CPSC 403/542A
Tentative course outline

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To find out about grading, hours, handouts, etc., surf to *http://www.cs.ubc.ca/spider/ascher/542-403.html*

1. Ordinary differential equations: Introduction
   - Initial and boundary value problems
   - Examples
   - Differential equations with constraints
   - Dynamical systems

Part I: Initial Value Problems (IVP)

2. Basic schemes, basic concepts
   - A simple scheme: Forward Euler
   - Convergence, accuracy, consistency and 0-stability
   - Absolute stability
   - Stiffness: Backward Euler
   - A-stability, stiff stability
   - Symmetry: Trapezoidal scheme
3. One step methods
   - Basic Runge-Kutta methods and general formulation
   - Convergence and order for Runge-Kutta methods
   - Error estimation and control
   - Implicit Runge-Kutta and collocation methods
   - Runge-Kutta software

- Special topics

4. Linear multistep methods
   - The most popular families: Adams-Bashforth, Adams-Moulton, Backward Differentiation Formulae (BDF)
   - Order, 0-stability and convergence
   - Absolute stability and stiff decay
   - Implementation issues: error estimation, predictor-corrector techniques, step selection and modification, nonlinear systems solution
   - Multistep software

Part II: Differential-algebraic equations (DAE)

5. Differential equations with algebraic constraints
   - More on DAEs: index
   - Index reduction and stabilization: ODE with invariant
   - DAE as limit of stiff ODE
   - BDF, collocation, Runge-Kutta and projected methods
   - DAE software

Part III: Boundary value problems (BVP)

6. More on BVP theory
   - Green's function and conditioning
   - Nonlinear problems
7. Shooting
   - Simple shooting: a simple method and its limitations
   - Multiple shooting: basic method; stability bound
8. Difference schemes
   - Simple schemes: Midpoint and trapezoidal
   - Convergence, accuracy, consistency and stability
   - Solving linear problems: elimination for block matrices; stability
   - Solving nonlinear problems: Newton's method and continuation methods

- Scalar, second order ODE
- Collocation and Runge-Kutta
- Convergence acceleration techniques
- BVP software
- Special topics

GRADING
30-40% Assignments
10-20% Midterm
50% Final (403) *or* Project (542)
A minimum of 40% in the final exam is required to pass the course

TEXT: U. Ascher and L. Petzold, *Computer Metods for Ordinary Differential Equations and Differential-Algebraic Equations*, SIAM, 1998.

REFERENCES:

- [4] – extensive treatment of numerical methods for nontiff initial value ODEs
- [5] – extensive treatment of numerical methods for stiff initial value ODEs and DAEs
- [1] – extensive treatment of numerical methods for boundary value ODEs
- [9, 7, 3] – texts for numerical initial value ODEs
- [6] – older monograph for boundary value ODEs
- [2] – book on initial value DAEs
- [8] – simple methods for dynamical systems
- [10] – numerical analysis of methods for dynamical systems

References

[1] U. M. Ascher, R. M. Mattheij, and R. D. Russell. *Numerical Solution of Boundary Value Problems for Ordinary Differential Equations.* Prentice-Hall, 1988.

[2] K. E. Brenan, S. L. Campbell, and L. R. Petzold. *Numerical Solution of Initial Value Problems in Differential-Algebraic Equations.* North-Holland, 1989.

[3] C. W. Gear. *Numerical Initial Value Problems in Ordinary Differential Equations.* Prentice-Hall, 1971.

[4] E. Hairer, S. P. Norsett, and G. Wanner. *Solving Ordinary Differential Equations I.* Springer-Verlag, second edition, 1993.

[5] E. Hairer and G. Wanner. *Solving Ordinary Differential Equations II.* Springer-Verlag, 1991.

[6] H. B. Keller. *Numerical Solution of Two Point Boundary Value Problems.* SIAM, 1976.

[7] J. D. Lambert. *Numerical Methods for Ordinary Differential Systems.* Wiley, 1991.

[8] T. S. Parker and L. O. Chua. *Practical Numerical Algorithms for Chaotic Systems.* Springer-Verlag, 1989.

[9] L. F. Shampine. *Numerical Solution of Ordinary Differential Equations.* Chapman & Hall, 1994.

[10] A.M. Stuart and A.R. Humphries. *Dynamical systems and numerical analysis.* Cambridge University Press, Cambridge, England, 1996.