

ABM/GIS Integration (from Gimblett, Parker 2005, and CASA report), Mr. Potatohead (Parker et al. forthcoming) and empirical methods for ABM decision models (Robinson et al, forthcoming)

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GIS structure

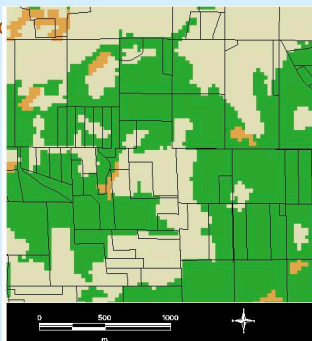
- Spatial data contained in “themes” or “layers” (new arcGIS terminology?)
- Layers may be at different spatial resolutions
- Vector layers have an associated database that may contain multiple attributes
- Raster layers are single-valued for each cell

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Raster vs. Vector Maps

- Resolution of the data is often defined by raster images
- Parcels have vector boundaries

Image credit: Tom Evans, Indiana University



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GIS and models of H/E interactions (Gimblett)

- Until recently, coupled GIS models of H/E interactions were rare
- Many GIS based biophysical models have been developed (soil erosion, hydrology, etc.) (Caveats)
- Urban CA models also common
- Need to include social science data in agent models, as well as create models of spatially intelligent agents
- A major barrier to building integrated models lies in the static structure of GIS databases

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Issue with temporal GIS (CASA)

- Storing/updating all data for each time step may not be efficient
- Several pieces of info may be of interest:
 - Change events
 - The time at which they occurred
 - The process through which they occurred
- Changes in agents and changes in landscapes may be independent
- May want to represent multiple potential futures (Star Trek again...)

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Gimblett examples of GIS integration:

- Box CA (Swarm GIS libraries)
- Westervelt (GRASS)
- Duke-Sylvester ATLSS (operates at multiple spatial scales)
- Note: Rosaria Conte is “she”.
- Deadman and Schlager: CPR and alternative rationality models
- Kohler et al.: archeological applications
- Gimblett et al.: Pedestrian models

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ABM/GIS user 1: end user

- May have limited programming knowledge
- Interesting in running and tweaking existing models
- Also interesting in viewing/analyzing a variety of output
- Likely to be comfortably computer-literate
- May want to develop his own simple model

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ABM/GIS user 2: geeky researchers

- Often interested in developing new ABM model
- May work as part of a larger team or project
- Likely to have a higher level of programming skill

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Geeky researcher activities:

- Design conceptual model
- Choose programming platform
- Design an agent decision module
- Define spatial and temporal interactions
- Input real-world data
- Execute multiple model runs (to capture a range of path-dependent outcome or sweep parameter space)
- Aspatial and spatial analysis of generated data
- Compare generated data to real-world data (aspatial, spatial, and temporal)

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Integration of ABM with GIS

- Integration is needed, but progress is slow
- For more, see old Parker chapter on MAS/LUCC and GIS integration and newer CASA report.
- Stay tuned for more as semester progresses

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Examples of current state of GIS integration:

- No integration (abstract landscapes and designed agents: Cell 1 models)
- GIS data used for model initialization
- GIS data used for display of output
- Very loosely coupled through external files
- Model can be run through GIS interface
- GIS called at run-time by lower-level or scripting language
- GIS functionality within ABM

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GIS needs: Programming/Modeling:

- Object-oriented structure
- Event-driven architecture
- 3-D modeling capabilities
- Dynamic modeling capabilities, especially with regard to interaction with other spatial models (hydrology models, transport cost models, erosion models)
- Modeling of mobile objects (pedestrians, vehicles, non-human organisms)
- Ability to model in both raster and vector environments

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GIS needs: Mathematical functionality

- Ability to construct a variety of agent types (includes the need for good math algorithms)
- Complex and robust optimization algorithms, including spatial integer programming and simulated annealing
- Finite element modeling
- Create random landscape configurations consistent with a distribution of patch sizes for a region

