FROM FACTORS TO ACTORS: COMPUTATIONAL SOCIOLOGY AND AGENT-BASED MODELING

Macy, M. W and R. Willer (2002). **From Factors to Actors:** Computational Sociology and Agent-Based Modeling, Annual Review of Sociology, **28**:143-166.

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December 6-8, 2016

CSCE990 Advanced Multiagent Systems

Introduction

- A flock of geese flying in tight formation …
  - No “group mind”, no “leader bird”
  - But … graceful dancelike movement of the flock … clearly patterned yet also highly nonlinear
  - Very difficult to model at a global level
- But, when the movement is modeled using local interactions …
  - *Separation*: don’t get too close to any object, including other birds
  - *Alignment*: try to match the speed and direction of nearby birds
  - *Cohesion*: Head for the perceived center of mass of the birds in your immediate neighborhood
- **Agent-based modeling!**

Introduction 2

- Agent-based models (ABMs) of human social interaction are based on the same theory-building strategy
- Sociologists have traditionally understood social life as a hierarchical system of institutions and norms that shape individual behavior from the top down
- Growing interest in the possibility that human groups may be highly complex, non-linear, path-dependent, and self-organizing
  - To understand these dynamics much better … by trying to model them as emergent properties of local interaction among adaptive agents

Historical Development of Agent-Based Models

- Three periods in the development of social simulation:
  - *Macrosimulation*: differential equation that predict population distributions as a holistic function of other systemic factors
  - *Microsimulation*: bottom-up strategy for modeling the interacting behavior of decision makers within a larger system
    - Resemble macrosimulation but they model *changes to each element of the population distribution* rather than *changes to the distribution at the population level*
    - *Do not permit individuals to directly interact or to adapt*
  - *Agent-based models*:
    - Like microsimulation, bottom-up models explored the microfoundations of global patterns
    - But: *the agents now interact interdependently*

Historical Development of Agent-Based Models 2

- ABMs impose four key assumptions
  - *Agents are autonomous*
  - *Agents are interdependent*
  - *Agents follow simple rules*
  - *Agents are adaptive and backward-looking*
    - Agents adapt by moving, imitating, replicating, or learning, but not by calculating the most efficient action
      - *Individual level: individuals learn through processes like reinforcement, Bayesian updating, ANN*
      - *Population level: populations learn through evolutionary processes of selection, imitation, and social influence*

Historical Development of Agent-Based Models 3

- Most applications congregated around two problems:
  - The self-organization of social structure
    - ***Emergent structure***
    - Agents may start out undifferentiated and then change location or behavior so as to avoid becoming different or isolated
      - Rather than producing homogeneity … produce global patterns of cultural differentiation, stratification, and clustering in social networks
    - Or, starting with a heterogeneous population and ending in convergence
      - Coordination, diffusion, and sudden collapse of norms, institutions, beliefs, innovations, standards, etc.
  - The emergence of social order
    - ***Emergent social order***
    - How egoistic adaptation can lead to successful collective action without either altruism or global (top-down) imposition of control

Social influence and the Paradox of Mimetic Divergence

- The ecological assumption that *adaptation occurs through a struggle of survival* is appropriate *if the agents are organizations competing for resources or members*
- If agents are individuals in a modern welfare state *… adaptation occurs through imitation of the fittest*
  - *Agents are not replaced by better performers; they simply copy their observed behavior*
- From a random start, a population of mimics might be expected to converge on a single profile
  - *Leading to the conclusion that cultural diversity is imposed by factors that counteract the effects of conformist tendencies*
  - *However, the surprising result: "the system achieved stable diversity. The minority was able to survive, contrary to the belief that social influence inexorably leads to uniformity"*

Emergent Structure

Social influence and the Paradox of Mimetic Divergence 2

- Another set of models couple local influence and homophily
  - *Local influence*: the tendency for people who interact frequently to become more similar overtime
  - *Homophily*: the tendency to interact more frequently with similar agents
- The more agents interact, the more similar they become, and the more similar they become, the more likely they are to interact …
  - Interaction, in turn, reduces remaining differences
  - This self-reinforcing dynamic would lead inexorably to cultural convergence and homogeneity
  - But: ***local convergence can lead to global polarization***

Emergent Structure

Diffusion of Innovation

- Social influence models can also lead to study self-reinforcing dynamics that lead to convergence
  - Start with some distribution of practices and a rule by which agents decide whether to abandon current practice in favor of one used by another agent
  - Positive feedback loop where adoptions by some actors increase the pressure to adopt for other actors
  - *Influence weighted by reputations of other agents in the population*

Emergent Structure

Models of Collective Action, Trust, and Cooperation

- Models of emergent order focus attention on the ways in which network structures affect the viability of prosocial behavior
- Four network properties shown to promote/inhibit cooperation and participation in collective action
  - *Relational stability:* On-going relationships lengthen the "shadow of the future"
    - it-for-tat, reciprocity, etc.
  - *Network density:* The coordination complexity of cooperation increases with the number of social ties
  - *Homophily:* Agents tend to interact with partners who use similar strategies
  - *Transitivity:* An agent's partners tend to interact with each other. This in turn affects:
    - Diffusion of reputations
    - Bandwagons caused by threshold effects
    - Monitoring and enforcement of conformity to prosocial norms (social pressure)

Emergent Order

Conclusion

- Computational sociology has traditionally used simulation to forecast social trajectories based on *statistical associations*, using models that are highly *realistic, empirically grounded*, and *holistic*
- Agent-based models use simulation to search for causal mechanisms that may underlie statistical associations, using models that are highly *abstract and microsocial*
- A series of recommendations for realizing the rich sociological potential of ABM approach
  - Start it simple
  - Avoid reliance on biological metaphors
  - Experiment, don't just explore
  - Test robustness
  - Test external validity (test identified causal mechanisms in lab or natural conditions)
  - Test domain validity
  - Bring factors back in

Comments

- Most of your final project proposals stated that there are some desired emergent properties
- Emergent structure or emergent order, or both?
- Only one group's hypotheses would test both emergent structure and emergent order
- Think about your final project: are you leveraging the advantages of a multiagent solution?
  - Local interactions (or decisions) vs. global coherence (or emergent behaviors)