Bachelor Thesis Proposal
Computationally Efficient Techniques in Nonlinear Medical Ultrasound

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Problem Description In modern applications of medical ultrasound imaging as shown in Figure 1(a), the amplitude of the generated pressure wave is over 1 MPa causing the wave propagation to become nonlinear. This implies that the changes in the wave speed due to the compression and expansion of the tissue can no longer be neglected. As a result, the peaks and valleys in the pressure wave propate at different speed, causing a gradual deformation of the wave shape a shown in Figure 1(b). Higher harmonics appear in the frequency spectrum that are very useful for imaging purposes as they yield a better resolution and a reduction of imaging artifacts. An imaging technique based on higher harmonics is therefore being developed by the TU Delft Imaging Science and Technology Group in collaboration with the Erasmus MC hospital. The propagation of a nonlinear acoustic wave in a biological tissue is modeled by the

(a) Medical imaging setup (b) Nonlinear wave propagation

Figure 1: Nonlinear waves in medical imaging.

so-called Westerveld equation given by

$$\nabla^2 p - \frac{1}{c_0^2}\frac{\partial^2 p}{\partial t^2} = -\frac{\beta}{\rho_0 c_0^4}\frac{\partial^2 p^2}{\partial t^2}$$

where p is the sound pressure, c_0 is the small signal sound speed, β is the non-linearity coefficient and ρ_0 is the ambient density. As in an imaging application, this equation needs to be solved repeatedly, it is a paramount importance to develop computationally efficicient techniques for this purspose.

Project Description The goal of the project is to compare the computational efficiency of a finite-element based approach with that of an integral approach. In this comparison, both the CPU-time and memory usage will need to be taken into account.

Reference T. L. Szabo, *Diagnostic Ultrasound Imaging*, Elsevier, Amsterdam, 2004.