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GIS needs: Model verification tools

- Real-time visualization
- Ability to conduct “on the fly” sensitivity analysis
- Generation of good quality temporal and spatial output graphics
- Save and export animations in standard formats

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GIS needs: Model Validation Tools

- Ability to call individual functions and components in batch mode, potentially for multiple runs which sweep the parameter space
- Ability to store model parameters and output for any execution
- Ability to analyze generated output using statistical models

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GIS needs: Built-in standard functions

- Transparent and well-documented algorithms for agent behavior, spatial processes, and calibration, verification and validation
- Built-in spatial and landscape statistics functions
- Built-in process-based models: flows, fluxes, transport, reactivity
- Built-in statistical functions and tools for output analysis and model verification and validation, including standard land-use modeling statistics and non-parametric stats

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GIS functionality included in integrated models

- Initialization with vector layers
- Mobile agents, over space and networks
- Peer-to-peer communication
- Sensing of spatial surroundings: line of sight, neighborhood information, distance and travel cost calculations
- Terrain/topographic models
- Buffering (new, alpha Sludge-V)

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Options for software development

- Single program vs. hybrid
- GUI vs. scripted (needs better consideration of the SIMILE approach)
- Commercial vs. open-source

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Call for a standard base model

- Without mathematics, some standard model is needed to develop a shared language.
- This standard model format can be thought of as a “conceptual design pattern”
- It would contain key generic elements of ABM/LUCC, and would be built on standard drivers of land-use change
- Could the DEVS formalism (Gimblett) serve as a model?
- This lead me to create Mr. Potatohead ...

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The MR POTATOHEAD framework

- Goal is to create a conceptual design pattern to be used to:
 - Describe the structure of existing models
 - Compare the structure of existing models
 - Create a template for design of new models
 - Create a design pattern for a set of shared code libraries
- Focus is on land use models for a start

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Seven/eight “Super-classes”

- Information/data
- Interfaces to other models
- Demographics
- Land-use decision
- Land exchange
- Feedbacks (new)
- Model operation
- Model outputs (deleted, but possible)

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NQ UML

- Although we have classes, functions, and data, this is not UML
- This CDP could have a different structure than the code itself.

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Key

- Bullets are generic elements
- Dashes are examples
- Asterisk are considered required

- Go over main figures from paper ...

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Your opinion?

- How boring of a read was it?
- Utility for:
 - Understanding/comparing models
 - Designing your own?
- Extensions (see SWA)
 - New classes/decisions functions for other resources?

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“Method 2 Method” paper

- Workshop compared 5 methods for building empirical ABM decision models:
 - Sample surveys
 - Participant observation
 - Field/lab experiments
 - Companion modeling
 - Analysis of spatial data

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Empirical data needs

- Data on macro/emergent/pattern outcomes
- Data to inform microprocesses
- Recall discussion from last week about calibration ...
- Both qualitative and quantitative data can play a role

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What questions need to be answered?

- *Social/biophysical environment*: What environmental or social factors influence actor decisions, and what are their relative influences?
- *Agents*: Agent classes and numbers & types, frequency, conditionality of interactions
- *Agent behavior*: Decision models/cognitive processes; learning and adaptation; & actor heterogeneity
- *Temporal aspects*: Sequence and duration of agent actions/interactions; event occurrences, agent updating? (note relationship to GIS discussion)

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Survey data

- Generally at the scale of the decision-making agent (here, households or land managers)
- Qualitative/quantitative questions regarding behavior, beliefs, information, characteristics, etc.
- Statistical models applied to survey data generally assume some kind of theoretical framework; analysis can be used to discover key drivers

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Participant observation

- Anthropologic approach using long-term observation and participation in target culture
- Means of building hypotheses/conceptual model about behavior
- Can be part of an iterative process of theory building
- Generally produces qualitative data
- Good means of identifying interactions/dynamic relationships

