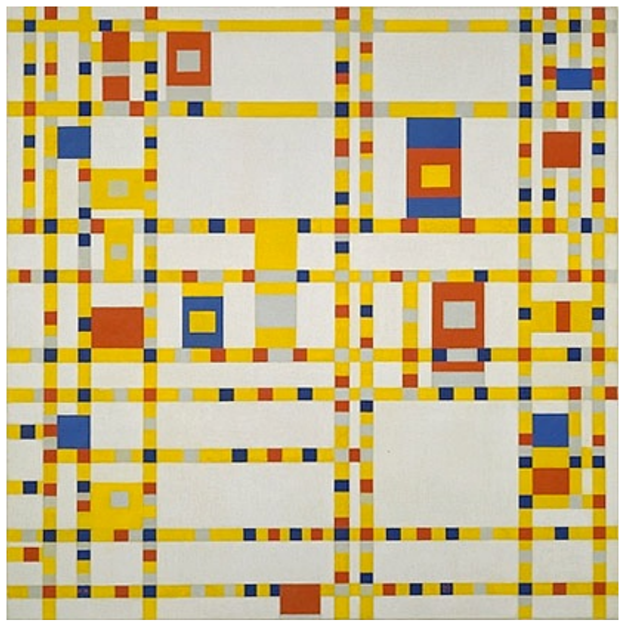
# CSS 610: Agent-Based Modeling and Simulation

Spring 2021

### Motivation for the Course

Interactions between people are the main subjects studied in the social sciences. Agent computing is a relatively new methodology for modeling such interactions. In *agent-based models* (*ABM*) a population of data structures/objects representing individuals is instantiated, given rules of interaction (object methods), and then allowed to interact. One then looks for systematic regularities to emerge at the macro-level. The shorthand for this is that aggregate structures "grow" from the bottom-up. No (explicit) equations govern the macrostructure in multi-agent modeling; if any equations are present, they are used by individual agents for decision-making. This new methodology is particularly useful for modeling (1) heterogeneous agents having (2) bounded rationality who (3) interact directly with one another (social interactions) through networks (4) out of equilibrium.



*Multi-agent systems* (*MAS*) are an emerging paradigm within computer science: for artificial intelligence (*AI*), distributed computation, and electronic commerce, among others. Increasingly, computer systems are being designed not from the 'top down,' in which each state is conceived and tested in advance, but rather from the 'bottom up' in which component behaviors are specified and the overall system is treated as *emergent*. New tools for the creation of agent systems in software are becoming more powerful and user-friendly.

In the field of ecology, agent models are known as *individual-based models* (*IBMs*) and have been used mostly to model animal groups (e.g., bird flocks) and mammal populations. At the fringes of biology so-called *artificial life* (*ALife*) models make use of *ABM* ideas.

In this course we will build a wide range of agent-based models of social and economic phenomena, including market processes, the evolution of social norms, customs, conventions, and institutions (e.g., residential segregation), the formation of multi-agent groups and organizations (e.g., firms), and the long-run evolution of whole societies. The methodological issues to be examined across models include the role of randomness (e.g., random number generation, variance reduction techniques), path-dependence (e.g., information content of single realizations), emergence (including self-organization and spontaneous order), the production and control of computational artifacts, estimation, verification and validation, and graphical representation/visualization of ABM output. This is a project-oriented course in which students will learn how to create ABMs in software.

**Rob Axtell**

Department of Computational and Data Sciences
College of Science
375 Research Hall
Fairfax, VA 22030
(703)-993-9302
rax222@gmu.edu

External Professor
Santa Fe Institute
1399 Hyde Park Road
Santa Fe, NM 87501

**Meets** Wednesdays, 4:30-7:10 7:20-10:00 PM — 205 225 Innovation Hall

**Website** ~~https://www.dropbox.com/home/CSS%20610-ECON%20895%20Spring%202021~~

**Office hours** I have an 'open door' policy  if my door is open you are welcome to stop in. I will be on campus each Wednesday this semester, assuming satisfactory completion of COVID-19 protocols. Karen Underwood knows my schedule. The best time to see me is in the afternoon.

## Texts

There is no satisfactory graduate-level textbook for this material, thus we will work from several books. Some sections from my textbook manuscript (*Foundations of Agent Computing*) will be distributed via the website as reading assignments some weeks. We will read Schelling (1978) and go through most of *Growing Artificial Societies* (weeks 1, 2, 9 and 10). If you have never done any agent modeling then Wilensky and Rand will be useful. It has good discussions and working code but is not very technical. It is based on NetLogo, which is fine to use for the homework assignments and the term project. If you are not using NetLogo there is no need to buy their book.

*Growing Artificial Societies: Social Science from the Bottom Up*, Joshua M. Epstein and Robert Axtell, MIT Press (Cambridge, Massachusetts, 1996).

*Micromotives and Macrobehavior*. Thomas C. Schelling, Norton (N.Y., N.Y., 1978). Classical pre-*ABM* treatment of a variety of problems in which there is a clear distinction between the agent and social levels. This book has proven to be very fertile for research topics that have subsequently been implemented with agents.

*An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo*, Uri Wilensky and William Rand, MIT Press (Cambridge, Mass., 2015). NetLogo-based introduction to agent computing; somewhat introductory, provides code, while giving only heuristic treatment of many topics we will go into in detail. *Optional*: recommended for those using NetLogo.

Beyond these, the following volumes may prove useful, depending on your background/field/discipline:

*Discrete-Event Simulation: A First Course*, Lawrence Leemis and Steve Park. Several editions available; there is a link to an e-version of this on the course website. Covers classical material on conventional simulation methodology, useful primarily if you have never built a simulation model before.

*Agent-Based Models of Geographical Systems*. Alison J. Heppenstall, Andrew T. Crooks, Linda M. See and Michael Batty, eds. Springer (Netherlands, 2012). Good reference for geographers. More closely related to CSS 645: Spatial ABMs, but the first dozen or so chapters are a good introduction to agent-based modeling.

*Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations.* Yoav Shoham and Kevin Layton-Brown, Cambridge University Press (N.Y., 2008). Textbook by computer scientists, focused on bringing game theoretic ideas to MAS. Too formal for our purposes and misses much of the point of ABMs for the social sciences, e.g., heterogeneous agents, bounded rationality, networks. An electronic version of the book is available at `www.masfoundations.org`. It is a good reference for computer scientists and game theorists interested in computational/algorithmic issues.

*Networks, Crowds, and Markets*. David Easley and Jon Kleinberg. Cambridge U. Press (N.Y., N.Y., 2011). Recent interdisciplinary approach to the disparate social phenomena in the title; surprisingly little computing.

