Theory Development

EES 4760/5760

Agent-Based and Individual-Based Computational Modeling

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Class #21: Monday, November 04 2024

Preliminaries:

Announcements

- Draft Model Code will be due Friday Nov. 15, not Friday Nov. 8
- No office hour today

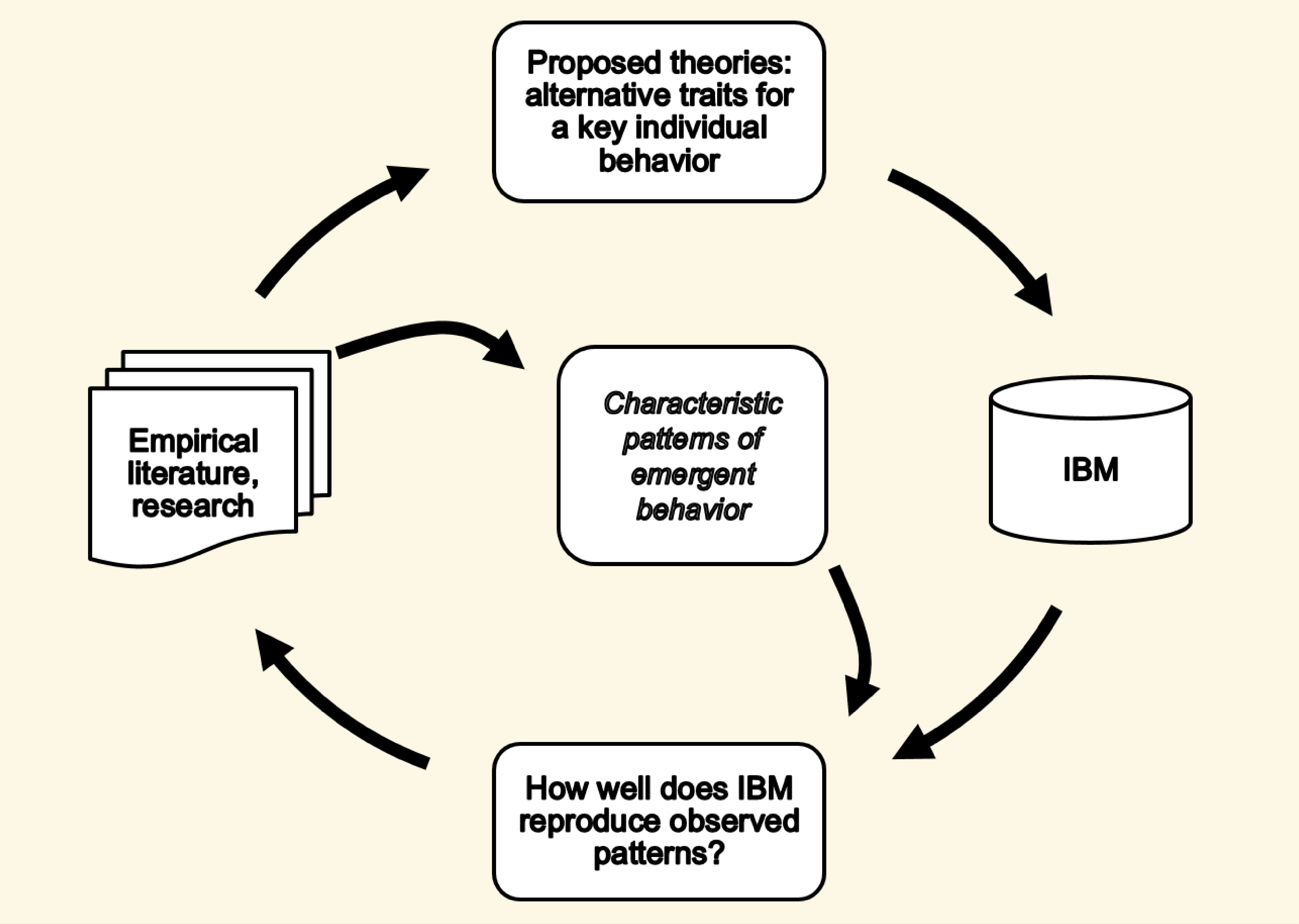
Theory Development

Models as a Virtual Laboratory

- How to use models to run experiments?
- Strong inference (John Platt)
- Identify traits (individual behaviors) that give rise to multiple macroscopic patterns

