TECHNISCHE UNIVERSITÄT
BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

MSELab

Thesis offer

Surrogate Modeling of Elastodynamic Impulses

Type of Thesis: BA/SA/Diplom/Project work or Seminar project

Suitable for: Applied Mathematics

Motivation & Background:
High-frequency ultrasound can be used in the non-destructive testing of microelectronic components by contrasting actual measurements against prior simulations of the wave field. Due to the high-frequency nature of the simulation task, it is preferable to forgo FEM in favor of semi-analytical methods that calculate an impulse response which is subsequently used to get the full wave field. To calculate such a full wave field, such a method has to be evaluated in a dense grid, resulting in way too many computations. It would be vastly more effective to iteratively build a surrogate of the impulse response from individual, sparse evaluations and use some form of interpolation. That's your task.

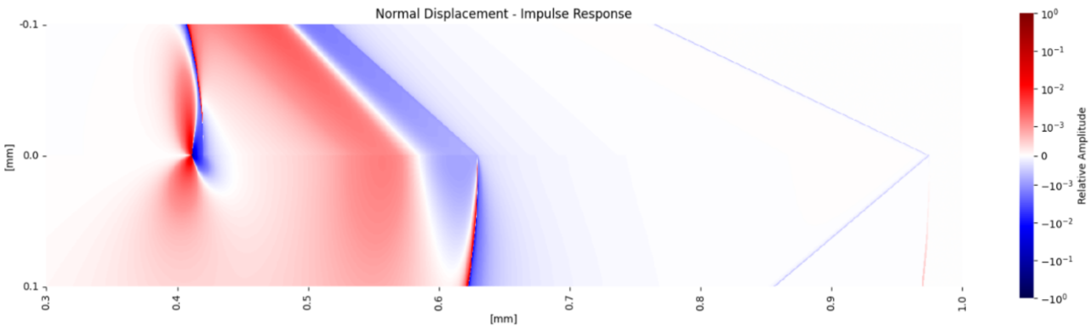

Figure: Example of a 2D slice of an impulse response that is the basis for visualizing a full wave field

Goals & Objectives:
The overarching goal of this project is to design an algorithm that can lower the amount of computational resources needed for calculating impulse responses in high-dimensional volumes. The student is expected to read associated literature to this known problem of function sampling/ surrogate building and evaluate to what extent known methods are applicable given the constraints in this project. After the initial study of literature an algorithm is to be chosen, adapted or created that fully complies with all constraints. This algorithm is to be implemented and validated to fulfill the projects requirements.

Milestones:
1. Understand the Problem
2. Design an algorithm that fulfills all project-specific constraints
3. Have a fully functional implementation of your algorithm of choice
4. Successfully validate the algorithm with actual simulation data

Character of the work:
50% algorithm development , 50 % programming (language is your choice, Julialang is preferred)

Supervision & Workflow:

- **Meetings:** weekly meetings between student and supervisor to evaluate status and progress and identify need for support; time and location (also possibly online) will be determined at the beginning of the work; additional meetings can be arranged
- **Mid-term presentation:** Students are encouraged to give a mid-term presentation as a preparation for the final presentation of the thesis. This is an opportunity to discuss the results with a broader audience and get important feedback on the current state of the work.

Technical Details:
Surrogate building, adaptive sampling and adjacent problems are extensively studied problems in literature. An impulse response can essentially be seen as a function R^5→R^9 in four spatial arguments and one temporal argument. This function is expensive to evaluate but its surrogate should be able to be evaluated cheaply in some constrained, user-defined region after building it by sampling the impulse response in the relevant region.

The constraints for this problem contain the following:
- Building the surrogate and evaluating for points of interest are to be two separated stages of computation, i.e. no new points are allowed to be sampled during the evaluation of the surrogate
- Evaluating the surrogate should be provably or at least statistically inside a user-defined error bound (for each of the 9 function values)
- (optional) Evaluating the surrogate should be able to be done purely on a database of sampled points with little or no additional data structures
- An impulse response contains multiple discontinuities
- The calculation of the impulse response may not be deterministic and produce outliers which should be detected and removed from the process of building the surrogate

Some opportunities that can/should be exploited are the following:
- Regions of interest (the discontinuities) follow a predictable pattern, i.e. wave propagation
- Outside of the regions of interest the impulse response is very well-behaved
- The Calculation of the impulse response can be neatly decomposed into a sum of “Rays” which have physical meaning
- Single groups of Rays show a known and detectable behavior at infinity

Supervisor: M.Sc. Sebastian Stahl