## Prerequisites

Students should have good working knowledge of at least one programming language (e.g., C/C++, Java, Python, Lisp/Scheme, Pascal/Delphi, BASIC, FORTRAN, Ruby, Swift,…), preferably one having some object orientation (agents are naturally coded as objects) but this is not essential. Solid knowledge of a mathematical or statistics package (e.g., MatLab, Mathematica, R, Stata, Gauss, possibly Excel) can substitute, as would learning a high-level agent programming system (e.g., NetLogo, AnyLogic, or AgentSheets). Less common languages (e.g., Clojure, Erlang, Go, Haskell, Julia, Rust, Scala) are also perfectly satisfactory but I won't be able to provide much feedback if your code doesn't work. CSS 600 and 605 are recommended as prerequisites but not strictly required. Also helpful is some background in basic probability and statistics, as well as introductory economics or game theory. I am not a stickler for prerequisites, however, and enthusiasm can substitute for preparation.

For those working on Apple machines the Xcode development environment is perfectly good for writing code in Objective C, C/C++ and Swift. Microsoft Studio works well for those with PCs. Eclipse and NetBeans have long been solid cross-platform integrated development environments (IDEs) supporting multiple languages. Specialized compilers are available that integrate with various IDEs (e.g., Intel's Parallel Studio) and are often available for free for educational use.

## Pedagogical Goals

We will be building representations of individual people in software, giving them plausible or empirically-grounded motivations and behavior, things to trade, data-gathering abilities, and cognitive capabilities. We will then let these software objects interact directly with one another, i.e., in social environments, and study what happens. When we build such agent models in the context of known models we are, in essence, 'agentizing' standard models. When we build agent models without conventional counterparts then we are relaxing more than one of the traditional assumptions e.g., rationality, equilibrium at once. Both kinds of models can yield interesting results and we will study each kind this semester. It is my belief that the agent modeling approach is sufficiently new and capable that each student should be able to apply it to some domain and make a significant contribution *this semester*.

## Workload, Assignments and Grading

*Homework:* All homework assignments consist of both a computational part and an interpretative discussion. Please submit PDFs online in advance of class. The code is to be submitted to your online folder and must include the following as comments at the beginning: (1) your name, (2) hardware platform employed, (3) the operating system used, (4) the software development environment (including version information), and (5) any special information needed in order to satisfactorily compile and run it, e.g. 'Must open an X window under Linux.' Additionally I expect extensive comments throughout your code 50% of keystrokes as comments is a good objective, although I won't be counting precisely. Failure to meet these requirements will reduce your grade. **8 homework assignments @ 5 pts each = 40 pts** max, graded as follows: 1 pt for on-time submission, 1 pt if the code compiles and runs and does something relevant to the problem, 1 pt for sufficient code comments (half of symbols), 1 pt for coherent write-up, 1 pt for the right answer; each week a homework assignment is late costs 1 pt; some students will be asked to present their homework to class, let me know if you want to present.

*Presentation of an agent-based model*: The agent field has grown to such an extent that models exist in essentially every one of the social sciences. Pick one such model, read the corresponding paper, run the model (if you can), and then do a ten minute presentation in class, preferably with a demo. The presentation will **count for up to 10 pts of your grade**, for both slides (5 pts) and competent manipulation of the model illustrating the main results (5 pts). Afterwards, deposit the slides online.

*Book review*: Suggestions for books to review are listed below in the weekly schedule. If there is a book you really want to review that is not mentioned below, you are welcome to propose it to me along with a presentation date. Before your presentation either email your review to everyone or add it to the website. Each book review should be written in a format comparable to a published book review in a professional journal, conveying the key messages of the book and providing appropriate critical analysis. If you are unfamiliar with book reviews, consult journals (e.g., the *Journal of Artificial Societies and Social Simulation*). In general, a review should have an introductory paragraph with an overall assessment, followed by a very brief summary of the book's key arguments, an evaluation of the book's strength and weaknesses, placement of the book within the larger literature, and summary comments. Your review should be 2-3 pages long with the in-class presentation lasting about ten minutes. It will be **worth 10 pts,** graded based on presentation (5 pts) and written review (5 pts).

*Team project*: Team sizes of 2-3 are recommended. Larger teams will be permitted for ambitious projects if a clear role for each participant is indicated. Each team member will receive the same grade on the project unless there is compelling reason to do otherwise. Singleton 'teams' are permitted. A sample project paper will be distributed in April. Projects that have been worked on in previous semesters can be extended in this class if you furnish me the original work so that the exact nature of the extension(s) is clear. Projects that you are working on in other classes *cannot* be used for this class without my consent. Submit a 20 pp research paper in the style of a scientific journal article; counts for **40 pts of final grade:** form team (2 pts), pick topic (3 pts), write an early draft (5 pts), make in-class presentation (10 pts), final paper (15 pts), and code (5 pts).

*Grading:* 40 pts + 10 pts + 10 pts + 40 pts = 100 pts

### Typical Class

7:20-9:00 Lecture, model demonstrations, and discussion
9:00-9:05 Break
9:05-9:20 Student presentation of previous HW assignment
9:20-9:40 Student book review or model demonstration
9:40-10:00 Student book review of model demonstration
10:00 PM Brief discussion of next week's assignment(s)
With ~15+ students, ~2 student presentations/week

### SPIRIT of the Course

Agent-based computational modeling is a new field within the social sciences. In many (most?) respects, the full scale and scope of the field is still emerging. Therefore, this course is designed to both codify what we presently know and give direction for future development, while identifying important lacuna.

The material to be covered in the course falls broadly into two main categories: methodology and applications. In the first group are topics having to do with the structure and function of successful agent-based computational models. In the second are areas of the social sciences where this approach has been fruitfully employed.

Everyone in the class is a graduate student (aside from the occasional precocious high schooler from TJ!) and therefore each of you is transitioning from being a 'student' to becoming an 'expert'. Specifically, Certificate and Master's degree students are expected to become capable of leveraging their knowledge of particular academic domains in order to build novel agent models in software. Ph.D. students and post-docs, in the process of gaining a distinctive 'voice' as a scholar, are further expected to develop a broad knowledge of agent models in their field.

