Chaos, Complexity, and Inference (36-462)

Lecture 23

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Common Elements of Agent-Based Models

- Stigmergy
- Mutual adjustment
- Frustration
- History dependence
- Adaptation

Mostly, variations on themes from Herbert Simon (1996)
Axelrod and Cohen (1999) is also very worth reading for general orientation

Stigmergy

stigma, “sign” + *ergon* “work”

the traces left by previous work become the signs directing future work

Classic examples: social insects (Camazine *et al.*, 2001)

- pheromone trails
- nest-building
- inspires “ant-colony optimization”

Not just social insects; lots of human stigmergy (e.g., footpaths)

- read `http://whimsley.typepad.com/whimsley/2008/03/mr-googles-guid.html` on footpaths

The Mind Is Not Just in the Head

People extend cognition into the physical environment

"give me pen and paper, I need to think!"

and into the social environment

conversation, law, bureaucracy, science, markets, government, . . .

though of course none of it works without the stuff *in* the head

(Clark 2003; Frawley 1997; Hutchins 1995; Mercer 2000; Simon 1956; Stinchcombe 2001; Vygotsky 1934/1986,. . .)

Cumulative Action

Previous actions by some agents create the conditions under which other agents act, and create those conditions in turn
Not *just* stigmergy

> *Men make their own history, but they do not make it as they please; they do not make it under self-selected circumstances, but under circumstances existing already, given and transmitted from the past. The tradition of all dead generations weighs like a nightmare on the brains of the living.*

[prize for the first student to identify the quoted author]

Mutual Adjustment

Everybody ends up making a *best response* move to what everybody else is doing (Young, 1998)

"Best move under the circumstances" $\neq$ "what your actions show you really want" (Slee, 2006)

Mutual adjustment (often) tends to create fairly stable equilibria (Hayek, 1937, 1945; Lindblom, 1965; Young, 1998; Borkar, 2002; Foster and Young, 2003)

Mutual responsiveness can create the illusion of central control...

Failure to grasp this leads to conspiracy theories, Intelligent Design, etc.

...which is not to say that no one ever has control!

Equilibrium Traps and Frustration

Equilibria are not necessarily good for anyone involved (Slee, 2006; Schelling, 1978)

Schelling's segregation model: free choice leads to *everyone* being worse off

Example of an **equilibrium trap**

Frustration: No way to make *everyone* happy at once; one agent improving worsens another

Related to satisfiability in computational complexity

Frustration often leads to cycling or churning

Equilibrium traps are often better for some than others

Loury (2002) model of self-reinforcing racial discrimination

Axtell *et al.* (2001) for a model of just how persistent inefficient, inequitable equilibria can be

Elvin (1973) argues that the failure of China to launch its own industrial revolution under the Song dynasty was partly due to a *high-level* equilibrium trap; cf. McNeill (1982)

History-Dependence

Following Brian Arthur (1994), the idea that history of the assemblage alters its current dynamics has come to be called "path dependence"

Classic examples of locking-in historical accidents:

QWERTY keyboard disputed by some paid apologists for Microsoft

Microsoft Windows

VHS vs. Beta

New York vs. Philadelphia Erie canal: faster and cheaper than the Pennsylvania turnpike

Shapiro and Varian (1998) is a guide to creating and exploiting lock-in for profit

Look back to lectures on heavy tails for examples of *highly* skewed outcomes which don't reflect any intrinsic differences

Following Scott Page (2006), can usefully distinguish 3 varieties

State dependence Current state matters, but not the route to it; all paths to the same end-point equivalent (Markov)

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Phat dependence *Which* states mattered, but their order can be scrambled without effect

A Statistical Issue with Path Dependence

Path dependence and phat dependence both imply that the number of statistical parameters *grows* over time!

faster growth for path than for phat

Responses:

Denial Everything people claim is phat/path dependent is really just state dependent

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Bargaining Microlevel process is state-dependent, but aggregate variables give imperfect information about it, and different bits of information depending on historical context

Adaptation

Huge topic, will return to this

ad- "to, toward, on top of, on outside of" + *aptare* "to make fit"

Making things fit together; making agents fit their environment

Basic strategy: do more of what works; do less of what didn't work; try something new

External adaptation: have lots of agents, copy the ones which did well

Internal adaptation: have lots of options, reinforce the ones which did well

Cultural transmission blurs distinction

Exploitation/exploration trade-off

How do you learn about what you haven't tried?

Statistical issue: enodgeneity

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EXERCISE: Read Jorge Luis Borges's "The Garden of Forking Paths"

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