Synthetic Aperture Beamforming Method in Medical Ultrasound Imaging

Vasiliki Stergiopoulou
Department of Electrical and Computer Engineering
University of Patras, Patras, Greece

Contact Information:

University Email: ece8532@upnet.gr
Personal Email: stergiopoulouvasilina@gmail.com
LinkedIn: Vasilina Stergiopoulou

Thesis Objective

The purpose of this diploma thesis is the study of an ultrasound imaging system which is going to be used in a capsule for endoscopy. The system should be characterized by low complexity, power and size in order to be suitable for such an application. The insurance of these conditions is accomplished in this work by the combination of two methods, Beamforming and Synthetic Aperture. Using the input data of a real system, a series of experiments is performed. Low resolution images are combined to create a new one of better quality and images are reconstructed in the polar coordinate system.

Acknowledgements

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Introduction

Medical ultrasound is a diagnostic imaging technique that has seen continuous development over several decades. It uses sound waves to form images of the inside of the body. Ultrasonography, comperes to other medical imaging modalities, is safe, uses non-ionizing radiation and is non-invasive. Also, it provides images in real-time and has portable and cheap equipment.

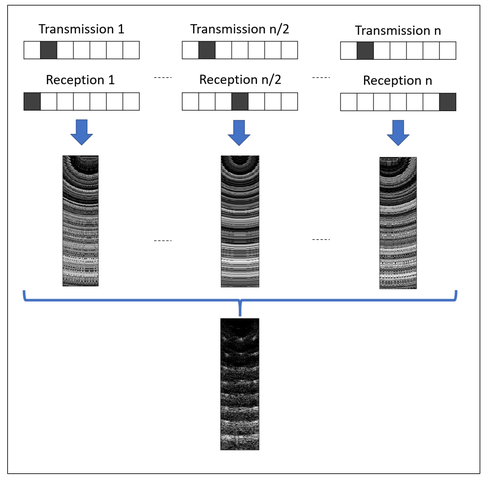
Improvements in technology lead in the implementation of miniaturized systems required for many intravascular, intracardiac, and endoscopic applications. These systems have lower complexity and size, but maintain the same image quality and diagnostic value.

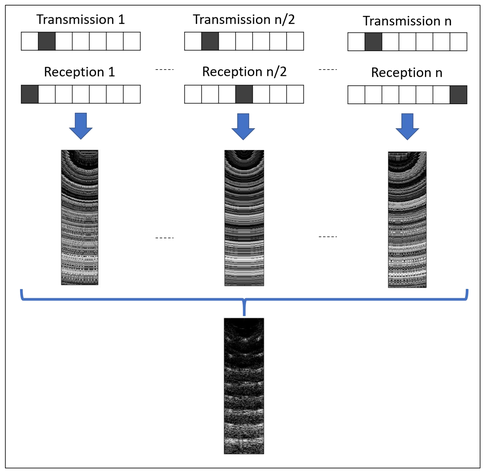
In this work, a synthetic aperture beamforming (SAB) method is performed on the received demodulated radiofrequency (RF) signals, in order to reduce the system complexity.

Synthetic Aperture Beamforming

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception, involving adjustments to the amplitude and delay in time of the electrical signals. The basic idea with synthetic aperture is to combine information from different emissions and receptions.

In this work, a spherical wave is produced by a single element, in order to fill the whole field of view. The transmission accomplished **n** times, for all receive elements, so as only a single channel to be used for receive data processing. As a result, **n** low resolution images are formed and their combination lead to a high resolution image.



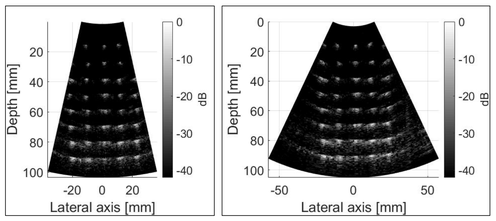


In order to increase the SNR of the final image, spatial compounding is used. The transmission is carried out from **m** different positions and the final image is the average of the higher resolution images obtained in the previous step. The image quality will be increased, but at the expense of frame rate

Image Reconstruction in Polar Coordinates

An interesting improvement of the imaging system is the representation of the images in polar coordinates.

The new images have flexible central angle and as a result, flexible field of view.



The new images cover a bigger area and are closer to the ultrasound images that doctors have used to see. However, in this approach, a bigger data storage space is needed and the lateral resolution is decreased as a function of the imaging depth, due to the peculiarity of polar coordinates.

The method's accuracy is evaluated by the comparison of the distance between two objects in the images in both coordinate systems.

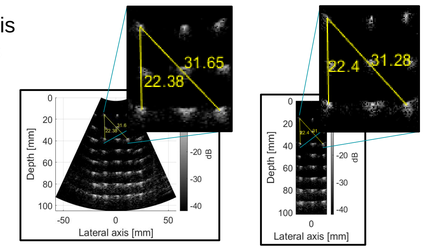
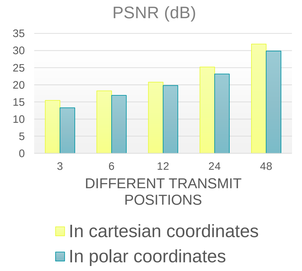
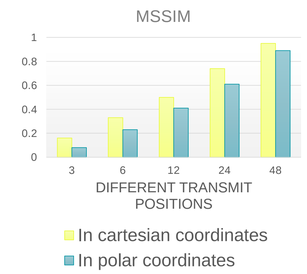


Image Quality Assesment

The images formed in both coordinate systems when different number of transmit positions were used should be evaluated. Two quality estimation metrics were used, Peak-Signal to Noise Ratio (PSNR) and Mean Structural Similarity (MSSIM) index.





Conclusions

The images represented in the polar coordinate system compared to those represented in the cartesian coordinates have a lower quality but a bigger and flexible field of view.
As the number of the different transmit positions increases, the image quality becomes better but to the detriment of frame rate.

References

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