Iowa State University
Department of Economics
Econ 509
Summer 2008

P. Marcelo Oviedo
oviedo@iastate.edu
279 Heady Hall
www.econ.iastate.edu/faculty/oviedo

Applied Numerical Methods in Economics

http://www.econ.iastate.edu/classes/econ509/Oviedo/
Class location: 274 Heady Hall Class time: M,W,F, from 16:00 to 18:15
Office hours: by appointment TA: Na Jin, jinna@iastate.edu

Course Description:

This is a six-week graduate course in applied numerical methods in economics.

Economists use mathematical models and numerical methods to solve economic problems. The solution strategy of many economic problems consists in three steps. The first involves the reformulation of the economic problem to express it as a mathematical problem; the second requires solving the mathematical problem; and the third step consists in interpreting the mathematical solution in economic terms. This course focuses on the second step of this solution strategy as it is intended to endow students with the knowledge on a set of numerical techniques commonly used to solve the mathematical problems that typically arise in economic problems.

Knowing how to apply numerical methods to solve economic problems is essential for advanced economic students because a rich set of problems in economics and finance, specially those that incorporate dynamic and stochastic aspects of economic decisions, cannot be solved analytically using standard mathematical techniques. To obtain insights from these increasingly complex economic models, economists appeal to numerical solutions.

Insofar as the course is intended for students who seek not to become developers, but users of numerical algorithms, the course emphasizes applied numerical methods over mathematical proofs. Nevertheless, the course provides an appropriate mix of numerical analysis theory and practical scientific computation. Application examples in several fields of economics as agricultural economics, resource economics, industrial organization, finance, and macroeconomics, just to mention a few, are going to be part of the course.

Three reasons suggest that the material taught in this class might be of interest to students in sciences different from economics. One is that, to a large extent, physical scientists also follow the three-step solution strategy mentioned above; the second reason is that the mathematical problems they came across are similar to the mathematical problems economists come across; and the third reason is that several techniques covered in this course, far from being exclusive of the economic science, are techniques commonly encountered in numerical analysis and scientific computation in general.

The class meets three times a week and students are expected to solve weekly assignments. Completing the assignments is essential to understanding how to use numerical techniques in practice. The programming software/language of the course is Matlab, which is available in the computer lab of the Department of Economics, although students are also allowed to write their codes in FORTRAN and C++.

Course textbooks:

- The course is taught mainly following two textbooks:
  - *Applied Computational Economics and Finance*, by Mario **M**iranda and Paul **F**ackler; MIT Press, 2002.
  - *Numerical Analysis and Scientific Computation*, by **J**effery **L**eader; Pearson Addison-Wesley, 2004
- Other reference books include:
  - *Applied Numerical Methods with Matlab for Engineers and Scientists*, by Setven C. Chapra; McGraw Hill, 2005.
  - *Computational Economics*, by David Kendrick, P. Ruben Mercado, and Hans Amman; Princeton University Press, 2006.
  - *Computational Methods for the Study of Dynamic Economies* edited by Ramón Marimon and Andrew Scott; Oxford University Press, 1999.
  - *Dynamic Economics*, by Jérôme Adda and Rusell Cooper; MIT Press, 2003.
  - *Numerical Methods in Finance: A Matlab-Based Introdution*, by Paolo Brandimarte; John Wiley & Sons, Inc., 2002.
  - *Numerical Methods in Economics*, by **K**enneth **J**udd, MIT Press, 1998.
  - *Numerical Methods for Engineers*, by Steven C. Chapra and Raymond P. Canale, fifth edition,McGraw-Hill 2006.

The course outline below uses the acronyms **MF**, **JL**, and **KJ** to refer to the three books whose author's initials have been written in boldface in the above lists. References to the other texts in the list will be made in class when necessary.

Requirements:

There will be four or five assignments and a comprehensive take-home final exam. Assignments account for 70% of the final grade and the final exam for the remaining 30%. Students are allowed to solve the assignments (but not the final exam) in pairs. However, pairs cannot be repeated except after exhausting all possible pairs. Students solving assignments in pairs have to submit one set of solutions indicating the name of the students in the pair. Notwithstanding this, every student should be able to come to the instructor's office and explain the reasoning followed to solve the assignment. Failure in this regard will result in a unsatisfactory grade.

No late homework will be accepted. Homework deadlines will be announced at the time the assignments are given out. The submission of homework solutions has two parts. First, students are required to submit electronic copies of the solution document (a text file or similar) and the computer code used to find the solutions. This part of the submission should be made in a single compressed file (preferably, a zip file) with the following file name: `names_HWx.zip`, where "names" identifies who the homework belongs to and "x" is the homework number. The submission has to be made to the TA and the instructor, at the same time. Second, students are required to turn hard copies of both the solution document and the computer codes wrote to solve the exercises.

