ECON 509: Numerical Methods in Economics

Spring 2016: Monday/Wednesday/Friday 10:00 - 10:50
Room: 68 (Computer Lab)
http://github.com/IASTATEECON509

Ivan Rudik   irudik@iastate.edu

Course Overview

Course Objective: The objective of this course is to familiarize you with the fundamentals of computation, and a set of state-of-the-art methods, primarily for large-scale dynamic modeling. In this course you should learn why we need computational methods for certain types of problems, the theory behind the methods, and most importantly, how to use them in practice. The course begins with the basics of computing, then moves into optimization and methods for dynamic economic models, and if there is time we will cover Monte Carlo methods and empirical techniques. The beginning of the course is heavy on theory to understand what is happening inside your machine when solving numerical models. As we begin studying techniques to solve economic problems you will also apply them in practice. Keep in mind this is not a programming course. Beyond the first week or two we will be solely focusing on methodology and not programming.

Prerequisites: ECON 500 and ECON 501, or ECON 600 and ECON 601.

Readings: Miranda and Fackler (2002) will be referred to frequently and is recommended. Nocedal and Wright (2006) is also highly useful as a detailed reference for optimization. Miranda and Fackler (2002) and Nocedal and Wright (2006) are available as eBooks in the ISU library. The remainder of the required readings will be from journal articles or excerpts from texts which will be accessible online.

Grading: 10% of your grade is class participation, 45% of your grade is the final project, and 45% of your grade is the problem sets.

Lab Sessions: We will occasionally hold lab sessions in class to practice the methods we learn. These classes will be located in the department computer lab. In the lab sessions we will be using MATLAB. MATLAB was selected due to their ease of learning for computing novices, and that many packages exist for these environments to employ the methods we will learn and practice. Much of what we do can be ported to R, Python, Julia, C++ and other popular languages in economics.

Office Hours: By appointment.

Contacting Me: Please put ECON 509 in the subject line of all e-mails and I will respond within 24 hours.

Assignments

1. Problem sets will be due periodically. You must submit your code on Github (url above) to your group's repository as well as a separate pdf of your output and results. You may work in a group **no larger than three people**. Groups should turn in one assignment with all

members' names on the front page of your submitted pdf. You may use any programming language you wish as long as the code is *clearly commented.*

2. There will be a final project for the course, due at the end of the semester, where each student will submit the beginning of a research paper. In week 9 each student will present a short proposal for the final project to obtain feedback from the class. In week 15 each student will present their completed work which should have a first-take at a numerical model and preliminary results. The paper should be 5-10 pages and should:
   - Clearly state the economic question you are answering and why it is important
   - Have a one page literature review
   - Analytically develop the model
   - Describe how you solve the model
   - Display results

Course Schedule

1 Git and MATLAB Tutorial

2 Introduction to Computation

Theory

Miranda and Fackler (2002, Chapters 1, 2, and 5); Judd (1998, Chapters 2, 3 and 7)

3 Rootfinding and Optimization: Basics and Advanced Methods

Theory

Miranda and Fackler (2002, Chapters 3 and 4); Judd (1998, Chapter 4 and 5); Nocedal and Wright (2006, Chapters 2-6)

4 Optimal Control: Theory, Methods, and Applications

Theory

Caputo (2005); Judd (1998, Chapter 10); Trimborn et al. (2008); Brunner and Strulik (2002)

Application

Goulder and Mathai (2000); Lemoine and Rudik (2014)

5 Dynamic Programming: Methods and Applications

Theory

Ljungqvist and Sargent (2004); Adda and Cooper (2003)
Bellman equations, contraction mappings, euler equations

Application

Rudik (2015); Lemoine and Traeger (2014); Traeger (2014); Springborn and Sanchirico (2013); Cai et al. (2015)

6 Final Project Proposals

7 Methods for Accelerating and Improving Approximation in Dynamic Programming

Theory

Smolyak (1963); Judd et al. (2014); Puterman and Shin (1978); Carroll (2006); Malin et al. (2011); Judd et al. (2011a,b, 2015); Winschel and Kratzig (2010); Maliar and Maliar (2015)

8 Maximum Likelihood

9 Markov Chain Monte Carlo

https://www.mathworks.com/help/stats/examples/bayesian-analysis-for-a-logistic-regression-model.html

Theory

Chib and Greenberg (1995, 1996)

Application

Orlik and Veldkamp (2014); Lieli and Springborn (2012); Lemoine, Rosenthal, and Rudik (Learning the Climate Sensitivity)

10 Final Project Presentations

References

Adda, Jerome and Russell W Cooper (2003) *Dynamic Economics: Quantitative Methods and Applications*: MIT press.

Brunner, Martin and Holger Strulik (2002) "Solution of perfect foresight saddlepoint problems: A simple method and applications," *Journal of Economic Dynamics and Control*, Vol. 26, No. 5, pp. 737–753.

Cai, Yongyang, Kenneth L Judd, and Thomas S Lontzek (2015) "The Social Cost of Carbon with Economic and Climate Risks," *arXiv preprint arXiv:1504.06909*.

Caputo, Michael Ralph (2005) *Foundations of dynamic economic analysis: optimal control theory and applications*: Cambridge University Press.

