Intro. Cont: EVP631/GEOG 631/CSS645, “Spatial Agent-based Models of Human-environment Interactions”

Jan. 30, 2007

Plan for today

- Questions about definitions, etc.
- Conceptual intro continued
- Pattern-oriented modeling
- Potential modeling platforms
- Market mechanism
- Logo models (short lab/writing assignment)

Course themes covered today …

- Understanding the behavior of complex models (3rd way of science)
- Model verification and validation (esp. pattern-oriented validation)
- Empirical methods for building agent decision models (somewhat, more next week)
- Modeling market interactions

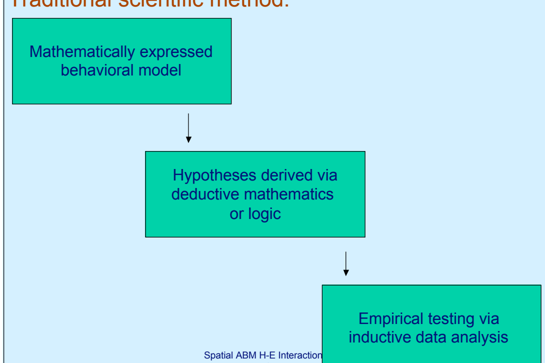
Typology of ABMs

		Agents: Designed	Agents: Analyzed
Environment	Designed	Existence proof; Discovery of new relationships	Laboratory experiments; Role-playing games
Environment	Analyzed	Explanation	Explanation; Projection; Scenario analysis

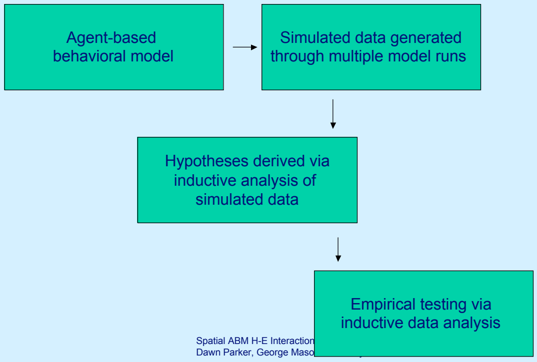
Berger/Parker (2002).

Jump to tables from new CASA report …

Traditional scientific method:



The “third way of science”:



“Pseudo-inductive” application to “Cell 1” models

- Design hypothetical causal rules/mechanisms into ABM
- Generate database of outcomes by sweeping model parameter space
- Analyze generated data using inductive methods that use emergent macro outcomes as dependent variables, and parameter values as independent
- Hypotheses (equivalent of comparative statics or dynamics are contained in the estimate coefficients: how to macro outcomes change as parameters change
- Dr. Parker will show this with the SLUDGE model later
- Happe paper also takes a similar approach

“Pseudo-inductive” application to “Cell 4” models

- Parameterize ABM using real-world derived rules and data
- Generate one or a range of model outcomes
- Analyze generated and real-world data using the same inductive model
- If estimated model coefficients are qualitatively similar (coefficient sign and significance), you have qualitative agreement with the real world
- If estimated model coefficients are statistically significantly similar, you have quantitative agreement with the real world (and I bet an incorrect model)

But …

- This is all open to discussion and we may change our mind!

Issues in calibration, verification, and validation

Definition: Calibration

- “Calibration refers to the process of creating a model such that it is consistent with the data used to create the model” (Verburg et al 2006)
- Derivation of best-fit model parameters from real-world data (Dawn)
- Goodness of fit measures of calibration only measure model applicability within the range of calibration data.

Definitions: Verification and Validation

- "Verification and validation concern, respectively, the correctness of model construction and the truthfulness of a model with respect to its problem domain. In other words, verification means building the system right, and validation means building the right system…Once a model is verified and works correctly, then the modeler is concerned with validation—comparing model outcomes to outside data and expectations." (Manson from Parker et al. 2003)

Model Verification

- Most important for deductively-structured models (mathematical programming and agent-based)
- The main idea is that you must test out your model rules methodically to make sure they are doing what you intend them to do
- Verification can also be similar to structural validation--are the rules the right rules?

