessitates the need for robust despeckling techniques in a wide spectrum of the aforementioned imaging applications. Despeckle filtering applications has been a rapidly emerging research area in recent years. The goal of the first book (book 1 of 2 books) was to introduce the problem of speckle in ultrasound image and video as well as the theoretical background, algorithmic steps, and the Matalb™ code for the following group of despeckle filters: linear despeckle filtering, non-linear despeckle filtering, diffusion despeckle filtering, and wavelet despeckle filtering. The goal of this book (book 2 of 2 books) is to demonstrate the use of a comparative evaluation framework of these despeckle filters (introduced on book 1) on cardiovascular ultrasound image and video processing. More specifically, the despeckle filtering evaluation framework is based on texture analysis, image quality evaluation metrics, and visual evaluation by experts. The filters covered represent only a snapshot of the vast number of despeckle filters and applications published in the literature. The source code of the algorithms presented in this book has been made available on the web, thus enabling researchers to more easily exploit the application of despeckle filtering in their problems under investigation.

The book is organized in five chapters. In Chapter 1 an introduction and review of different despeckle filtering techniques for ultrasound imaging and video is presented, a despeckle filtering evaluation protocol is proposed and selected applications for ultrasound image and video despeckle filtering techniques are outlined. In Chapter 2 we present the application and results of the segmentation of the intima-media complex (IMC), the media-layer (ML) and the intima layer (IL) of the common carotid artery as well as the segmentation of the atherosclerotic carotid plaque from ultrasound images and videos following despeckle filtering. In Chapter 3, we present the results on image and video texture analysis. We provide results from the texture analysis of the IMC and the atherosclerotic carotid plaque performed on a large number of ultrasound images and videos. In Chapter 4 we present results on ultrasound wireless video encoding and transmission which is performed before and after despeckle filtering. Chapter 5 discusses, compares and evaluates the proposed despeckle filtering techniques for image and video and provides an outline of future directions. Finally, at the end of this book, appendices provide details about the IDF and VDF despeckle filtering MATLAB™ toolboxes.

Furthermore, it is noted that for those practicing engineers/scientists whose principal need is to use existing image despeckle filtering technologies and apply them on different type of images or video, there is no simple answer regarding which specific filtering algorithm should be selected without a significant understanding of both the filtering fundamentals, and the application environment under investigation. A number of issues would need to be addressed. These

include availability of the image/video to be processed/analyzed, the required level of filtering, the application scope (general-purpose or application-specific), the application goal (for extracting features from the image or for visual enhancement), the allowable computational complexity, the allowable implementation complexity, and the computational requirements (e.g., real-time or offline). We believe that a good understanding of the contents of this book can help the readers make the right choice of selecting the most appropriate filter for the application under development. Furthermore, the despeckle filtering evaluation protocol documented in Table 1.4 could also be exploited.

This book is intended for all those working in the field of image and video processing technologies, and more specifically in medical imaging and in ultrasound image and video preprocessing and analysis. It provides different levels of material to researchers, biomedical engineers, computing engineers, and medical imaging engineers interested in developing imaging systems with better quality images, limiting the corruption of speckle noise.

We wish to thank all the members of our carotid ultrasound imaging team, for the long discussions, advice, encouragement, and constructive criticism they provided to us during the course of this research work. First of all we would like to express our sincere thanks to Emeritus Prof Andrew Nicolaides, of the Faculty of Medicine, Imperial College of Science, Technology and Medicine, UK, and founder of the Vascular Screening and Diagnostic Centre in Cyprus. Furthermore, we would like to express our thanks to Dr Marios Pantziaris, consultant neurologist, at the Cyprus Institute of Neurology and Genetics, Dr Theodosis Tyllis, consultant physician in the private sector in Cyprus, Associate Professor Efthyvoulos Kyriakou, at the Frederick University, Cyprus, Dr Christodoulos Christodoulou, Research Associate at the University of Cyprus, and Associate Professor Marios Pattichis, University of New Mexico, USA. Last but not least, we would like to thank, Prof Andreas Spanias, Arizona State University, USA, for his proposal and encouragement in writing this book, and to Joel Claypool, and the rest of the staff at Claypool publishing house, for their understanding, patience and support in materializing this project.

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We hope that this book will be a useful reference for all the readers in this important field of research and to contribute to the development and implementation of innovative imaging and video systems enabling the provision of better quality images.

Christos P. Loizou and Constantinos S. Pattichis
August 2015