Theory Development

EES 4760/5760

Agent-Based & Individual-Based Computational Modeling

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Class #21: Tuesday, Mar. 27 2018

Live web page: https://ees4760.jgilligan.org/Slides/Class_21
PDF: https://ees4760.jgilligan.org/Slides/Class_21/EES_4760_5760_Class_21_Slides.pdf

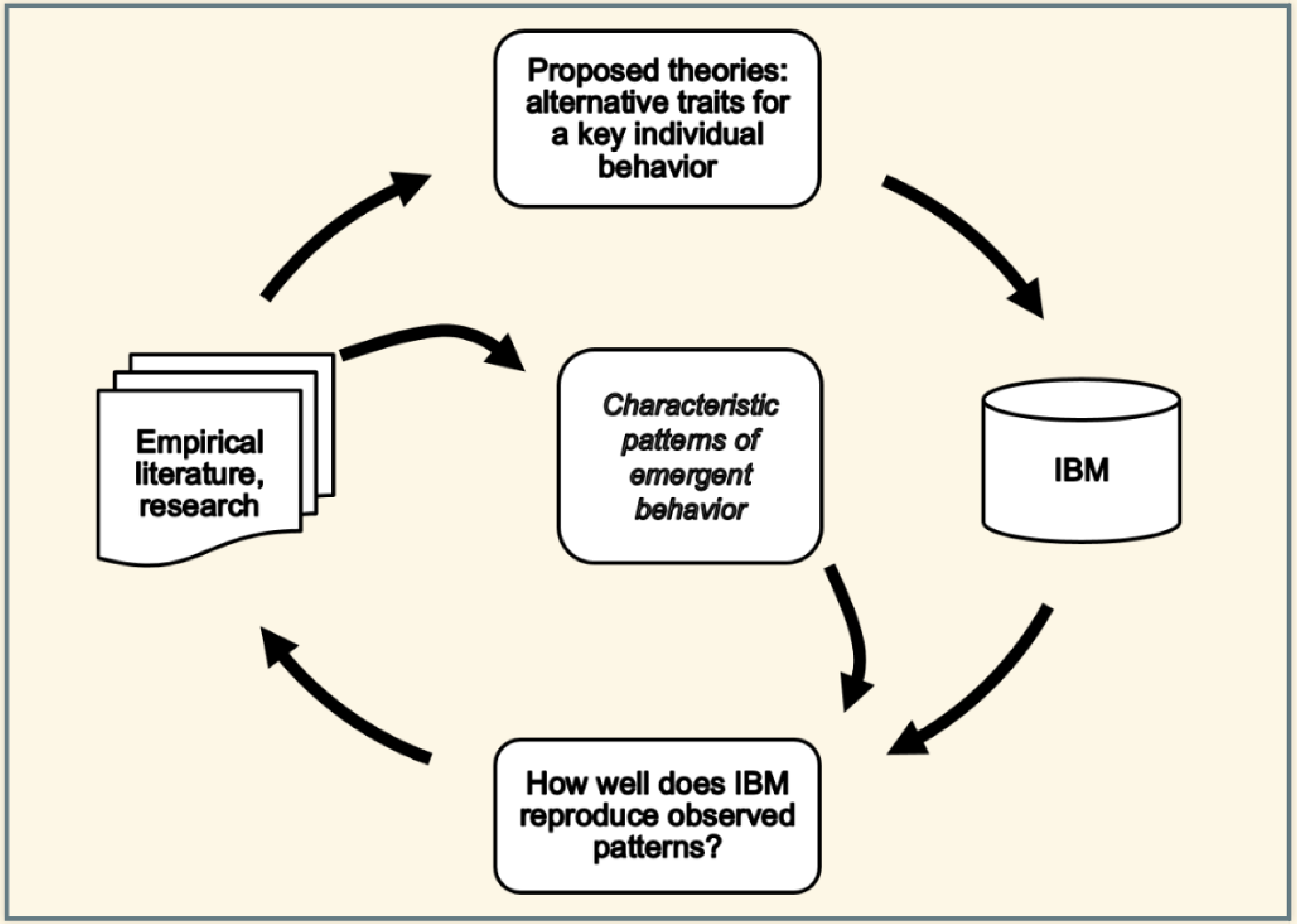
Downloads

- Download page: https://ees4760.jgilligan.org/downloads/hoopoe_class_21/
- Zip file https://ees4760.jgilligan.org/models/class_21/class_21_models.zip containing Wood Hoopoe breeding model:
  - NetLogo model: https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_class_21.nlogo
  - ODD: https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_odd.pdf
  - NetLogo model with alternative strategies: https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_strategies.nlogo

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

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 $P_{i,\text{sell}} \leq P_{j,\text{buy}}$, then transaction occurs.