### Departmental Compute Resources

In the Computational Social Science Program/Center for Social Complexity there exist the following hardware resources and operating systems:

1. Ganesha: 2 x 8 core CPUs (32 logical cores), 256GB RAM, NVIDIA GTX 680, 2 x 30" displays, Centex Linux
2. Brahma: 2 x 6 core CPUs (hyperthreaded, 24 logical cores) 64 GB RAM, 3 x 30" displays, MacOS
3. ~~Vishnu: 4 core CPU (hyperthreaded, 8 logical cores), 32 GB RAM, GTX 280/680, 30" display, MacOS~~
4. ~~Oxford: 2 x 4 core CPUs (hyperthreaded, 16 logical cores), 128 GB, ATI Radeon 5770, 30" display, MacOS~~
5. ~~Cambridge: 2 x 4 core CPUs (hyperthreaded, 16 logical cores), 64 GB RAM, 30" display, MacOS~~
6. ~~Dusk: 2 x 4 core CPUs, 32 GB RAM, 30" display, MacOS~~
7. ~~Dawn: 4 core CPU, 16 GB RAM, 24" display, MacOS~~

### Weekly Schedule and Assignments

**Week 1** (January 27th): **Introduction** to the course background material on cellular automata, distributed AI and multi-agent systems; autonomous agents; complex adaptive systems; object-oriented programming;

Read: Schelling (1978), chapters 1 and 2, Simon (1996) chapter 7, Axtell (2000), Rauch (2002) and Epstein and Axtell (1996) chapter 1;

*Deeper reading*: Wilensky and Rand (2015), chapters 0, 1 and appendix; graduate students in the social sciences should read Axelrod (2003); economists, read Tesfatsion (1997) and Axtell (2007); natural scientists should read Laughlin and Pines (2000) who argue that 21st C science will be all about *emergence*;

Demo: Quick passes through various agent models;

Homework #1: Sign-up for book to review or model to demo by February 3rd;

Homework #2: Basic computing skills, due February 3rd.

**Week 2** (February 3rd): Application of agents to **economics**: in-class market experiment and demonstration of an artificial computational market reproducing simple supply and demand concepts; 'invisible hand' and the philosophy of emergence; sources of randomness in agent models and the importance of making multiple realizations; path-dependence; *agentization*;

Read: Gode and Sunder (1993); Wilensky and Rand (2015), chapters 4 and 5 if using Net Logo; economists read Epstein and Axtell (1996) chapter 4;

*Deeper reading*: Graduate students in economics should read Plott (1986), Gode and Sunder (1997), and Axtell (2005) and skim Cliff and Bruten (1997; 1997); on the mathematical expediency of equilibrium assumptions see Kaldor (1972; 1985); Anderson, Arrow and Pines (1988) is a somewhat dated overview of complexity economics; on adaptive vs. rational foundations for economic science, Leijonhufvud (1999); importance of heterogeneity, Kirman (1992); rationality as an 'ideal type' (Simon 1955; 1956; 1978); role of direct agent-agent interactions, Kirman (1997); Kohn (2004) was the motivation for Axtell (2007) and most of the papers in that issue of the *Review of Austrian Economics*; a non agent take on economic complexity is due to Krugman (1996);

Demo: ZI agents;

Homework #3: ZI traders, due February 10th;

Books/suites of papers to review: Friedman and Rust (1994) and Clearwater (1996); anyone interested in financial economics is invited to review the papers of Arthur *et al*. (1997), Lux (1998; 1999) and LeBaron (2000; 2001; 2001; 2001; 2001; 2001; 2002) as a group, the papers of Farmer and co-authors as a group (1999; 2005; 2009; Forthcoming), or one of the following books: Mandelbrot (1997), Abu-Mostafa *et al.* (2000), Levy *et al*. (2000), Sornette (2003), Johnson *et al*. (2003), Beinhocker (2005) or Taleb (2007).

**Week 3** (February 10th): Rational choice **game theory**: two person, two strategy games of full information, normal and extensive forms, pure and mixed strategies, solution concepts, repeated games, the 'folk' theorem; games played in populations; evolutionary game theory; implementation using agents; social norms and conventions;

Read: Schelling (1978) chapters 6 and 7; excerpt on Axelrod's prisoner's dilemma tournament (Axelrod 1984);

*Deeper reading*: Wilensky and Rand (2015), chapter 3, pp 141-151; many good texts on this subject exist, at the upper undergraduate level (e.g., Binmore 1992; 2007) through advanced graduate level (e.g., Fudenberg and Tirole 1991; Osborne and Rubinstein 1994); computer science students should read Shoham and Layton-Brown (2009), chapters 3 and 4; students using evolutionary game in their research should familiarize themselves with Friedman (1991) and Gintis (2000);

Demo: games of coordination and assurance; the 'El Farol' (bar) problem (Arthur 1994);

Homework #4: Games played in a population of agents, due February 17th;

Books to review: Luce and Raiffa (1957), Dresher (1961), Axelrod (1984), Rosenschein and Zlotkin (1994), Green and Shapiro (1994), Rubinstein (1998), Fudenberg and Levine (1998), and Gintis (2000).

**Week 4** (February 17th): **Agent activation** regimes (aka scheduling) including serial vs. parallel activation, deterministic vs. random activation, and synchronous vs asynchronous activation; single vs multi-threading; random number generation and avoiding the production of computational artifacts;

Read: Nowak and May (1992), Huberman and Glance (1993) and Axtell (2001);

*Deeper reading*: There is a large literature in numerical analysis that differentiates synchronous, partially asynchronous and fully asynchronous parallel updating (e.g., Bertsekas and Tsitsiklis 1993) and I have tried to interpret these results for agents (Axtell 2003); furthermore, there is a growing literature in so-called *interacting particle systems* and game theory that attempts to discriminate between those models for which the agent activation order matters from those in which it does not (e.g., Gacs 1997; Chen and Micali 2013);

Demo: Java version of Huberman and Glance (code by Steve Scott);

Homework #5: Activation effects, due February 23rd;

Books to review: Resnick (1994), Casti (1994; 1997), Holland (1995; 1998; 2012) and Miller and Page (2007).

**Week 5** (February 23rd): Behavioral, computational and 'low rationality' **game theory**: games of incomplete information, 'fictitious play,' 'best reply' strategies and adaptive dynamics; learning; behavioral game theory;

Read: Schelling (1978), chapter 3; Axtell, Epstein and Young (2001);

*Deeper reading*: Economics students should familiarize themselves with Camerer (2003); computational science students should read Shoham and Layton-Brown (2009), chapters 5, 6 and 8 along with section 7.7;

Demo: Spontaneous emergence of classes in a bargaining model (Axtell, Epstein and Young 2001);

Homework #6: Perturbed games, including noisy games, due March 3rd;

Books to review: Bicchieri *et al.* (1993; 2006), Weibull (1997), Young (1998), Parsons and Gmytrasiewicz (2002), Bowles (2003), Camerer (2003), Gintis *et al*. (2004), Skyrms (2004), and Vega-Redondo (1996).

