Welcome!

May 18, 2015, Faculty EEMCS, TU Delft

Seminar: **Recent Developments in Fast Helmholtz Solvers**

Organizing committee: Domenico Lahaye, Jok Tang and Kees Vuik

Celebration

Hermann Ludwig Ferdinand von Helmholtz

1821 –1894

German physician and physicist who made significant contributions to several widely varied areas of modern science.

Celebration

Occasion:
Complex Shifted Laplace preconditioner invented 10 years ago.

- Y.A. Erlangga, ***A robust and efficient iterative method for the numerical solution of the Helmholtz equation***, PhD Thesis, Delft, 2005

- Y.A. Erlangga, C.W. Oosterlee and C. Vuik, ***A Novel Multigrid Based Preconditioner For Heterogeneous Helmholtz Problems***, SIAM J. Sci. Comput., 27, 1471-1492, 2006

Helmholtz equation

The Helmholtz equation without damping in a domain Ω:

$$-\Delta u(x,y) - k^2(x,y)u(x,y) = g(x,y)$$

u is the pressure field,
k is the wave number,
g is the point source function.

Often, absorbing boundary conditions are used for the problem.

Helmholtz problem

- Discretization by a finite-difference or finite-element stencil
- Resulting linear system: **Au = g**
- Properties of **A**:
  - Large and sparse
  - Complex-symmetric
  - Indefinite for large *k*

- Linear system is often solved by a Krylov-subspace method

Preconditioned problem

- Equivalent linear system

$$\boldsymbol{M^{-1}Au = M^{-1}g}$$

where *M* is the preconditioning matrix.

- Desired properties of the preconditioner:
  - Better spectral properties of $M^{-1}A$.
  - Cheap to perform $M^{-1}r$.

Helmholtz Laplace-type Preconditioning

- Laplace — Bayliss and Turkel (1983)
- Definite shifted Laplace — Laird (2000)
- Complex shifted Laplace — Erlangga, Vuik, Oosterlee (2005)

Various other classes of Helmholtz preconditioners have been considered in the past.

Helmholtz Laplace-type operator

$$M(\alpha,\beta) = -\Delta - (\alpha - \beta i)k^2, \qquad \alpha,\beta \in \mathbb{R}$$

- α = 0, β = 0: Bayliss and Turkel
- α = -1, β = 0: Laird
- α = 1, β = 0.5: Erlangga, Vuik and Oosterlee

Seminar Program

14:00 – 14:30: Dr. Rene-Edouard Plessix
Principal researcher at Shell Global Solutions International.
Talk: *Frequency-Domain or Time-Domain Wave Equation in Seismic Imaging*

14:30 – 15:00: Dr. Christiaan Stolk
Associate professor at University of Amsterdam.
Talk: *Accelerating Helmholtz Solvers using an Outer Classical-Multigrid Iteration*

15:00 – 15:30: Dr. Michel Tournour
Product development manager at Siemens Industry Software.
Talk: *Higher Order Finite Element Modeling for the Helmholtz Equation*

Seminar Program

15:30 – 16:00: Coffee break

16:00 – 16:30: Prof.dr. Ira Livshits
Associate professor at Ball State University
Talk: Multigrid with Multiple Coarsening for the Helmholtz Equation

16:00 – 17:00: Prof.dr.ir Kees Vuik
Full professor at Delft University of Technology
Talk: Multi-level Krylov: the Next Generation Helmholtz Solver

17:00 – 18:00: Closing by Dr. Domenico Lahaye, Drinks and Demonstration

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Seminar Program

14:00-14:30: Talk by Dr. R.-E. Plessix

14:30-15:00: Talk by Dr. C.C. Stolk

15:00-15:30: Talk by Dr. M. Tournour

15:30-16:00: Coffee break

16:00-16:30: Talk by Prof.dr. I. Livshits

16:30-17:00: Talk by Prof.dr.ir. C. Vuik

17:00-18:00: Closing by Dr. D.J.P. Lahaye and Reception