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

Canonical Experiment

- 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.

Sugarscape

- **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

Sugarscape Economics

- Introduce second commodity--"Spice"--and second metabolism. With fixed neoclassical preferences:

$$W(w_1, w_2) = w_1^{m_1/T} w_2^{m_2/T}; T = m_1 + m_2.$$

Evolving Preferences

- **Non-neoclassical evolving preferences;**
- **f = the frequency of 1's in Agent's Tag string.**

$$W(w_1, w_2) = w_1^{fm_1/T} w_2^{(1-f)m_2/T};$$

$$T = fm_1 + (1-f)m_2$$

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)