Technische Universität Graz

Workshop on

Numerical Simulation of the Maxwell Equations

Graz, 17.–18.3.2008

O. Steinbach (ed.)

Berichte aus dem Institut für Numerische Mathematik

Book of Abstracts 2008/2

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Program

Monday, 17.3.2008	
9.00–10.00	M. Kaltenbacher (Universität Erlangen) Challenges in Computational Electromagnetics
10.00–10.30	Coffee
10.30–11.30	O. Biro (TU Graz) Computational Electrical Engineering – Achievements and Challenges
11.30–14.00	Lunch Break
14.00–15.00	J. Schöberl (RWTH Aachen) Low Frequency – High Frequency Maxwell Solvers
15.00–15.30	Coffee
15.30–16.30	M. Kuhn (TransLight, Jena) Simulation of Photonic Systems Using Locally Adapted Models
Tuesday, 18.3.2008	
9.00–9.45	L. Weggler (Universität des Saarlandes) Reformulation of the Double Layer Potential for Maxwell Equations
9.45–10.30	C. Pechstein (JKU Linz) FETI Methods for Multiscale PDEs
10.30–11.00	Coffee
11.00–11.45	S. Zaglmayr On locally exact high–order finite element sequences for computational electromagnetics

Computational Electrical Engineering – Achievements and Challenges

O. Bíró
TU Graz

The application of the method of finite elements to problems of electrical engineering in a wide frequency range has become state of the art in the last decade. Typical solutions to some practical electromagnetic problems are presented with the relevant formulations highlighted. Some difficulties encountered today are pinpointed to facilitate a discussion among the participants of the workshop about future trends and possible joint efforts towards overcoming the existing limitations.

Challenges in Computational Electromagnetics

M. Kaltenbacher
University of Erlangen–Nuremberg, University of Klagenfurt

In the last 20 years a lot of progress has been made in the numerical solution of Maxwell's equations. Among these are: correct discretization of Maxwell's equation by using Nédélec (edge) finite elements, fast solution approaches by applying appropriate geometric and algebraic multigrid methods and enhanced formulation for the nonlinear and hysteretic behavior of ferroelectric materials. Currently the main focus of research is towards multifield applications, in order to provide a realistic numerical computation of electromagnetic devices.
Within our talk we will concentrate on multifield problems and will demonstrate successfully applied coupling strategies as well as open problems by discussing the following practical examples:

- *Optimization of fast switching electromagnetic vales:* Fully coupled simulation of a whole switching cycle taking contact mechanics into account
- *Analysis of Magnet-Resonance-Imaging (MRI) scanners:* Motional electromotive force as a major cause for eddy currents leading to boil-off
- *Noise reduction in electric power transformers:* Modeling and simulation of load (Lorentz forces) and no-load (magnetostriction) noise

Simulation of Photonic Systems Using Locally Adapted Models

M. Kuhn
LightTrans GmbH Jena

Advanced photonic systems combine different types of optical elements such as lenses and nano- or micro-structured components. For those systems one single modelling technique is not feasible. Instead various modelling techniques have to be combined within a unified modelling platform in order to exploit their advantages. In particular a well balanced solution between accuracy and performance is required. In this talk, we discuss simulation techniques based on Domain Decomposition ideas and local approximations of the physical model. Some results, including designs of diffractive beam shaping elements and the simulation of optical systems, using the optical engineering software VirtualLab(TM) (www.lighttrans.com) are presented.

FETI methods for multiscale PDEs[1]

C. Pechstein[1], R. Scheichl[2]

[1]SFB F013, Johannes Kepler University Linz, [2]University of Bath

In this talk we consider a Poisson-type equation in two and three dimensions with a highly varying coefficient, i. e.,

$$-\nabla \cdot [\alpha \nabla u] = f \quad \text{in } \Omega \,,$$

and with some Dirichlet and/or Neumann boundary conditions on $\partial\Omega$. We are interested in solvers of the underlying finite element system which are robust with respect to the variation in $\alpha(\cdot)$. A great success has been made with FETI-type domain decomposition methods: If the domain Ω can be decomposed into regular subdomains Ω_i where $\alpha(\cdot)$ is constant (or at least only slightly varying) on each of the subdomains, one can construct robust preconditioners for the iterative solution of the discretized PDE. It has been shown that the condition number of the preconditioned system behaves like

$$\mathcal{O}(\max_i \,(1 + \log(H_i/h_i))^2) \,,$$

where H_i denotes the subdomain diameter and h_i the subdomain mesh size. This estimate is independent of the values of α, and in particular of the jumps across subdomain interfaces.

In the present work, we generalize these standard results on FETI methods. We have two applications in mind: (i) the case of coefficient jumps not aligned with the subdomain interfaces, and (ii) highly varying coefficients within the subdomains. The latter situation appears for example when considering Newton linearizations of nonlinear magnetic field problems. We propose modifications of the standard FETI preconditioners which depend only (very mildly) on the variation of the coefficients near the interfaces.

If we assume for each subdomain Ω_i, that the coefficient varies only mildly near the boundary, i. e., $\frac{\alpha(x)}{\alpha(y)} \leq \alpha_i^*$ for all x, y that are less than η_i away from the boundary $\partial\Omega_i$, but varies arbitrarily otherwise, we can even give a rigorous analysis. In this case we can show that the condition number can be bounded by

$$C \, \max_i \left(\alpha_i^* \left(\frac{H_i}{\eta_i} \right)^2 (1 + \log(H_i/h_i))^2 \right) ,$$

both in 2D and 3D. Provided the minimum of α in each subdomain Ω_i is attained in the boundary layer, this bound can be improved to linear dependence on H_i/η_i. This is confirmed in numerical experiments.

