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FACULTY OF ELECTRONICS, TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY

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PhD. THESIS

SPARSE BLIND DECONVOLUTION IN ULTRASOUND IMAGING USING AN ADAPTIVE CLEAN ALGORITHM

REZUME

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Key Words

Ultrasound Imaging, post processing, deconvolution, greedy algorithm, Matching Pursuit, Rarefaction, CLEAN adaptive.

Introduction and motivation of the thesis

Ultrasound based Imaging is one of the most used medical technology of our times. This technology presents a wide range of independent techniques like (A mode, B mode, Doppler, Elastography, and so on), but the most common known technique is ultrasound. This technique produces images caused by ultrasonic wave reflection at the meeting of the interfaces between tissues with different physical properties.

The main advantages of the ultrasound technique are invasiveness, portability and low costs. In comparison with other related techniques, the main disadvantage is it's low resolution. Low resolution is caused by the limited bandpass of the ultrasonic transducer. Another problem regarding ultrasound technique is the presence of granular texture feature, also called speckle noise. It is present due to the explored tissue and different interactions encountered on the time of wave propagation (diffraction, reflection and non linearity).

Since the beginning, the quality improvement of ultrasound medical images presented a huge interest for researchers in the field. Thus were developed two main research directions. On one hand, the quality of image acquisition was enhanced using new and powerful transducers, new beamforming techniques, and/or new appdization ideas. On the other hand, the researches was focused on image post processing techniques. While enhancing the image acquisition systems quality the final price of the whole device tends to increase, which is not the case when using post processing techniques.

Regarding post processing approaches, in the literature are presented different techniques which provide interesting results. In some cases the nature of images degrade the performance of standard algorithms developed for natural scenes, and involves the concept of ad-hoc filters. The majority of the proposed methods are using the inverse filter based on matrix inversions. Such matrix operations can introduce unwanted problems like complex computations and memory usage increasing. Such unwanted problems require new and more efficient solutions, which can solve the main disadvantages of the ultrasound imaging.

Thesis Objectives

This thesis is focused on providing new ways of improving the ultrasound image quality using numerical post processing techniques.

The major objective consist of defining a strong automatic algorithm which is able to eliminate the low pass filtering effect generated by the strap ultrasound and the wave propagation effects in tissues.

The second objective is to select and adjust a greedy algorithm to the requirements of the previous objective, but without matrix inversion, which is in fact the system function. It is well known that matrix inversion can produce the amplification of oscillations and require some extra regularization parameters for a better solution.

The third objective consist of testing the greedy algorithm on ultrasound images. The test results can offer a classification of such images. According to bayesian approach, it is well known that deconvolution algorithms ensure good results only on certain conditions. Also the test results can ensure an evaluation of the algorithm's ability to extract scatters, and to adapt to the situation when they are bellow Rayleigh resolution limit.

Thesis structure

The structure of the thesis has two parts which hold five chapters :

- First part holds general information about ultrasound medical imaging and the problem of improving the resolution(First Chapter). The Second Chapter presents the general overview and the classical techniques used in domain for resolution improvment.
- The second part holds authors personal contributions to the metter. The proposed algorithm is presented in comparison with other well known algorithms.
  - Third Chapter presents the general overview of the proposed method and it's simulations ;
  - Fourth Chapter presents the experiments which claim the performance of the proposed ultrasound greedy algorithm ;
  - Fifth Chapter presents the reconvolution of the sparse signal using an ideal PSF, obtained so that it ensures the best sparsity / smoothness ratio based on the Rayleigh distribution.

Personal Contributions

This section presents authors contributions to the research topic.

1. The most important contribution is the development of an blind deconvolution algorithm, in the time domain, completely capable of reconstructing the scatters from the explored tissues and reducing the spekle noise. This technique integrates some other contributions :
   (a) The proposal of an algorithm capable of operating in the time domain. In this way the matrix inversion problem is eliminating from the filtering procedure thus reducing the processing time ;

   (b) The proposed algorithm is applied on the RF signal envelope, allowing faze reconstruction elimination for the RF system function which abase the information.

   (c) The proposed blind deconvolution algorithm is build to estimate the PSF in a first step and, then to reconstruct the tissues reflectivity function in another two steps. This allows us to obtain a sparse solution by use of a greedy algorithm for deconvolution (Matching Pursuit). Exploiting the sparsity property it is able to extract the scatters from exploited environment and to remove an important quantity of speckle noise. The second solution is no more a sparse one and supposes a result obtained after the reconvolution with a so called ideal PSF in a such way to respect some statistical properties of envelope based ultrasound images. The σ parameter of the proposed gaussian ideal PSF is automatically computed with a Newton algorithm using a cost function which exploits the properties of Rayleigh distribution.

2. Another contribution is implementing and testing greedy algorithms in ultrasound images deconvolution domain. In order to claim the performance of those algorithms test were performed according to the bayesian statistics approach for finding the conditions in which the proposed algorithm works.

3. Last contribution concerns the documentation work aimed to support this research. Thus, signal processing for information reconstruction techniques were investigated in order to establish the general point of view and the main adjacent research directions. Based on this new techniques were proposed aiming the enhance of performance.

Publications List

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