PGE 383 or CAM 383 (Unique Number 17505)
Scientific Computing with Emphasis on Finite Element Methods for PDE's

TTH 9:30 -11:00

RLM 5.126

Instructor: Mary Fanett Wheeler

Office: SHC 414; Office Hours: MW: 1:30 - 2:30 and by appointment
TA (Office Hours SHC 413: W,Th: 4 - 5:30 pm and by appointment): Bahareh Momken
Monday Tutorial (Time TBD): Sharon Lozano

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Course Objectives

- Design and analyze algorithms for solving mathematical problems that arise in computational science and engineering with emphasis on differential equations
- Survey basic numerical algorithms: general strategy, linear equations, linear least squares, nonlinear equations, optimization, interpolation, numerical integration and differentiation
- Develop basic mathematical formulation and understanding of the finite element, finite volume, and finite difference methods for partial differential equations.
- Apply tools for several engineering applications arising in porous media and computational fluids.

Texts

- **Main Textbook**: Heath, M. *Scientific Computing, An Introductory Survey*, McGraw Hill, NY (1997).
- Lecture Notes can be found at http://www.cse.uiuc.edu/heath/scicomp/
- *Class Notes on PDE's*
- **References**
  - Brezzi, F. and Fortin, M. , *Mixed and Hybrid Finite Element Methods*, Springer-Verlag, NY (1991).
  - Ciarlet, P. and Lions, L. *Handbook of Numerical Analysis: Volume I, Finite Difference Methods*, North Holland, NY (1990).
  - Ciarlet, P. and Lions, L. *Handbook of Numerical Analysis: Volume II, Finite Element Methods*, North Holland, NY (1991).
  - Fortin, M. and Glowinski, R. , *Augumented Lagrangian Methods: Applications to the Numerical Solution of Boundary Value Problems*, North Holland, NY (1983).

- Fox, G. , Williams, R. and Messina, P. , em Parallel Computing Works, Morgan Kaufman, San Francisco, (1994).
- Briggs, W. , *A Multigrid Tutorial*. SIAM, Philadelphia (1987) .
- Johnson, C. , *Numerical Solutions of Partial Differential Equations by the Finite Element Method*, Cambridge University Press, Cambridge, (1987).
- Kalia, R. and Vashishta, P. , *Toward Teraflop Computing abd New Grand Challenge Applications*, Nova Science, NY (1995).
- LeVeque, R. , *Numerical Methods for Conservation Laws*, Birkhauser, Verlag, Basel (1990).
- McCormick, S. , *Multilevel Adaptive Methods for Partial Differential Equations*, SIAM, Philadelphia (1989).
- McCormick, S. , *Multigrid Methods*, SIAM, Philadelphia (1987).
- Pironneau,O. , *Finite Element Methods for Fluids*, John Wiley and Sons, NY (1989).
- Press, W. , Flannery. B. , Teukolsky, S. and Vetterling W. , *Numerical Recipes*, Cambridge, NY (1989).
- Szabo, B. and Babuska, I. , *Finite Element Analysis*, John Wiley and Sons, NY (1991).
- Thompson, J. and Martin, C. , *Numerical Grid Generation*, North Holland, NY (1985).
- Collection of Research Papers

Course Outline

- Scientific Computing (1 Lecture)
- Systems of Linear Equations (2 Lectures)
  - Gaussian Elimination and LU Factorization
  - Norms, Condition Numbers, and Accuracy of Solutions
- Linear Least Squares (2 Lectures)
  - Normal Equation Method
  - Orthogonization Method
- Nonlinear Equations (2 Lectures)
  - 1d approaches
  - Systems
- Optimization (2 Lectures)
  - Local versus Global
  - Multidimensional Unconstrained

  - Nonlinear Least Squares
  - Constrained
- Interpolation (Polynomial and Piecewise Polynomial) (2 Lectures)
- Numerical Integration (2 Lectures)
  - Numerical Quadrature
  - Richardson Extrapolation
- Initial Value Problems for ODE's (2 Lectures)
  - Accuracy and Stability
  - Stiff ODEs
  - Survey of Numerical Methods
- PDE's (12 Lectures)
  - Finite Element and Finite Difference Methods for Twopoint Boundary Value Problems
    * Construction of Finite Element Spaces
    * Approximation Properities and Error Bounds
  - Finite Element and Finite Difference Methods for Multidimensional Elliptic Problems
    * Construction of Finite Element Spaces
    * Approximation Properities and Error Bounds
    * Solution Techniques (Iterative Methods, Conjugate Gradient and Conjugate Residual, Multigrid, Domain Decomposition)
  - Discretization and Solution Techniques for Parabolic and Hyperbolic Partial Differential Equations
  - Operator/Time Splitting for Reaction, Advection, Diffusion Equations
- Applications: Single Phase Flow, Miscible Displacement, Twophase Flow

Grading

- Homework (Problems and Computer Programs) (30 percent)
- Test (30 percent)
- Final (40 percent)

Prerequisite: Graduate Standing
Evaluation Plan: Evaluation will be conducted at the end of the semester.