Image processing in medical ultrasound

This Ph.D project addresses image processing in medical ultrasound and seeks to achieve two major scientific goals: First to develop an understanding of the most significant factors influencing image quality in medical ultrasound, and secondly to use this knowledge to develop image processing methods for enhancing the diagnostic value of medical ultrasound. The project is an industrial Ph.D project co-sponsored by BK Medical ApS., with the commercial goal to improve the image quality of BK Medicals scanners. Currently BK Medical employ a simple conventional delay-and-sum beamformer to generate B-mode images. This is a simple and well understood method that allows dynamic receive focusing for an improved resolution, the drawback is that only optimal focus is achieved in the transmit focus point. Synthetic aperture techniques can overcome this drawback, but at a cost of increased system complexity and computational demands. The development goal of this project is to implement, Synthetic Aperture Sequential Beamforming (SASB), a new synthetic aperture (SA) beamforming method. The benefit of SASB is an improved image quality compared to conventional beamforming and a reduced system complexity compared to conventional synthetic aperture techniques. The implementation is evaluated using both simulations and measurements for technical and clinical evaluations. During the course of the project three sub-projects were conducted. The first project were development and implementation of a real-time data acquisition system. The system were implemented using the commercial available 2202 ProFocus BK Medical ultrasound scanner equipped with a research interface and a standard PC. The main feature of the system is the possibility to acquire several seconds of interleaved data, switching between multiple imaging setups. This makes the system well suited for development of new processing methods and for clinical evaluations, where acquisition of the exact same scan location for multiple methods is important. The second project addressed implementation, development and evaluation of SASB using a convex array transducer. The evaluation were performed as a three phased clinical trial. In the first phase, the prototype phase, the technical performance of SASB were evaluated using the ultrasound simulation software Field II and Beamformation toolbox III (BFT3) and subsequently evaluated using phantom and in-vivo measurements. The technical performance were compared to conventional beamforming and gave motivation to continue to phase two. The second phase evaluated the clinical performance of abdominal imaging in a pre-clinical trial in comparison with conventional imaging, and were conducted as a double blinded study. The result of the pre-clinical trial motivated for a larger scale clinical trial. Each of the two clinical trials were performed in collaboration with Copenhagen University Hospital, Rigshospitalet, and Copenhagen University, Department of Biostatistic. Evaluations were performed by medical doctors and experts in ultrasound, using the developed Image Quality assessment program (IQap). The study concludes that the image quality in terms of spatial resolution, contrast and unwanted artifacts is statistically better using SASB imaging than conventional imaging. The third and final project concerned simulation of the acoustic field for high quality imaging systems. During the simulation study of SASB, it was noted that the simulated results did not predict the measured responses with an appropriate confidence for simulated system performance evaluation. Closer inspection of the measured transducer characteristics showed a severe time-offlight phase error, sensitivity deviations, and deviating frequency responses between elements. Simulations combined with experimentally determined element pulse echo wavelets, showed that conventional simulation using identical pulse echo wavelets for all elements is too simplistic to capture the true performance of the imaging system, and that the simulations can be improved by including individual pulse echo wavelets for each element. Using the improved model the accuracy of the simulated response is improved significantly and is useful for simulated system evaluation. It was further shown that conventional imaging is less sensitive to phase and sensitivity errors than SASB imaging. This shows that for simulated performance evaluation a realistic simulation model is important for a reliable evaluation of new high quality imaging systems.

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