**Week 6** (March 3rd): Social network theory and practice for agent models; regular and random graphs, including 'small world,' Erdös-Renyi and 'scale free' (power law) graphs, along with strategies for making agents mobile in networks; digression on power laws and social complexity;

Read: Watts and Strogatz (1998), Barabasi and Albert (1999), and Axtell and Epstein (1999);

*Deeper reading*: Students wishing to become expert in this area should study Barabasi and co-authors (1999; 2002), Watts (1999; 2002), and Newman and colleagues (2001; 2002; 2006); economists should become familiar with Bala and Goyal (2000), Morris (2000), Wilhite (2001), Vega-Redondo (2007), Jackson (2008), and Acemoglu *et al*. (2012); those interested in disease processes on networks should study Morris (1997), Liljeros *et al*. (2001), Pastor-Satorras and Vespignani (2001), Deszo and Barabasi (2002), and Eubank *et al*. (2004); diffusion on networks is relevant to marketing and opinion dynamics and good work includes Valente (1996) and Young (1999); Wilensky and Rand (2015), chapter 6;

Demo: Social norms of retirement (Axtell and Epstein 1999);

Homework #7: Game on graphs, due March 10th;

Books to review: Scott (1991), Wasserman and Faust (1994), Valente (1995), Watts (1999), Barabasi (2002), Goyal (2007), Dorogovtsey and Mendes (2003), Vega-Redondo (2007), Jackson (2008), Barrat *et al.* (2010), Easley and Kleinberg (2010), and Newman (2010).

**Week 7** (March 10th): Application of agents to **sociology**: neighborhood formation via sorting and Schelling segregation; cultural tags; programming mobile agents on landscapes; crime as a social and spatial process;

Read: Schelling (1978) chapter 4 and 5, Macy and Willer (2002), Hegemann *et al.* (2011);

*Deeper reading*: Schelling (1971); Wilensky and Rand (2005), chapter 3, pp 128-141; Hedstrom's (2005) book is important for sociology students interested in agents; extensions of Schelling's basic models include Zhang (2001; 2004; 2004; 2011), Vinkovic and Kirman (2006), Benard and Willer (2007), Pancs and Vriend (2007), Dall'Asta *et al.* (2008), and Gerhold *et al.* (2008); Glaeser, Sacerdote and Scheinkman (1996) study models capable of producing excess variance of violent crime across cities, as is found empirically;

Demo: Schelling segregation;

Homework #8: Variations on Schelling segregation, due March 17th;

Project week #0: Form project teams, select project, and email me your team and tentative subject by March 17th;

Books to review: Gilbert and Conte (1995), Troitzsch *et al.* (1996), Gaylord and D'Andria (1998), Gilbert and Troitzsch (1999), and Hedstrom (2005).

**Week 8** (March 17th): Agent-based software frameworks, focusing on NetLogo and MASON/RePast/FLAME;

Read: Luke *et al*. (2005), North *et al*. (2006); skim Scott and Koehler (on website) and Scott (handout/website);

*Deeper reading*: Ascape is an older framework (Parker 2001; Centola 2002);

Demo: Various NetLogo and MASON models;

Project week #1: Each project team submit 1 page description of what you will work on, due March 24th;

Books to review: O'Hare and Jennings (1996), Wooldridge and Jennings (1995) + Wooldridge and Mueller (1996), Wooldridge (2002), and North and Macal (2007).

**Week 9** (March 24th): Application of agents to **human ecology** (demography, environment, urban systems, ecology); brief digression on the relation of agent systems to evolutionary computation;

Read: Epstein and Axtell (1996) chapters 2-3; economists read chapter 4 if you have not already;

*Deeper reading*: Wilensky and Rand (2015), chapter 2; Lawson and Park (2000) on the agent activation scheme in Sugarscape; Elsaway *et al*. (2020) advocate for *ABM*s in coupled socio-environmental systems; Parker *et al*. (2003) review *ABM*s in land use and cover change (*LUCC*); Axtell *et al*. (2002) argue for *ABM*s in *industrial* ecology;

Demo: Sugarscape;

Project week #2: Get going!

Books to review: Jacobs (1970; 1992), Ostrom (1990; 1994), Kohler (2001), Gimblett (2002), Grimm and Railsback (2005), Batty (2005), Heppenstall, Crooks, See and Batty (2012).

**Week 10** (March 31st): Application of agents to **disease processes** generally and **epidemiology/epidemics/pandemics**; initial discussion of empirical calibration of agent models;

Read: Ferguson *et al*. (2020); Epstein and Axtell (1996), chapter 5;

*Deeper reading*: Halloran *et al*. (2008), Ferguson *et al*. (2006), Gemann *et al*. (2006), Longini *et al*. (2005), Ferguson *et al*. (2003);

Demo: Various NetLogo models;

Project week #3: Some code written or at least sketched, some literature review done;

Books to review: McNeill (1976), Anderson and May (1991), Daley and Gani (1999), Vynnycky and White (2010), Bjornstad (2018).

**Week 11** (April 7th): Application of agents to **anthropology** and **archaeology**; further discussion of empirical ABMs

Read: Axtell *et al*. (2002), Diamond (2002) and Kohler *et al.* (2005);

*Deeper reading*: Dean et *al.* (2000), Kohler *et al.* (1999), Reynolds (1999), Kuznar (2006);

Demo: Artificial Anasazi model;

Project week #4: Assemble a ms (3-5 pages) of text, code and any preliminary output, due April 14th;

Books to review: Taintner (1988), Gilbert and Doran (1994), Kohler and Gumerman (2000), Diamond (2004), Beekman and Baden (2005), Schwartz and Nichols (2006) and McAnany and Yoffe (2010).

**Week 12** (April 14th): Application of agents to **organization science**; group formation via team production and multi-agent firms; further digression on power laws; more discussion of empirical calibration of agent models;

Read: Axtell (2016) and Axtell (2018);

*Deeper reading*: Firm sizes (Simon 1955; Simon and Bonini 1958; Axtell 2001; de Wit 2005), ages (Coad 2010), growth (Ijiri and Simon 1964; 1967; Evans 1987; 1987; Hall 1987; Sutton 1997; Bottazzi and Secchi 2006; Perline, Axtell and Teitelbaum 2006; Coad 2008), and dynamics (Kwasnicki 1998; Axtell 2002; Luttmer 2011);

Demo: FIRMS model;

Project week #5: Keep moving!

Books to review: Cyert and March (1963), Steindl (1965), Ijiri and Simon (1977), Carley and Prietula (1994), Prietula *et al.* (1998), Lomi and Larsen (2001), Ormerod (2005) and Saichev *et al.* (2010).

**Week 13** (April 21st): **Identification** (calibration and estimation) of agent models; 'docking' models; design of computational experiments; significance testing model output; verification and validation of agent models;

Read: Axtell and Epstein (1994), Axtell *et al*. (1996) and Grimm *et al*. (2005);

*Deeper reading*: Wilensky and Rand (2015), chapter 7; estimation by simulation is standard practice in econometrics (cf. McFadden and Ruud 1994); identifying agent models is made trickier due to their multi-level character, e.g., Alfarano *et al*. (forthcoming).

Demo: Axelrod culture model in Sugarscape;

Project week #6: Draft ms: describe problem (2 pp), literature (2 pp), your model (2 pp) w/placeholders for results;

Books/suites of papers to review: Box and Draper (1998), Box, Hunter and Hunter (2005), and Mitzenmacher (2004) + Perline (2005) + Clauset *et al*. (2009).