A computer code that does not run will be graded lower than inaccurate but running computer code. Well documented codes will receive higher grades.

Prerequisites

The mathematical background required for this course includes (sound) college-level calculus and matrix algebra; for the material taught in the final week, some knowledge on dynamic programming is desirable. A refreshing reading on linear algebra before starting the course is recommended. A basic knowledge of economic theory is helpful but not necessary. Non-economic students should not hesitate to ask the instructor for clarifying explanations when they consider that the lack of economic background hampers their ability to understand the numerical methods explained in class.

To have all students on the same baseline, the instructor will presume that students have no experience at programming with Matlab. An elementary introduction to Matlab is given during the first week of classes.

Course Outline:

Week 1

1. Introduction to numerical methods and to Matlab;
   - KJ 1.2 to 1.4.
   - Griffiths D. (2001): "An Introduction to Matlab", University of Dundee (pdf file available from the course website).
   - Gerald Recktenwald, Course Material accompanying the book "Numerical Methods with MATLAB: Implementations and Applications" (Prentice Hall, 2000), Lecture Slides corresponding to Chapters 2 and 3 of the book. Available at http://web.cecs.pdx.edu/∼gerry/nmm/course/
2. programming style and programming documentation.
   - Gerald Recktenwald, Lecture Slides corresponding to Chapter 4.
   - Johnson R. (2002): "Matlab Programming Style Guidelines", Datatool (linked from course website).
3. Computer Arithmetic; MF Appendix 2A; KJ pg. 29; JL 1.7.
4. Systems of linear equations: LU decomposition; Gaussian elimination; the QR and Cholesky decompositions.
   - MF 2.1 and 2.2; JL 2.1 to 2.3 and 2.4.

Week 2

1. Systems of linear equations (cont.): iterative method, Jacobi and Gauss-Seidel algorithms.
   - MF 2.6; JL 2.6 to 2.8, 3.1 and 3.2; (KJ 3.1, 3.2, and 3.6)
2. Nonlinear equations: bisection method; inverse linear interpolation; and function iteration.
   - MF 3.1 and 3.2; JL 1.1 and 1.3; (KJ 4.1 to 4.4 and 5.1).
3. Nonlinear equations (cont.): Newton's method, secant method and Broyden's method. Problems with Newton's method. Choosing a solution method.
   - MF 3.3 to 3.6; JL 1.2, and 1.4 to 1.9; (KJ 4.1 to 4.4 and 5.3)

Week 3

1. Complementarity problems
   - MF 3.7
2. Finite-dimensional optimization: derivative-free methods (line search method, golden search method, and the Nelder-Mead method.
   - MF 4.1; JL 7.1, 7.5, and 7.6.
3. Finite dimensional nonlinear optimization (cont.): Newton-Raphson method.
   - MF 4.2; JL 7.3.
4. Finite dimensional nonlinear optimization (cont.): Quasi-Newton methods.
   - MF 4.3; JL 7.2; (KJ 5.5)

Week 4

1. Special optimization problems in economics and constrained-optimization problems.
   - MF 4.5 and 4.6; (KJ 4.7)
2. Numerical Integration: Newton-Cotes methods; Gaussian quadratures; other quadrature methods.
   - MF 4.5 and 4.6; JL 5.1 to 5.5; (KJ 7.1 to 7.3).
3. Numerical Integration: Monte-Carlo and Quasi-Monte Carlo methods. The integration tool kit in MF.
   - MF 5.3 to 5.5; (KJ 8.1 and 8.2).
4. Numerical differentiation and initial value problems
   - MF 5.6 and 5.7; JL 6.1; (KJ 2.5 and 7.3)

Week 5

1. Interpolation principles

   - MF 6.1.

2. Polynomial interpolation: Lagrange interpolating polynomials; piecewise linear interpolation; cubic splines; Chebychev interpolating polynomials.

   - MF 6.2 to 6.4; JL 4.1 to 4.4. (KJ chapter 6)

3. Multidimensional interpolation. Choosing an approximation method.

   - MF 6.5 and 6.6; (KJ 7.5)

4. The collocation method and the MF approximation toolkit

   - MF 6.7 and 6.8.

Week 6

1. Discrete time, discrete state, dynamic models.

   - MF 7.1 to 7.6; (KJ 3.11, 12.1, 12.3, and 12.4)

2. Discrete time, continuous state, dynamic models: theory.

   - MF 8.1 to 8.6; (KJ 12.1, 12.5, and 12.7 to 12.9)

3. Discrete time, continuous state, dynamic models: methods.

   - MF 9.1 to 9.9.