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Field and lab experiments

- Generally economic experiments with cash incentives
- Goal is to understand/test alternative models of decision making--which models are most consistent with observed data?
- Generally not used to estimate parameters for decision models
- Experiments could help address the “identification problem” discussed last week.
- Can be used to explore interactions as well as individual decisions

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Companion modeling

- Virtual representation of decision environment is constructed
- Role-playing games are conducted using this environment
- Results can be used to develop a set of ABM rules
- Model and rules are refined through an iterative process with stakeholders
- Also effective for discovering interactions

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Spatial data

- Can be used to create input variables that affect agent decisions:
 - Transportation networks
 - Neighborhood effects
 - Etc.
 - These could enter into MP decision models (Berger, Happe)
- Spatial statistical models can quantify the relationship between these inputs and the probability of a change event
- These models can be assumed to represent an agent decision

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Move to strength/weakness tables ...

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Housekeeping

- Article assignments-check, make modifications?
- Tim Kohler talk--CSC, 2:30 on Friday (!!!!!)
- Normal SWA for next week: review guidelines
- Extra (but short) SWA--MR Potatohead extension ideas. Note that you can create a new MP class instead of an SWA any week but next. Nest 2 or more models from that week.
- Schelling slides following are just maintained for your reference--we are not covering this year. Could change our mind.

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Schelling, Thermostats, Lemons, etc.

Main themes:

- Conditional behavior
- Inductive, adaptive responses
- Expectations
- Agent heterogeneity

Leading to:

- Multiple equilibria
- Oscillatory dynamics
- Divergence between individual wants and the public good

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Schelling on "Models"

- "precise and economical statement of set of relationships sufficient to produce the phenomena in question"
- "an actual biological, mechanical, or social system that embodies the relationships in an especially transparent way, producing the phenomena as an obvious consequence of the relationships"
- We need the model if it "gives us a head start in recognizing phenomena and the mechanisms that generate them and in knowing what to look for in the explanation of interesting phenomena"
- "Models tend to be useful when they are simultaneously simple enough to fit a variety of behaviors and complex enough to fit behaviors that need the help of an *explanatory model*"
- Shared models also assist communication.

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Critical Mass models

- Behavior is dependent on proportion or number of other engaging in that, or another, behavior
- Activity is self-sustaining beyond a critical threshold; below this, activity may die out.

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“Lemons” model

- Sellers know quality of each used car, but buyers only know average quality levels, and are willing to pay only for average quality
- As a result, sellers with higher than average quality cars take their cars off the market
- Consequently, the average quality level fall, as does the buyer’s willingness to pay
- More sellers leave the market, average quality falls again ...
- Note model depends on heterogeneous quality levels

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“Tipping” models (seminar example)

- Each person has a minimum number of others for which he/she is comfortable in the seminar
- These numbers differ among individuals, some will go even if few others go, some require a large crowd.
- This distribution of preferences can be described as a cumulative density function (see figure)

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Seminar example cont.

- Three equilibria:
- None expected and none attending
- 85 expected and 85 attending
- 40 expected and 40 attending (unstable: what if one person gets sick? Or brings a visiting scholar?)
- See figure 2 for other examples

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“Commons” problems

- See Parker short entry
- “Commons” problems involve economic externalities
- Schelling distinguishes three levels of resource use: socially optimal, in between, and all individual benefits extinguished (private marginal benefit=private marginal cost)
- “social contract” section contains great examples of free-riding

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Self-fulfilling expectations

“Expectations are of such a character that they induce the kind of behavior that will cause the expectations to be fulfilled.” Types:

- Mutually reinforcing: “If each of use believes that the other will attack without warning at the first opportunity, each of us may feel it necessary in self-defense to attack without warning at the first opportunity”
- Progressive: need to get there early to get a seat
- Critical mass: bank failure

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More ... your turn to give examples

- “Self-displacing prophecy”
- “Self-equilibrating expectation”
- “Self-correcting expectations”
- “Self-confirming signals”
- “Self-enforcing conventions”

Many of these create a need for coordination among individuals

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