Zero-intelligence agent

- Agent sets random buying and selling price
- If $P_{i,\text{buy}} > P_{i,\text{sell}}$, then trader i will lose money.

Minimal-intelligence agent

- Random buying and selling price with constraint: $P_{i,\text{buy}} < P_{i,\text{sell}}$.

Results

- 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

- 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

- 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

https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_class_21.nlogo

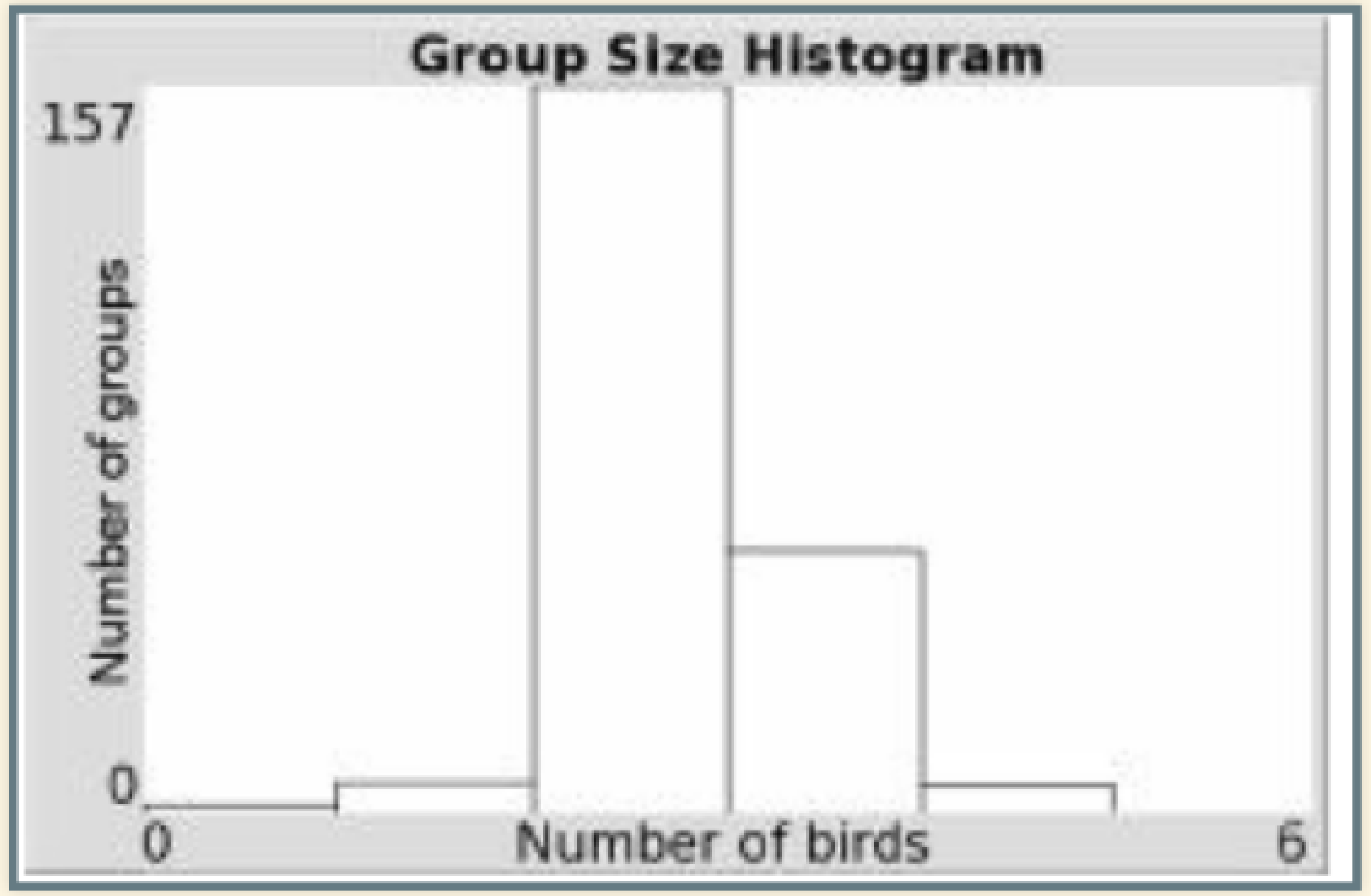
https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_odd.pdf

Observed Behaviors

- Groups occupy spatial territories
- One **alpha** of each sex in a territory
- Only alpha couple 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 couple 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 1% chance of dying (0.99 probability to survive)
  - Scouting forays have 20% chance of death (0.80 probability to survive)
  - Adult subordinates go scouting at random (50% probability each tick)
- Does model reproduce patterns?

Developing Alternative Strategies

https://ees4760.jgilligan.org/models/class_21/wood_hoopoe_strategies.nlogo