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Report of the application project at the Faculty of AMP

Simulation of a medical therapy method with finite elements

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Lets talk about:

- Medical Treatment of Tumor
- Radio frequency ablation
- Why RFA Simulation is important
- Motivation
- This project in General

2. Computer-aided simulation of radio frequency ablation with finite elements

Introduction

2.1. About Errors in numerical appoaches

- see TUM dissertation

- There are different sources for errors following the simulation from the line from the real problem down to the discrete solution

- Idealization error: discrepancy between reality and the idealized reality and the idealized constitutive laws and boundary conditions -> Systems are often way more complex in reality, every patient is different

- Modeling errors: discrepancy between mathematical formulation and physical model -> e.g. using dimensionally reduced approaches, like linear dependencies or even constant parameters

- Discretization errors: discrepancy between the continous description and discrete discription of the model

- Solution errors: using iterative approximation methods and rounding errors

- It's basically a butterfly effect

- Optimizing one error source often conflicts with another one -> e.g. handling nonlinearity can cause fatal numerical errors (at least that's what Kroeger said ...)

2.2. Theory of finite elements

- Elliptical problems
- Using the cylindric domain
- Axial symmetrie - Torus elements

- Rewrite the equations to zylindric coordinates

2.3. This part is about the concrete PDEs itself

Laplace in kartesian coordinates:

$$\nabla^2 := \Delta := \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \tag{1}$$

Laplace in cylindric coordinates:

$$\Delta := \frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2 f}{\partial \varphi^2} + \frac{\partial^2 f}{\partial z^2} \tag{2}$$

Laplace in polar coordinates:

$$\Delta := \frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \varphi^2} \tag{3}$$

2.4. PDE for Electric potential

Three parts are interesting: - Inner domain
- Fixed Potential of electrodes
- Inner domain
- Outer boundary -> Robin

Constant material parameters:

2.4.1. Inner Domain

The PDE :

$$-\nabla \cdot (\sigma(x,y,z,t)\nabla\varphi(x,y,z,t)) = 0 \tag{4}$$

- Elliptical boundary problem
- Assuming constant material parameters: Equation becomes Laplaces equation, phi becomes time independant

$$\sigma\Delta\phi(x,y,z) = 0 \tag{5}$$

- Using zylindric domain, we can use cylindric coordinates

2.4.2. Electrodes

2.4.3. Outer boundary

The inner domain:

(6)

3. Applied FEM-Simulation

3.1. Grid generation / Triangulation

3.2. Graphical output

3.3. Numerical challenges

3.4. Optimization

3.5. MatLab vs C++

- Basically the performance advantages of using C++

3.6. Interpretation of numerical solutions

4. Summary and Outlook

4.1. Project Summary

This is the conclusion part

4.2. Current Research

- Research in the simulation of medical therapy methods

4.3. Other FEM projects and software

References

[1] Tim Kröger et. al. *Numerical Simulation of Radio Frequency Ablation with State Dependent Material Parameters in Three Space Dimensions*. Springer, 2006.

[2] Michael McLaughlin. *C++ Succinctly*. Syncfusion Inc., 2012.

[3] Physicists like to think that all you have to do is say 'These are the conditions now what happens next?'. *Richard Feynman*. The Character of Physical Law, 1965.

[4] Not only is the Universe stranger than we think it is stranger than we can think. *Werner Heisenberg*. Across the Frontiers, 1972.

A. Source code Visual C++

Listing 1: For loop to print numbers from 1 to 10

```
// Print numbers from 1 to 10
#include <stdio.h>
int main() {
  int i;
  for (i = 1; i < 11; ++i)
  {
    printf("%d ", i);
  }
  return 0;
}
```

B. Source code MatLab

TODO