Model validation: Verburg et al 2006

Rykiel (1996) defines validation as "a demonstration that a model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model". Model validation is therefore the process of measuring the agreement between the model prediction and independent data. If there is a good match, then the method used to make the prediction is said to be valid. It is crucial to distinguish between model calibration and model validation.

Goals of validation (Verburg et al 2006; Manson 2003)

- Manson, answer question: "How well does a model characterize the target system?"
- Verburg et al: "It is not particularly useful to attempt to crown a model as valid, or to condemn a model as invalid based on the validation results. It is more useful to state carefully the degree to which a model is valid. Validation should measure the performance of a model in a manner that enables the scientist to know the level of trust that one should put in the model. Useful validation should also give the modeller information necessary to improve the model."

General validation criteria (Quote Manson 2003 from Kwansnicki 1999)

- Correctness: model structure and outcomes must be similar to those of the target system.
- Consistency: the model must be internally consistent and match the conceptual framework in order to describe the target system.
- Universality: the model should be applicable to circumstances beyond those described by the calibration data.
- Simplicity: when choosing between two models, all other things being equal, the less complicated model is preferable.
- Novelty: a model should create new knowledge or outcomes.

Competing measures?

- Note there may be conflicts between these criteria
- Correctness may be more important for empirical, case specific models
- Novelty may be more important for generalizable, theoretical models
- Manson notes (p. 61) that the final structure of the model may be the outcome of interest

Structural vs. outcome validation

- Structural validation examines whether the mechanisms in your model correctly represent real-world mechanisms: are the exogenous components of your model representative of the system under study?
- Outcome validation asks whether model output (endogenous components) conform with data derived from the real-world system
- Outcome validation can be either spatial or a-spatial; today's articles mainly focus on spatial validation

Pattern-oriented modeling (Grimm et al. 2005; Grimm forthcoming)

- Key point is that validation targets are identified a-priori
- Targets are patterns (emergent phenomena) at multiple (but higher) scales
- Recall definition of emergence from Auyang: something about outcome patterns at higher scale that are qualitatively different that the lower-scale entities that produced them.
- Remember the quilting example!

POM rationale (Grimm et al. 2005)

- Patterns represent underlying structure, process, and function
- Goal of POM is to identify underlying processes (note similarity to concept of generative social science, Epstein and Axtell)
- Many processes could create the same single observed pattern
- Therefore, multiple patterns at different scales are required
- Observed patterns should define research questions

Optimizing model complexity …

- Need enough complexity, not too much
- Approach I suggested last week focuses on identifying key sources of complexity in real-world systems
- Grimm et al also note that pattern outcomes of interest should guide model development: your model has to be complex enough to produce the patterns you are interested in
- Both approaches should increase structural realism

Pattern/macro-scale validation: differing perspectives

- Grimm et al advocate model calibration based on higher-scale patterns.
- He proposes "inverse modeling", where behavioral rules are assumed, and a calibration approach is taken to choosing the best parameters (or set of parameters) that can reproduce the patterns
- This approach could at least narrow down potential parameter sets, or rule some out
- See Caruso et al. 2005 for example

Why do I worry about this approach?

- It assumes that the specified structure of the behavioral model is correct. OK for trees, but not so much for humans
- There is a potential identification problem (but multiple pattern outcomes may address this point)
- You can't validate against outcome patterns that you have used for calibration
- Calibration can be highly path dependent
- You would need a lot of data to use this approach to distinguish between competing behavioral models
- Grimm et al. do acknowledge this point and suggest "strong inference" to test alternative models, but they don't relate this to the problem of calibration
- See Robinson et al. next week for more discussion and an alternative approach.

The "home run" goal

- Predicting something outside the range of model validation is a home run--for example, location of new archeological site
- Predicting a macro-scale or emergent pattern not used for model development would be a world series win.
- Examples?

Return to tables for discussion of different simulation platforms

Modeling markets

Why model markets?