**Week 14** (April 28th): Application of agents to **politics**; Axelrod culture model; models of group identity, political party formation, and civil conflict; country-specific models;

Read: Axelrod (1997), Castellano *et al.* (2000) and Lustick *et al*. (2004);

*Deeper reading*: Cederman (2001) on international relations; Epstein on civil conflict; Cioffi on the evolution of political complexity; computer scientists should read Shoham and Layton-Brown (2009) chapters 9 and 10;

Demo: Axelrod culture model;

Project week #7: Draw conclusions and work on your presentation;

Books to review: Axelrod (1997), Cederman (1997), the suite of papers by Kollman, Miller and Page (1992; 1997; 1997), and de Marchi (2005).

**Week 15** (May 5th): Project presentations; we will use an online poll to sign up for presentation slots.

### Summary of Homework assignments

Homework #1: Propose book to review or model to demo by February 3rd;
Homework #2: Basic computing skills, due February 3rd.
Homework #3: ZI traders, due February 10th;
Homework #4: Games played in a population of agents, due February 17th;
Homework #5: Activation effects, due February 24th;
Homework #6: Perturbed games, including noisy games, due March 3rd;
Homework #7: Game on graphs, due March 10th;
Homework #8: Schelling variations, due March 17th;

### Suggestions for Projects and Models (those with * are feasible class demos)

Background for the course:

0. Make 'Artificial Social Life' video Part II (Ch III), Part III (Ch IV), Part IV (Ch V) or Part V (Ch VI).

Anthropology and Archaeology (5)

1. Collapse or rebirth of a small-scale society (Diamond 2002; 2004).
2. Can a model inform the debate between the theorists of collapse (Taintner 1988; Diamond 2004) and the nay-sayers (Schwartz and Nichols 2006; McAnany and Yoffee 2010)?
3. Societal transition from competing tribes to chiefdoms and simple states (Griffin and Stanish 2007).
4. The Iroquois (Haudenosaunee) League/Confederacy was governed by a Grand Council which the ethnographer Morgan mistakenly interpreted as a central government (Morgan 1851). B. Franklin's early attempt to unite the 13 British colonies in his 1754 Albany Plan for Union may have derived from the workings of the League and gave rise to his well-known admonition to the Constitutional Congress that if the Iroquois could form a union then American colonists could too. Build a model of Iroquois governance.
5. Modify the rules in the Anasazi model to improve the spatial distribution of population (Axtell et al. 2002).

Biology and Artificial Life (15)

6. *Bird flocking: fluid dynamics and bioenergetics (Reynolds 1987; Smale 2007).
7. *Starling flocks are famously complex and have been modeled in detail (Hemelrijk and Hildenbrandt 2011);
8. *Ant colony dynamics (Bonabeau, Dorigo and Theraulaz 1999; Couzin and Franks 2003).
9. *Predator avoidance by fish schools (Couzin 2007).
10. *Emergence of leaders in animal groups (Couzin et al. 2005).
11. Disease agent propagation in 3D tissue (cellular automata) model; many models of this in biology.
12. Reimplement Nowak and May (1992).
13. Reimplement Fontana's 'algorithmic chemistry' (Langton et al. 1991).
14. *Build the 'Game of Life' (e.g., Gardner 1970) using RePast or MASON or analyze the NetLogo version.
15. Reimplement 'self-reproducing automata' of von Neumann and Burks (1966) using agent technology.
16. Comb *Artificial Life* for social science models and reimplement one of them, e.g., Padgett (1997).

17. Locust swarms and the recent efforts to genetically modify certain species (Buhl et al. 2006).
18. Fish school size distributions are heavy-tailed (Bonabeau, Dorigo and Theraulaz 1999). Model this.
19. *The mathematical equations of fishery dynamics typically abstract from spatial processes, minor species, even fishermen as individuals, in favor of a 'fishing fleet' as harvester model (Clark 2005). Agent models have begun to appear, including several in MASON. Survey these and extend them in some direction.
20. *Marine protected areas (MPA) are a common fisheries management policy. 'Fishing the line' is the phenomenon of fishers operating their boats right along the MPA boundary. Model this with agents and focus on why this is very hard to model mathematically (Scott 2016).

Demography (5)

21. Build a model of local social norms of fertility (Kohler 2001).
22. Compare the Leslie matrix (well-mixed) version of demography with spatially or network-based view.
23. Take the 'life tables' view of demography and agentize it, then critique the extreme methodologically-individualist approach to agent lifetimes and enrich your agent model to include such factors as serial correlation in spousal death probabilities and local fertility norms (see #21 above).
24. Emigration and immigration between two countries having disparate wage levels; Ben Clemens of Census has worked on this, see me for his draft paper(s).
25. According to a famous essay by Amartya Sen (1990), 100 million women are 'missing'. Model this!

Economics (25)

26. Emergence of 'middlemen' in 2 good economy (Feldman 1973).
27. Extend my model of $k$-lateral exchange (Axtell 2005) to CES preferences or parallel execution.
28. Take my model of firm dynamics and study the lifecycle of firms (Nelson 2006).
29. Study the network of job-to-job changing in my model of firm dynamics, the 'labor flow network' (Guerrero and Axtell 2013).
30. Friedman famously argued (1953) that inefficient firms would go extinct in competition with efficient firms. Later this was shown to be naive by various authors, including Blume and Easley (2002). Build a model to inform this debate.
31. *Redo Padget's (1997) model of goods production via complementary skills.
32. *Money (Menger 1892; Kiyotaki and Wright 1989; Marimon, McGrattan and Sargent 1990; Howitt and Clower 2000).
33. *Modify the model of local store pricing in Howitt and Clower (2000) and study the effect on the emergence of money.
34. Create a model of monetary transmission into the real economy and investigate Cantillon effects (Veetil 2016).
35. Study inflation using agents (see me for a recent working paper by Howitt).
36. *Circulation of bank-issued currency (e.g., 18th C Scotland; see McBride (2010)).
37. Agentize Akerlof's famous 'market for lemons' (Akerlof 1970) extending (Tilles et al. 2011).
38. Reimplement Gintis's macroeconomic model having explicit microeconomic foundations (2007).
39. Build a simple Keynesian macroeconomic model (Bruun 1999).
40. Consumption theory is normally rendered in terms of a single agent. Palmer (2015) has recently written a dissertation agonizing the theory of consumption. Review his dissertation and extend his model.
41. Review and extend recent ideas on heterogeneous agent macroeconomics (Guvenen 2011).
42. 'Agentize' the 'dynamic stochastic general equilibrium' (DSGE) macro model(Colander et al. 2008).
43. Extend the Parker and Filatova models of housing markets (2007; 2009; 2009).
44. *Extend the Resources for the Future model of housing markets (Magliocca et al. 2011).
45. *Model a housing market bubble (Geanakoplos et al. 2012).
46. *International trade with country-specific labor and mobile capital; see Guden (2004) dissertation.
47. Agentize the Melitz (2003) model of international trade, grounded in firm behavior.