[1]This work has been supported by the Austrian Science Founds (FWF) under grant F1306.

Low Frequency – High Frequency Maxwell Solvers

J. Schöberl
RWTH Aachen

In this talk we outline the essential role of the de Rham complex for many aspects of numerical analysis of the (low frequency) Maxwell Equations, such as finite elements, preconditioning, and a posteriori error estimates. We rise the question, whether it is important also for the high frequency regime. Here, serveral discontinuous Galerkin schemes independent of de Rham have been successful very recently.

Reformulation of the Double Layer Potential for Maxwell Equations

L. Weggler
Universität des Saarlandes

We consider the boundary element method to solve problems of electromagnetic scattering. On the dicretised level a crucial task is the efficient generation of the corresponding layer potential matrices. For this purpose we deduce a new representation of the double layer potential in terms of well-known potentials. Not only in what concerns the numerical realisation, but also for theoretical studies, this can be advantageous.

On locally exact high–order finite element sequences for computational eletromagnetics

S. Zaglmayr[1], J. Schöberl[2]
[1]TU Graz, [2]RWTH Aachen

The goal of this work is the efficient computation of Maxwell boundary value problems on hybrid meshes using high–order Nedelec elements.
The concept of exact de Rham sequences

$$\mathbb{R} \xrightarrow{id} H^1(\Omega) \xrightarrow{\nabla} H(\mathrm{curl}, \Omega) \xrightarrow{\nabla\times} H(\mathrm{div}, \Omega) \xrightarrow{\nabla\cdot} L_2(\Omega) \xrightarrow{0} 0$$

perfectly fits into electromagnetics: the electric potential lies in H^1, the magnetic and electric fields are in $H(\mathrm{curl})$ and their flux fields in $H(\mathrm{div})$. Above sequence is exact – the range of one operator in the sequence is exactly the kernel the next operator, e.g. gradients fields exactly span the kernel of the curl–operator.
The innovation of our work is obeying the exactness of the de Rham sequence locally already in the FE construction process. Namely, in case of Nedelec elements, our FE basis includes an explicite basis of higher–order gradient fields. This yields a general, unified construction principle for for H(curl)–conforming finite elements. The constructed local exactness of the FE spaces allows for variable and arbitrary polynomial orders on each single entitiy of the mesh as well as independent approximaton orders for the kernel and the range space of the curl–operator.
Further practical advantages will be discussed by means of robust preconditioning and reduced basis gauging strategies.

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Erschienene Preprints ab Nummer 2006/1

2006/1	S. Engleder, O. Steinbach: Modified Boundary Integral Formulations for the Helmholtz Equation.
2006/2	O. Steinbach (ed.): 2nd Austrian Numerical Analysis Day. Book of Abstracts.
2006/3	B. Muth, G. Of, P. Eberhard, O. Steinbach: Collision Detection for Complicated Polyhedra Using the Fast Multipole Method of Ray Crossing.
2006/4	G. Of, B. Schneider: Numerical Tests for the Recovery of the Gravity Field by Fast Boundary Element Methods.
2006/5	U. Langer, O. Steinbach, W. L. Wendland (eds.): 4th Workshop on Fast Boundary Element Methods in Industrial Applications. Book of Abstracts.
2006/6	O. Steinbach (ed.): Jahresbericht 2005/2006.
2006/7	G. Of: The All–floating BETI Method: Numerical Results.
2006/8	P. Urthaler, G. Of, O. Steinbach: Automatische Positionierung von FEM–Netzen.
2006/9	O. Steinbach: Challenges and Applications of Boundary Element Domain Decomposition Methods.
2006/10	S. Engleder: Stabilisierte Randintegralgleichungen für äussere Randwertprobleme der Helmholtz–Gleichung
2007/1	M. Windisch: Modifizierte Randintegralgleichungen für elektromagnetische Streuprobleme.
2007/2	M. Kaltenbacher, G. Of, O. Steinbach: Fast Multipole Boundary Element Method for Electrostatic Field Computations.
2007/3	G. Of, A. Schwaigkofler, O. Steinbach: Boundary integral equation methods for inverse problems in electrical engineering.
2007/4	S. Engleder, O. Steinbach: Stabilized Boundary Element Methods for Exterior Helmholtz Problems
2007/5	O. Steinbach, G. Unger: A Boundary Element Method for the Dirichlet Eigenvalue Problem of the Laplace Operator
2007/6	O. Steinbach, M. Windisch: Modified combined field integral equations for electromagnetic scattering
2007/7	S. Gemmrich, N. Nigam, O. Steinbach: Boundary Integral Equations for the Laplace–Beltrami Operator.
2007/8	G. Of: An efficient algebraic multigrid preconditioner for a fast multipole boundary element method.
2007/9	O. Steinbach (ed.): Jahresbericht 2006/2007.
2007/10	U. Langer, O. Steinbach, W. L. Wendland (eds.): 5th Workshop on Fast Boundary Element Methods in Industrial Applications. Book of Abstracts.
2008/1	P. Urthaler: Schnelle Auswertung von Volumenpotentialen in der Randelementmethode.