Fast Plane Wave Imaging

This PhD project investigates and further develops methods for ultrasound plane wave imaging and blood flow estimation with the objective of overcoming some of the major limitations in conventional ultrasound systems, which are related to low frame rates and only estimation of velocities along the ultrasound beam. The first part of the contribution investigates the compromise between frame rate and plane wave image quality including the influence of grating lobes from a λ-pitch transducer. A method for optimizing the image quality is suggested, and it is shown that the frame rate can be increased by a factor of three without loss of image quality for a particular λ/2-pitch transducer, when compared to a λ-pitch transducer. The second part presents a method for high frame rate 2-D vector flow imaging. The method was validated in simulations and measurements, and it is shown that angles can be estimated with a bias and standard deviation less than 2°, and the velocity magnitude can be estimated with a bias and standard deviation less than 4% over a large range of beam-to-flow angles. The vector flow method was also investigated under laminar and complex flow conditions in the carotid arteries in ten healthy volunteers. Complex flow patterns were measured in an anthropomorphic flow phantom and showed good agreement with the velocity field simulated using computational fluid dynamics. The last part of the contribution investigates two clinical applications. Plane wave imaging was used for slow velocity flow estimation in the human placenta, which made it possible to map the vessel resistance in several fetal arteries. Finally, vector flow imaging was used for volume flow estimation in patients undergoing dialysis. The sources of error related to the volume flow estimation were investigated, making it possible to compensate for the errors. The developed techniques for plane wave imaging using high frame rates and/or estimation of 2-D vector flow may give the clinicians new tools for assessing the health of blood vessels and aid while examining patients with cardiovascular and organ diseases.