Agent-Based Computational Models and Generative Social Science

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Key Features of Agent-Based Computational Models

- Heterogeneity
- Autonomy
- Bounded Rationality
  - Bounded information
  - Bounded Computing Capacity
- Explicit Space
- Local Interactions
- Non-Equilibrium Dynamics
  - Tipping Phenomena
To explain macroscopic phenomena, we situate an initial population of autonomous heterogeneous agents in the relevant spatial environment; allow them to interact according to simple local rules and thereby generate--or “grow”--the macroscopic phenomenon from the bottom up.

Generative Sufficiency is the core explanatory notion.
• Events unfold on a landscape of renewable resource: ”Sugar”
  – The sugarscape proper a twin peaked distribution
  – The darker the yellow, the greater the sugar value
  – Each site has a capacity, a current level, and a simple rule: If less than capacity, grow back at unit rate.
The Sugarscape Agents

- Ultimately, they move, feed, age, reproduce, transmit genes, transmit cultural identities, form social networks, fight, trade, contract diseases, and more.
- Initially, they are minimal
  - Vision (heterogeneous)
  - Metabolism (heterogeneous)
  - One **Simple Local Rule**: Inspect all unoccupied sites **within your vision**; select the one richest in sugar; move there and harvest the sugar
- When they “eat,” we up their sugar wealth by that amount, then we charge them their metabolic rate; if the result is negative, they die. Otherwise, go again.
What Can You Grow?

- **Empirical fact:** All industrial societies since the turn of the century display a Pareto distribution of income.

- **Is the extremely minimal Sugarscape microspecification in fact sufficient to generate** a Pareto distribution at the macro-level?
Simple Environmental Couplings

- Divide Landscape into a North and South
- Introduce “seasons.” For 50 periods, it’s bloom in north, drought in south. Then the reverse.
- Generates environmental refugees.
- Environmental degradation can have security implications.
Evolutionary Dynamics

- Population Growth via Sexual Reproduction
- Evolution via Mendelian One Locus Two-Allele Genetics for Vision and Metabolism.
- Watch Darwinian Natural Selection.
  - Vision: Red if V > Initial Median
  - Metabolism: B if M < Initial Median
- Nature-Nurture
Cultural Transmission

- Tag-Flipping on Cultural Bit Strings
- $A(j) = 100101001; A(k) = 001101100$
- Vertical Transmission: ∀ position, equal chance of inheriting mom’s or dad’s tag.
- Horizontal Transmission: Agent $j$ hops next to agent $k$ and “transmits” to $k$ his value at a random position.
- Sufficient to generate spatially segregated “tribes.”
Combat

- Now that there are “tribes,” combat between tribes is possible.
- R attacks B if R>B and no retaliating B, and vice versa
- Mode 1: Victor takes entire accumulated wealth. Ethnic Cleansing or Oligopoly
- Mode 2: Victor takes fixed reward of x units. Stable Trench War
Combat vs. Assimilation

- Combat Mode 1 (winner take all) Plus Tag-Flipping
- Big agents “converted” before they run to monopoly
- Study interplay of assimilation and combat as modes of group defense.
The Proto-History

- Turn four modes on at once
  - Movement
  - Reproduction
  - Cultural Transmission and Tribe Formation
  - Combat
- Grow a “Toy history” of civilization
- Lead to the Artificial Anasazi Project
Artificial Anasazi

• Kayenta Anasazi of Longhouse Valley: 800-1350
• Digitize Actual Environmental and Demographic History
  – Hydrology, Top Soil, Drought Severity, Maize Potential
  – Household Sizes and Locations
• Use an Agent-Based Model to Test Whether Various Microspecifications (movement, farming, reproduction rules) Suffice to Generate—or “Grow”—the Actual History.
  – Phase I focused on purely environmental factors
• Phase II To Include Cultural Factors
• Introduce second commodity--"Spice"--and second metabolism. With fixed neoclassical preferences:

\[ W(w_1, w_2) = \frac{m_1}{T} w_1^{m_1/T} \frac{m_2}{T} w_2^{m_2/T}; T = m_1 + m_2. \]
Evolving Preferences

- Non-neoclassical evolving preferences;
- \( f \) = the frequency of 1’s in Agent’s Tag string.

\[
W (w_1, w_2) = w_1^{\frac{f m_1}{T}} w_2^{\frac{(1-f)m_2}{T}};
\]

\[
T = fm_1 + (1-f)m_2
\]
Empirical, Policy, and Commercial Applications Since Sugarscape

- Firms
- Anasazi
- Civil Violence
- Retirement
- Classes
- Crime
- Traffic
- Military Tactics and Alliances
- Decentralized Scheduling
- DisneyScape
- Stock Market Dynamics (NASDAQ Model)
- Optimization (TSP/ Ants)