Including markets can:

- Increase the realism of ABM/LUCC models
- Better reflect the incentives faced by agents
- Endogenously regulate the number of agents and amount of occupied territory in the model
- Provide additional policy-relevant outputs to the models

Note: Modeling markets does not require assuming perfectly rational profit-maximizing behavior.

Potential Economic/Market Mechanisms for ABM/LUCC Models

- Land markets
- Endogenous commodity prices
- Labor markets
- Fixed costs of adopting new land use
- Risk management and portfolio diversification
- Economies of Scale
- Capital markets (lending and borrowing)

Benefits of land market models:

- More accurate modeling of heterogeneous land values
- Development of a more complex and realistic landscape
- Ability to address questions about market structure/distributions of land holdings
- Feedbacks between quantity, location, and pattern: allows for adjustments based on neighborhood changes
- Modeling land abandonment

(See Polhill, Parker, Gotts ESSA 2005, AAG 2006 and forthcoming chapter for details)

Endogenous Output Prices

- If markets for a product are local, the price received may fall as production increases
- This is very easy to model!
- This endogenous price creates high payoffs for an innovator--if very little is produced, the price received for the very scarce commodity will be high.
- Endogenous output prices also assure that some of that product will be produced in the landscape.

Labor markets

- Most important in developing country models (Berger, Brazilian Amazon models)
- A household's land-use decisions may be constrained by available labor if there is no labor market
- A labor market balances demands for additional labor for some households with supply of surplus labor by others, resulting in different production patterns.
- Outside labor opportunities may also facilitate capital accumulation by households.

Fixed Costs to Change Land Use

- Often, there are substantial start-up costs when a manager changes land uses: physical conversion, new knowledge, new equipment, transition periods
- If fixed costs are present, payoffs for conversion may need to be quite high (and certain) to induce conversion
- Fixed costs can explain managers who stick with less profitable strategies
- In general, fixed costs will slow the rate of transitions in ABM models

Risk Management and Portfolio Diversification

- Farming is an incredibly high risk activity due to uncertainty related to input prices, output prices, and weather.
- This risk may lead managers to diversify their outputs.
- By creating a portfolio of outputs that negatively co-vary (ie, when prices for one are likely to be low, prices for the other are likely to be high, farmers can reduce the overall risk for a given profit threshold
- The availability of crop insurance may also play an important role in decision making.
- Inclusion of risk can lead to fewer transitions and increased heterogeneity of strategies.

Economies of Scale

- If average cost of production fall as farm size increases, economies of scale are present.
- Fixed costs lead to economies of scale. (Example: tomato harvester in US, also precision farming)
- The large increase in farm size in the US has been widely attributed to economies of scale.
- Including scale economies in models should also lead to more consolidation.

Capital Markets (Borrowing and Lending)

- Access to capital plays an important role for farmers in terms of investments to meet fixed costs of transitioning to new outputs and managing risk
- Capital markets are also important for assessing the long-run value of an investment
- Modeling capital markets can reveal linkages between interest rates and land management strategies.
- If long-term investments play an important role in profitability, forward-looking decision models are very important.

Putting the pieces together

- Fixed costs, risk and uncertainty, and scale economies all lead to greater success of large land management operations
- Helps to explain near extinction of small farms in the US
- Also helps to explain the prevalence of urban and residential land developers

Non-market values and create markets

- Many resources have value but are not traded in markets
- Many "ecosystem services" fall in this category: water purification, climate regulation, biodiversity, etc.
- ABM may be useful to explore the implications of market creation and of different institutional structures for markets

Spatial ABM H-E Interactions, Lecture 2
Dawn Parker, George Mason University

Netlogo and assignment for next week

- May be some Netlogo tutorial seminars on Fridays--interest?
- http://ccl.northwestern.edu/netlogo/models/Segregation
- http://ccl.northwestern.edu/netlogo/models/Cooperation
- Assignment posted on internal web site

Spatial ABM H-E Interactions, Lecture 2
Dawn Parker, George Mason University