Agent-Based Computational Economics: Virtual Economic Reality

Presenter:

– Leigh Tesfatsion
– Professor of Economics and Mathematics
– Iowa State University
– www.econ.iastate.edu/tesfatsi/
– tesfatsi@iastate.edu
Outline

- What are CAS (Complex Adaptive Systems)?
- What is ACE (Agent-Based Computational Economics)?
- Agent-Oriented vs. Object-Oriented Programming
- ACE Implementation via Computational Laboratories
- Example: The Trade Network Game Computational Lab
- ACE Research Areas
What are Complex Adaptive Systems?

- Systems composed of distributed interacting units with adaptive capabilities
- Exhibit global regularities hard (impossible?) to predict solely from the structure of the individual units
- **Examples**: Immune systems; Multicellular organisms; Insect colonies; Ecologies; Economies; Robot herds.
What is ACE?

- Computational study of economies modeled as evolving systems of autonomous interacting agents with learning capabilities

- Specialization to economics of the basic complex adaptive systems paradigm
ACE Methodology

- **Primary Concern:**
  Microfoundations for macro regularities

- **Primary Tool:**
  Computational laboratories

- **Basic Approach:**
  Culture-dish experiments
Culture Dish Analogy

- Virtual economic world with both passive and active agents
- Modeler sets initial conditions of the world
- The world then evolves over time without further outside intervention
- Driven solely by agent-agent interactions
Illustrative Issues

- What explains the wealth of different nations?
- How does a society come to adopt one particular form of money?
- How do workers/employers self-organize into firms?
- Will a proposed electricity market design improve social welfare?
AOP vs. OOP

- What is an object?
- What is an agent?
- How does Agent-Oriented Programming (AOP) extend conventional Object-Oriented Programming (OOP)?
What is an OBJECT?

- A piece of software that encapsulates attributes (data) and methods that act on these attributes.
- Access to the attributes and methods of an object is controlled by declaring them public, private, or protected.
- Communication among objects occurs via their public attributes (interfaces)
What is an AGENT?

A piece of software capable of displaying...

- **Reactivity**: Perception of and response to the environment
- **Social Ability**: Interaction with other agents through some form of language
- **Pro-Activity**: Goal-directed actions
- **Autonomy**: Some degree of control over its own actions (“self-activation”)
Key Distinction is Autonomy

- Distributed *control*, not just distributed actions
- Conventional objects encapsulate attributes and methods but NOT behavioral *activation* and action *choice*

Autonomy means...

- Agents have their own persistent thread of control.
- They decide for themselves which actions they should perform at what time.
- Thus, in multi-agent systems (CAS), a potential source of uncertainty is not knowing for sure what other agents will do (“strategic uncertainty”)! 
Computational Laboratories

- Computational frameworks for the study of CAS by means of controlled and replicable experiments

- GUI permits experimentation by users with no background in programming

- Modular/extensible form permits framework capabilities to be changed/extended by users with programming skills
Example: The Trade Network Game Lab

- Evolution of trade networks among strategical interacting traders (buyers, sellers, and dealers)
- Traders are instantiated as "tradebots" (autonomous software entities with internal data and methods)
- The tradebots engage in event-driven communication
- The tradebots evolve their trading behaviors over time
TNG Lab Architecture

■ Four-layers:
  - SimBioSys (C++ class framework)
  - TNG/SimBioSys (extension classes)
  - TNG/COM (permits interactive display)
  - TNG Lab (graphical user interface)

■ Downloadable freeware
  www.econ.iastate.edu/tesfatsi/tnghome.htm
SimBioSys (McFadzean, 1995)

- Simulation toolkit
- C++ class library
- Designed for artificial life simulations (populations of autonomous interacting agents evolving in a virtual spatial world)
TNG/SimBioSys
(McFadzean/Tesfatsion 1997)
Each Tradebot has...

- Internalized social norms (market protocols) taken as given
- Internally stored state info that can change through experiences
- An internal trading strategy (personality) that the tradebot evolves over time in an attempt to increase its profits
TNG Flow Diagram

- INITIALIZATION

- LOOP Through Tmax Trade Cycles
  - Trade Cycle: Search/Match
    Trade Interactions
    Update expectations

- EVOLUTION STEP

- LOOP Through Tmax Trade Cycles...
Learning About State → Expectations → Welfare Outcomes → Worksite Behavior → Contractual Networks → State of the World → Evolution of State

... t-1 t t+1 t+2 ...
TNG Lab 4-Layer Architecture
(McFadzean, Stewart, and Tesfatsion, IEEE-TEC, 2001)

- TNG Lab
- TNG/COM
- TNG/SimBioSys
- SimBioSys class framework
TNG Settings Screen

TNG Lab - C:\tng\fig3-7.tng

Genetic Algorithm
- Generations: 50
- Trade Cycles: 150
- Seed: 19
- Mutation Rate: 0.005

Payoffs
- Initial Expected: 1.4
- Refusal: -0.5
- Inactive: 0
- Experience Gain: 0
- Both Co-op: 1.4
- Both Defect: -0.6
- Temptation: 3.4
- Sucker: -1.6

FSM
- States: 16
- Memory: 1

Trade Network Game
- Buyer: 12
- % Elite: 0.67
- Quotas:
  - Buyer: 1
- Seller: 12
- % Elite: 0.67
- Dealer: 0
- % Elite: 0.67
TNG Results Screen
TNG Network
Animation Screen
TNG Physics Screen
ACE Research Areas

http://www.econ.iastate.edu/tesfatsi/aapplicant.htm

- Building comp labs
- Learning/embodied cognition
- Evolution of norms
- Network formation
- Market case studies
- Industrial organization
- Political economy
- Market design
- Automated markets with software agents
- Parallel experiments ...