48. Build an agent model of open source software development, e.g., extending Madey (2008).
49. *Create a model in which technology evolves (see me for references, prototypes).
50. Build a model of market-based regulation in the context of heterogeneous firms.

Finance (10)

51. Re-implement Lux's (1998) financial market; study how results depend on the number of agents.
52. Convert one of LeBaron's MatLab-based financial market models into MASON or some other framework.
53. Redo the Cont (2006) model which reproduces many of the statistics of real financial markets.
54. Model order book flows in a financial market (e.g., Farmer, Patelli and Zovko 2005).
55. Model the way the Treasury Department auctions U.S. bonds (Koesrindartoto 2004).
56. According to Kindelberger (2005) there are just a few 'types' of financial crises; model one of these.
57. Most financial crises are, before the onset of crisis, believed to be different from previous crises (Reinhart and Rogoff 2009); build a model in which people who have experienced crises in immune to them but people who have not are vulnerable.
58. Build a model of the Panic of 1907 JP Morgan intervenes to 'save' the financial system and bank clearinghouses are born (Bruner and Carr 2007).
59. Create a simple agent model of the Great Depression and compare it to Bernanke and Gertler (2004).
60. *The CRISIS project is an EU funded effort on-going at several European universities. Take some of their models and experiment with them (Aymanns and Farmer 2015; Aymanns et al. 2016).

Environmental Science and Policy including Energy and Sustainability issues (20)

61. *Take a CA-type forest fire model with fire breaks, other policies (Doyle and Carlson 2000) and agentize it.
62. *Build a model of the 'tragedy of the commons' type dilemmas (Ostrom 1990); see me for a prototype.
63. Agentize the Hahn and Axtell (1995) model in which there is uncertainty in compliance and enforcement.
64. Build a model of cap-and-trade policies and compare with Pigouvian taxes, e.g., agentize Weitzman (1974).
65. Build a coalition formation model for climate change, starting from the work of Scott Barrett (1994).
66. Compare auction mechanisms when goods can be resold (Hailu and Schilizzi 2005).
67. *International environmental negotiations are often spear-headed by parties with large stakes in the outcomes, coalitions led by 'norm entrepreneurs'. A recent CSS Ph.D. dissertation by Rouleau develops this idea. Read his work and extend his model (you will need to ask him for his code).
68. Agent models are used in the field of *industrial ecology*. Survey this area (Andrews 2001; Axtell, Andrews and Small 2002) and build something relevant.
69. *Individual-based models (IBMs) are common in ecology (Grimm and Railsback 2005). Go to a relevant journal (e.g., *Ecological Modeling*), find a policy relevant IBM and extend it.
70. ABMs are being increasingly used in climate change research. Survey the literature, assess the various uses (e.g., sea level rise, energy infrastructure) and extend one of them (e.g., Farmer et al. 2015).
71. *Integrated assessment models are historically *not* agent-based. Survey these and focus on the few attempts to add agency to them. Try to get your hands on one of these and agentize it.
72. *Solar photovoltaic technology is in a period of rapid evolution. What can agent modeling teach us about it? (There are a variety of examples in recent years from the Department of Energy.)
73. Wearable technologies are limited by energy sources. Recent technology promises use of body heat to fuel such devices. Build agent models of people wearing devices that interact with one another. How might these be used for detecting environmental pathogens or in other ways?
74. For many technologies, including some energy technologies, unit costs fall with increasing production, a phenomenon known as Wright's law or industrial 'experience curves' (McNerney, Farmer and Trancik 2011). Build agent models of this phenomena.
75. Fisheries regulations, like individual traceable quotas (ITQs) and effort limitations (TAC), can be modeled at either the fleet or individual vessel level (Gordon 1954; Rosser 2002). Build an ABM that compares these.
76. Scott (2016) has modeled the Chesapeake Bay. Familiarize yourself with his work and extend it.

77. A recent paper in this broad area mentions 8 grand challenges (Elsaway et al. 2020). Build a related model.
78. Build an ABM of forestry management (e.g., Bone and Dragicevic 2010; e.g., Spies et al. 2017).
79. NEON is a new NSF-funded data acquisition technology for ecosystems. How might it be relevant to ABMs.
80. ABMs are increasingly used in agricultural research. Review and extend some of this work (Bert et al. 2011).

Game Theory (10)

81. Redo Axelrod's prisoner's dilemma tournament (Axelrod 1984).
82. Reimplement the emergence of classes model or extend it to include agents having class preferences.
83. *Reimplement the retirement model (Axtell and Epstein 1999).
84. Reimplement Kristian Lindgren's evolutionary prisoner's dilemma model (Lindgren 1992).
85. Implement Skyrmes' model for the emergence of meaning through signaling (Skyrms 2010).
86. Prisoner's dilemma with tags (Riolo, Axelrod *et al.* (2001)).
87. Explore the 'cost allocation' problem: a boss ('principal') writes contracts for many agents for joint use of a facility, and wants the contract to be incentive compatible (agents tell the truth), individually rational (it is in agents' best interest to use the facility), and Pareto optimal (no better contract exists). Only 2 of these 3 criteria can be achieved (Young 1985)!
88. *Reimplement he 'El Farol' (aka bar) problem emergence of mixed strategies (Arthur 1994).
89. Study 'anti-coordination' games (see me for a dissertation on this topic).
90. Build a game theoretic model in which rationality is tempered by one or more emotions (active topic within MAS see recent years in the *AAMAS* conferences on this topic as well as Epstein (2013)).

Geography, including Traffic (15)

91. Re-implement Simon's city formation model using agents (Ijiri and Simon 1964; 1967; 1977).
92. Focus the above to reproduce the Zipf distribution of city sizes (Axtell and Florida 2006; Waters 2019).
93. Extend the nighttime lights work of Gulden and Florida ('The World is Spiky').
94. *Compare stop signs, traffic circles and stop lights in an agent- model of traffic (CSS qualifying exam question from a few years ago).
95. *Emergence of social driving norms at a one lane bridge (see me for the Reston bridge example).
96. *Pedestrian traffic flow on the Millenium Bridge leading to instability (Strogatz 2003).
97. Crowd dynamics in an emergency egress setting (e.g., Helbing, Farkas and Vicsek 2000; Ha and Lykotafitis 2012).
98. Debottlenecking pedestrian traffic Mecca and Medina (various people have worked on this).
99. TRANSIMS was built at Los Alamos for Albuquerque, Portland and Dallas (Barrett and Beckman 1995; Beckman 1997). Learn about it, survey related models, and write a review paper of the state of the field while prototyping your own traffic simulator.
100. Capture geographically-tagged Twitter feeds on some topic and build an agent model to explain the spatial structure of the data (Stefanidis, Crooks and Radzikowski 2013).
101. Wise (2014) built an emergency egress model based on fire risk; review and extend her work.
102. Geographically accurate models of segregation in Boston (Vandell and Harrison 1978) and Baltimore were built in the 1970s . Compare these and discuss what makes them more or less scientifically-interesting than the abstract Schelling model. How would you build a model of Washington, D.C.?
103. Review ABMs of slum formation and operation (Mahabir et al. 2016) and extend the state-of-the-art.
104. A variety of models exist of The Station nightclub fire in 2003. Review this work and build an ABM.
105. Combining ABM with GIS is the speciality of Professor Andrew Crooks in the Computational Social Science Program (www.gisagents.org). Review research in this broad area and build a model of this type.