1. Identify alternative traits (hypotheses)
2. Implement traits in ABM
3. Test and compare alternatives:
    - How well did model reproduce observed patterns?
    - Falsify traits that did not reproduce patterns
4. Repeat cycle as needed. Revise behavior traits, look for additional patterns, etc.

Pattern-Oriented Modeling Cycle



Example: Trader intelligence

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Continuous Double Auction

1. Traders establish buying and selling prices
   - If someone offers a price $\geq$ selling price, trader sells.
   - If someone offers to sell for $\leq$ buying price, trader buys
2. Match traders:
   - If traders i and j have $P_{i,\text{buy}} \geq P_{j,\text{sell}}$, then transaction occurs.

Different Models of Agent Intelligence-models

Zero-intelligence agents:

- Agents set random buying and selling prices
- If an agent has $P_{\text{buy}} > P_{\text{sell}}$, then they will lose money.

Minimal-intelligence agents

- Random buying and selling price with constraint:
  - Each agent sets its $P_{\text{buy}} < P_{\text{sell}}$.
  - Sales can still happen because agents i and j may have
    - $P_{i,\text{buy}} \geq P_{j,\text{sell}}$
    - Even though
      - $P_{i,\text{buy}} < P_{i,\text{sell}}$
      - $P_{j,\text{buy}} < P_{j,\text{sell}}$

Results

- Compare simulated market to transactions from real markets
- Minimal-intelligence agent was better than zero-intelligence
  - Zero-intelligence produced wild price fluctuations
  - Minimal-intelligence reproduced observed pattern of rapid price convergence
  - Minimal-intelligence also reproduced observed effects of price-ceiling.
- But simple models had limits:
  - Observed volatility of lower-end prices was not reproduced by models
  - As experimental markets got more complicated, human traders did worse, but models did ***much*** worse.

Lessons

Using zero-intelligence as a baseline, the researcher can ask: what is the minimal additional structure or restrictions on agent behavior that are necessary to achieve a certain goal.

Example: Harvesting Common Resource

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- Experimental subjects move avatars on screen to harvest tokens (like simple video game)
- Players compete to get most tokens
- Tokens grow back at some rate
- Patterns:

1. Number of tokens on screen over time
2. Inequality between players
3. # tokens collected in first four minutes
4. Number of straight-line moves

Theory development

1. Näive model: (random) Moves randomly
2. Näive model: (greedy) Always goes to nearest token
3. Clever model:
   - Prefers nearby tokens
   - Prefers clusters of tokens
   - Prefers tokens straight ahead
   - Avoids tokens close to other players

Results:

- Näive models do not match any of the four patterns.
- Ran clever model 100 times for each of 65,536 different combinations of parameters that characterize preferences.
  - Only 37 combinations of parameters matched all four patterns in data.
  - Patterns 2 and 3 are seen for most parameter values
  - Patterns 1 and 4 seen less frequently
  - Therefore:
    - Patterns 2 and 3 are built into the structure of the game.
    - Patterns 1 and 4 may give insight into human behavior.

