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Fast transcranial ultrasound simulations based on time-of-flight minimization

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Fast transcranial ultrasound simulations based on time-of-flight minimization

Background, Motivation and Objective

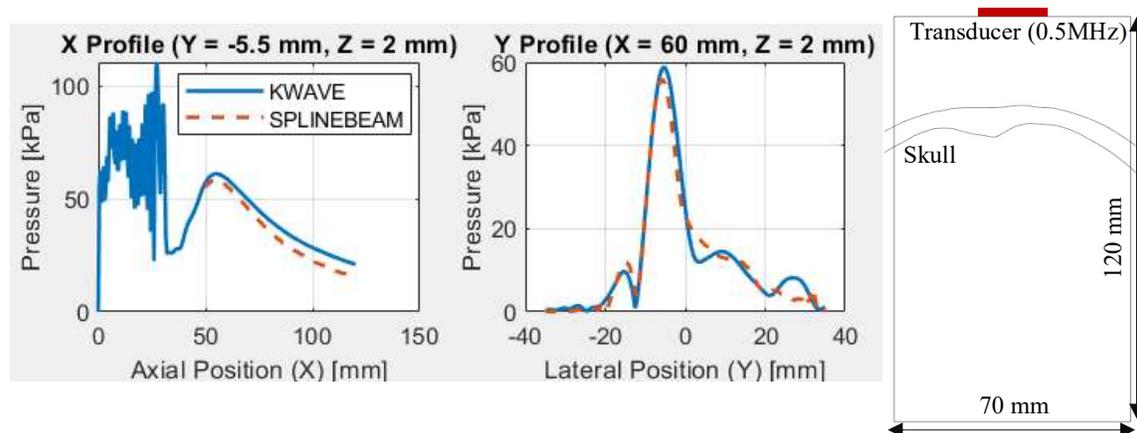
Transcranial ultrasound (US) simulations are of great interest to optimize transcranial US treatments and to ensure their safety by allowing focus corrections and dose adjustments. Such simulations are often based on numerical methods, as they are considered to be more accurate, although slower, than semi-analytical methods. However, a study [1] recently showed this is not necessarily true. To improve the execution time and memory use, a semi-analytical method based on time of flight minimization was developed.

Statement of Contribution/Methods

The skull is described as a homogeneous medium, whose interfaces are modeled as smooth surfaces using multi-level b-spline approximation. The probe is discretized into small elements. The ultrasound path between a probe element and a computation point is found by minimizing the time-of-flight function. This is possible thanks to the smoothness of the surfaces. The impulse responses for all probe elements are then computed and summed up according to the applied phase law. Hydrophone measurements were performed through *ex-vivo* human skulls with a therapeutic probe, for experimental validation of the method.

Results/Discussion

Our algorithm was benchmarked on the configurations proposed by [2], and gave results pretty similar to those of the other solvers, with an average focal position error of 0.21mm and an average maximum pressure error of 3.19% compared with K-Wave. As an example, benchmark 7 configuration and results are shown in the figure below. The computation times were respectively 287s with K-Wave C++ solver and 388s with our algorithm, for a same number of computation points, on the same computer. With our method, convergence is achieved without any constraint on the spatial step and on the zone size and location. Thus, the area can be restricted to the focal spot, resulting in a computation time of a few seconds. In addition, computation points are independent from one another, making the method very conducive to parallelization. Our new semi-analytical method is a promising tool, combining speed and accuracy, which are both of crucial importance for medical interventions.



[1] IEEE-UFFC, 68:2554-2565, 2021; [2] JASA, 152(2) :1003-1018, 2022.