History (5)

106. Pre-industrial town markets for agricultural goods were believed to dampen weather-related production shocks, but it has recently been argued they do the opposite. Build a model to test these hypotheses.

107. The English Civil Wars of the 17th C were essentially conflict between the monarchy and Parliament, culminating in the Glorious Revolution and the structural reduction in kingly power. Can an agent model teach us anything about this era?
108. The American, French and subsequent revolutions through 1848 have much in common. Build an abstract model of the general forces that led to these events.
109. Why did the Industrial Revolution happen where and when it did (Mokyr 1998; 2009), and did it even happen (Mokyr 1987; 1990)? Build a model of some of these issues, perhaps starting with (Allen 2009)
110. Model Napoleon's failed attack on Russia no one has tried this, proceed at your own risk and see me before embarking!

International Security and Military Operations (5)

111. *Infantry combat (pick your era: Revolutionary War, 2-3 shots/min w/muskets; Civil War, 3-10 shots/min w/ cartridges; WWI, trench warfare, up to 100 shots/min w/machine guns); Ilachinski is best source on simple models of this kind (2004).
112. Prototype an agent model of Gettysburg (analogs exist there).
113. Submarine warfare against supply convoys during WWII (McCue 2006).
114. Model counterinsurgency (COIN) dynamics (Johnson et al. 2011).
115. Terrorist networks: formation, evolution and disruption (MacKerrow 2003).

Marketing (10)

116. Agentize the Bass diffusion model (Bass 1969).
117. Viral marketing is a data-intensive, bottom up approach to marketing, as compared to top-down advertising (Goodin 2000). Build a model of the uptake of a consumer good with both kinds of advertising.
118. A game theoretic version of adoption dynamics is due to Young (1999). Build this model with agents.
119. Technology standards are characterized by network externalities, e.g., VHS vs Betamax (Economides 1996). Build an agent-based marketing model in the presence of network externalities. In such environments some amount of piracy may even be useful. Model this phenomenon.
120. Read a book on high-tech marketing (Moore 1991; Mohr, Sengupta and Slater 2009). How is marketing different in this arena and what can be learned by building agent models in this domain?
121. Read CSS Ph.D. student Wyn Farrell's "How Hits Happen" and build a relevant agent model.
122. Build an information cascade model and contrast the perspectives of Watts (2002) and Gladwell.
123. Build bottom up marketing models and compare the effects of alternative interaction topologies.
124. Product placement is important in actual marketing. Build a spatial agent model where this matters.
125. Companies claim to be able to turn cash register receipt data into targeted marketing; model this.

Methodology of Agent Computation and Simulation (10)

126. *Use of GPU technology for agent models (D'Souza, Lysenko and Rahmani 2007).
127. Investigate alternative activation regimes in Sugarscape (Lawson and Park 2000).
128. Investigate parallel activation regimes (see me for references).
129. Investigate parallel languages for agent modeling (e.g., Erlang, Scala, Go, Haskel); see me for a paper.
130. Investigate shared memory machines vs clouds for agent modeling (see me for a white paper).
131. Emotional agents are an active topic in MAS. Leverage some of those formulations for social models.
132. Agents that talk directly to one another is another active area of MAS; extend Tesfatsion (2001).
133. What would an agent-oriented operating system look like? See me for some references.
134. Compare agent learning in CS vs economics; see special issue of *AI Journal* (Vohra and Wellman 2007).
135. Build large-scale models and study how to efficiently execute them or glean data from them.

Operations Research and Business Management (5)

136. *Take the Axtell and Kimbrough (see me) model of bipartite matching with aspirations, convert it to Java (possibly MASON), and study the role of matchmakers.

137. *Information flow in an organization through formal organizations and informal networks (there exist a variety of extant models in the org theory literature).
138. *Airline 'free flight': pilots pick their own routes (see me for a recent Mason dissertation).
139. Study leaderless organizations (see me for a recent GWU dissertation).
140. Compare mathematical programing solutions to agents for a well-known OR problem.

Politics (10)

141. Societal transition from simple states to feudalism (Engels 1972 (1884)); model it.
142. Societal transition from feudalism to capitalism and its recent incarnation in the 'Brenner debate' (Dobb 1963; Brenner 1976; 1978; Aston and Philpin 1987); model the essential elements.
143. Write a Tiebout model agents 'vote with their feet' to satisfy preferences (Kollman, Miller and Page 1997).
144. Build a voting model (a la Nate Silver, www.538.com) that uses polling data.
145. The formation of political parties by politicians to attract a majority of votes; possibly focus on reproducing theoretical cycling results (Kollman, Miller and Page 1992).
146. Cross-border flows and refugee camp formation as a response to civil violence (Groen 2016).
147. *Extend the party competition model of Laver and Sergenti (2011).
148. Agentize a model of local/city government.
149. Agentize an informal model of federalism (Bednar, Eskridge and Ferejohn 2001; Bednar 2011).
150. *Build a new model of civil violence that does not use global variables like legitimacy (Epstein 2002).

Public Health (15)

151. Compare distinct approaches (Luke and Stamatakis 2012).
152. *Build a disease propagation ABM (SIS, SIR, or SIER) on a graph. Compare critical fractions of populations that need to be vaccinated to stop disease spread as a function of the $R_0$ parameter; see (Pastor-Satorras and Vespignani 2001).
153. Build a spatial or network model of disease propagation among agents and compare it with a system dynamics model of the same process; Sterman (2000) for references..
154. *Spread of addictive behavior, such as drug 'epidemics' (Agar and Wilson 2002).
155. Extant epidemiological models do not alter behavior once agents are sick. Try this (see me for a paper).
156. Experiment with a policy-relevant model for flu to study policy options (Gemann et al. 2006).
157. Build an ABM of cardiovascular health (Li et al. 2018).
158. Build an ABM of the obesity epidemic (Shoham et al. 2015).
159. Spread of flu in emergency rooms (Laskowski et al. 2011).
160. Validation of models in this area is a problem. Build such a model and review alternative V&V approaches.
161. ABMs have been used to study of STDs (Rutherford, Friesen and McLeod 2012); review and extend.
162. RFID tracking systems are used in hospital settings and modeled with ABMs (Laskowski et al. 2010).
163. Review and extend ABMs of the opioid epidemic (e.g., Bobashev et al. 2018; Keane, Egan and Hawk 2018).
164. ABMs can also be used to study diabetes and other noncommunicable diseases (Li et al. 2016).
165. Tobacco use ABMs have a reasonably long history (Wallace, Geller and Ogawa 2015; Luke et al. 2017).