Example: Woodhoopoe

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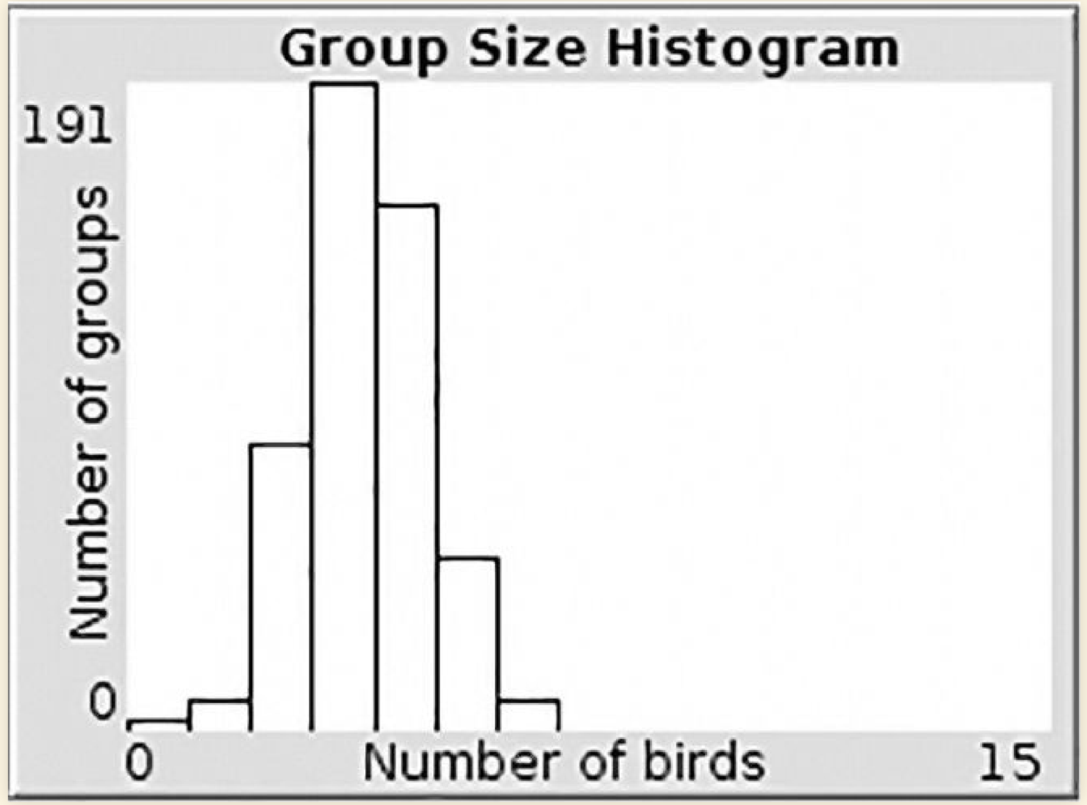
Observed Behaviors

- Groups occupy spatial territories
- One **alpha** of each sex in a territory
- Only alpha pair reproduces
- If alpha dies, oldest subordinate of that sex becomes alpha
- **Scouting forays**
  - Subordinate adult leaves territory
  - If it finds territory without alpha, it stays, becomes alpha
  - Otherwise, returns home
  - Risk of predation (death) is high on scouting forays
- Alpha pair breeds once a year, in December

Observed Patterns

1. Characteristic group size distribution (adults)



2. Average age of birds on scouting forays is younger than average age of all subordinates.
3. Scouting forays most common April–October

Modeling Woodhoopoe

- Start simple:
  - One-dimensional world
  - One tick = one month
  - Every tick, bird has 2% chance of dying (0.98 probability to survive)
  - Scouting forays have 20% chance of death (0.80 probability to survive)
  - Adult subordinates go scouting at random (10% probability each tick)
- Does model reproduce patterns?

Developing Alternative Strategies

Alternative Strategies:

1. **Random:** Subordinates go scouting randomly with probability `p-scout`.
2. **Always:** Subordinates always go scouting
3. **Never:** Subordinates never go scouting
4. **Direct:** Subordinates calculate the probability of reproducing within a certain time horizon if they go scouting or if they stay in the next and wait to become alpha. They choose the option that gives the greatest probability of reproducing.
5. **Indirect:** Approximate the direct method by scouting randomly, with a probability that depends on the number of subordinate adults older then them:

$$P_{\text{scout}} = 1 - (0.5)^{\text{elder subordinates}}$$

- For 0 elders, P_{scout} = 0%
- For 1 elder, P_{scout} = 50%
- For 2 elders, P_{scout} = 75%
- For 3 elders, P_{scout} = 87.5%
- ...