Carroll, Christopher D. (2006) "The method of endogenous gridpoints for solving dynamic stochastic optimization problems," *Economics Letters*, Vol. 91, No. 3, pp. 312–320.

Chib, Siddhartha and Edward Greenberg (1995) "Understanding the Metropolis-Hastings Algorithm," *The American Statistician*, Vol. 49, No. 4, pp. 327–335.

——— (1996) "Markov Chain Monte Carlo Simulation Methods in Econometrics," *Econometric Theory*, Vol. 12, No. 3, pp. 409–431.

Goulder, Lawrence H. and Koshy Mathai (2000) "Optimal CO2 Abatement in the Presence of Induced Technological Change," *Journal of Environmental Economics and Management*, Vol. 39, No. 1, pp. 1–38.

Judd, Kenneth L. (1998) *Numerical Methods in Economics*, Cambridge, MA: MIT Press.

Judd, Kenneth L., Lilia Maliar, and Serguei Maliar (2011a) "How to Solve Dynamic Stochastic Models Computing Expectations Just Once."

——— (2011b) "Numerically stable and accurate stochastic simulation approaches for solving dynamic economic models," *Quantitative Economics*, Vol. 2, No. 2, pp. 173–210.

Judd, Kenneth L., Lilia Maliar, and Serguei Maliar (2015) "Numerically stable and accurate stochastic simulation approaches for solving dynamic economic models," *Quantitative Economics*, Vol. 2, No. 2, pp. 173–210.

Judd, Kenneth L., Lilia Maliar, Serguei Maliar, and Rafael Valero (2014) "Smolyak method for solving dynamic economic models: Lagrange interpolation, anisotropic grid and adaptive domain," *Journal of Economic Dynamics and Control*, Vol. 44, pp. 92–123.

Lemoine, Derek and Ivan Rudik (2014) "Steering the Climate System: Using Inertia to Lower the Cost of Policy," *University of Arizona Working Paper 14-03*.

Lemoine, Derek and Christian Traeger (2014) "Watch Your Step: Optimal policy in a tipping climate," *American Economic Journal: Economic Policy*, Vol. 6, No. 1.

Lieli, Robert P. and Michael Springborn (2012) "Closing the Gap between Risk Estimation and Decision-Making: Efficient Management of Trade-Related Invasive Species Risk," *Review of Economics and Statistics*, Vol. 95, No. May, pp. 632–645.

Ljungqvist, Lars and Thomas J Sargent (2004) *Recursive Macroeconomic Theory*: MIT press.

Llc, Ziena Optimization (2014) "KNITRO Documentation."

Maliar, Lilia and Serguei Maliar (2015) "Merging Simulation and Projection Approaches to Solve High-Dimensional Problems with an Application to a New Keynesian Model," *Quantitative Economics*, Vol. 6, pp. 1–47.

Malin, Benjamin A., Dirk Krueger, and Felix Kubler (2011) "Solving the multi-country real business cycle model using a Smolyak-collocation method," *Journal of Economic Dynamics and Control*, Vol. 35, No. 2, pp. 229 – 239, Computational Suite of Models with Heterogeneous Agents II: Multi-Country Real Business Cycle Models.

Miranda, Mario J. and Paul L. Fackler (2002) *Applied Computational Economics and Finance*, Cambridge, MA: MIT Press.

Nocedal, J. and S. J. Wright (2006) *Numerical Optimization*, New York: Springer, 2nd edition.

Orlik, A and L Veldkamp (2014) "Understanding uncertainty shocks and the role of the black swan."

Puterman, Martin L. and Moon Chirl Shin (1978) "Modified Policy Iteration Algorithms for Discounted Markov Decision Problems," *Management Science*, Vol. 24, No. 11, pp. pp. 1127–1137.

Rudik, Ivan (2015) "The Fragility of Robustness: Climate Policy When Damages are Unknown."

Rust, John (1987) "Optimal Replacement of GMC Bus Engines: An Empirical Model of Harold Zurcher," *Econometrica*, Vol. 55, No. 5, pp. 999–1033.

Smolyak, S. (1963) "Quadrature and Interpolation Formulas for Tensor Products of Certain Classes of Functions," *Soviet Mathematics, Doklady*, Vol. 4, pp. 240–243.

Springborn, Michael and James N. Sanchirico (2013) "A density projection approach for non-trivial information dynamics: Adaptive management of stochastic natural resources," *Journal of Environmental Economics and Management*, Vol. 66, No. 3, pp. 609–624.

Traeger, Christian (2014) "A 4-Stated DICE: Quantitatively Addressing Uncertainty Effects in Climate Change," *Environmental and Resource Economics*, Vol. 59, No. 1, pp. 1–37.

Trimborn, Timo, Karl-Josef Koch, and Thomas M. Steger (2008) "Multidimensional Transitional Dynamics: a Simple Numerical Procedure," *Macroeconomic Dynamics*, Vol. 12, No. 03, pp. 301–319.

Winschel, Viktor and Markus Kratzig (2010) "Solving, Estimating, and Selecting Nonlinear Dynamic Models Without the Curse of Dimensionality," *Econometrica*, Vol. 78, No. 2, pp. 803–821.