Sociology and Crime (10)

166. Investigate non-lattice topologies in Schelling segregation (Flache and Hegselmann 2001).
167. *Evolution of opinions within social networks; huge literature here so pick some specific topic (Deffaunt et al. 2002).
168. *Adoption of smoking behavior among adolescents in social networks (see me for a paper).
169. Compare alternative personnel promotion systems (e.g., tenure vs seniority-based systems; see me for a recent computational paper).
170. Investigate emergence from the perspective of Parsons' theories (Parsons 1937; 1937); build a model.
171. Build an agent model relevant to "Coleman's boat" (1964) and interpretations of emergence that result.
172. Build a model of crime as a socially-interactive process (e.g., Glaeser, Sacerdote and Scheinkman 1996).

173. Build a model of crime as occurring in 'hot spots' and/or on the boundaries of gang 'territories' (Brantingham et al. 2012).
174. Extend Redfish's model of the UK justice system (see me for slide deck).
175. Build a model for the interaction between drugs and gun violence (see me for prototype).

Sports and Entertainment (25)

176. *RoboSoccer (review state-of-the-art; modify and existing team or design your own team).
177. Bicycle racing: peleton formation, paceline dynamics (see UC-Irvine dissertation on this topic).
178. Auto racing on an oval track, in particular the social dynamics of 'drafting' (are there no models?).
179. Build a computational model of drag racing. If cars + drivers can be absolutely ranked in terms of their performance (mean + variance), what fraction of the time do the top 16 actually qualify for eliminations? How often do the top eight all win the first round and the best 4 reach the semi-finals? Is it rare or common for the two best vehicles to make it to the finals? Does the best vehicle usually win? How are any of these modified by 4 lane racing (e.g., Charlotte)? Are there better ways to arrange eliminations?
180. Model 'relegation' in the English Premier League (Soccer/football in England).
181. Model league division formation from undifferentiated teams (e.g., youth soccer leagues).
182. Study the mathematics of ranking system and build an agent model to better understand their dynamics.
183. Exactly how extraordinary was Joe DiMaggio's 57 game hitting streak? Build a model to explore this.
184. Study the empirics of 'streak' behavior in sports and build a general purpose agent model to study these.
185. Model football play-calling using machine learning (e.g., genetic algorithms).
186. *Why did it take 15-20 years for hockey helmets in hockey to go from bering rare to common? Model it.
187. *Dynamics of a so-called 'stadium wave' (Farkas, Helbing and Vicsek 2002).
188. *Formation and evolution of a standing ovation in an audience (CSS qualifying exam problem).
189. Recreate *Lord of the Rings*-type battle scenes (There many popular accounts of how this was done).
190. *Movie profitability is notoriously hard to predict, for reasons well-described by De Vany (2004). Build a model the 'grows' some of the empirical regularities in Professor De Vany's book.
191. Get the MASON version of Monopoly, created in CSS 605 in Fall 2014, and develop effective strategies.
192. Built a model of *Risk* or some other classic board game (this was done in CSS 605 several years ago).
193. Make a dynamic *Broadway Boogie-Woogie* (Mondrian; see p1 above), maybe by morphing Sugarscape code.
194. Build a model of how Intel prices their chips, particularly focusing on strategic pricing at the high end.
195. Build a model of the lifecycle of a computer game, from introduction to peak popularity and decline.
196. A recent paper (Gabel and Redner 2012) convincingly demonstrates that basketball score differentials follow a random walk, with slight deviations just before halftimes and games ending. They propose a model but it is purely mathematical, with any behavioral or social science content. Propose such a model.
197. In the context of the above, Clauset *et al*. (2015) attempt to determine what constitutes a 'safe lead'. Once again, their formal model is devoid of any social phenomena. Build a model that remedies this deficiency.
198. Football simulation games are essentially agent-based but have very simple algorithms. Explore the guts.
199. Ditto for basketball games. Can these be used vis-a-vis the Redner (Gabel and Redner 2012) papers?
200. Are football teams too conservative, i.e., punt too much on 4$^{th}$ down (Romer 2006)? Model this with agents.

### Academic Integrity

The integrity of the University community is affected by the individual choices made by each of us. Mason has an Honor Code with clear guidelines regarding academic integrity. Three fundamental and rather simple principles to follow at all times are that: (1) all work submitted be your own; (2) when using the work or ideas of others, including fellow students, give full credit through accurate citations; and (3) if you are uncertain about the ground rules on a particular assignment, ask for clarification. No grade is important enough to justify academic misconduct. Plagiarism means using the exact words, opinions, or factual information from another person without giving the person credit. Writers give credit through accepted documentation styles, such as parenthetical citation, footnotes, or endnotes. Paraphrased material must also be cited, using MLA or APA format. A simple listing of books or articles is not sufficient. Plagiarism is the equivalent of intellectual robbery and cannot be tolerated in our class. If you have any doubts about what constitutes plagiarism, please see me.

### Disability Accommodations

If you have a disability and need academic accommodations, please see me and contact the Office of Disability Services (ODS) at (703) 993-2474, ods.gmu.edu. All academic accommodations are to be arranged through the ODS.

### Diversity

George Mason promotes a living and learning environment for intellectual growth and research productivity, through its curriculum, programs, policies, procedures, services and resources. Emphasis upon diversity and inclusion throughout the campus community is essential to achieve these goals. Diversity is broadly defined to include such characteristics as, but not limited to, race, ethnicity, gender, religion, age, disability, and sexual orientation. Diversity also entails different viewpoints, philosophies, and perspectives. Attention to these aspects of diversity helps promote a culture of inclusion and belonging, and an environment where diverse opinions, backgrounds and practices have the opportunity to be voiced, heard and respected. Mason's commitment to diversity and inclusion goes beyond policies and procedures to focus on behavior at the individual, group and organizational level. This commitment to diversity and inclusion can be found in all settings, including individual work units, student organizations, and classroom settings; it is also found in the delivery of services and activities, including, but not limited to, curriculum, teaching, events, advising, research, service, and community outreach. The attainment of diversity and inclusion are dynamic and continuous processes, evolving over time, Mason seeks to continuously improve its environment and to this end, the University promotes continuous monitoring and self-assessment regarding diversity. The aim is to incorporate diversity and inclusion within the philosophies and actions of the individual, group and organization, and to make improvements as needed.

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