COMP451: Agent–Based Simulation

Semester 2, 2002
Today’s Class

- leftovers from last week
  - Game of Life
  - example of spontaneous mutation
- a look at SWARM
- Epstein and Axtell (Chapters 2 & 3)
References

Modelling Social Processes: Difficult

- study of social processes split up into separate fields: economics, demography, culture, . . .
- difficult to experiment in real life on how individual behaviours lead to “macroscopic regularities”
- for tractability individuals have to be made homogeneous and rational—“a perfectly informed individual with infinite computing capacity who maximizes a fixed (nonevolving) exogenous utility function”
E&A Definitions

- *artificial societies*: agent-based models of social processes
- *in silico*: (cf. *in vivo, in vitro*) use artificial society as laboratory, attempting to ‘grow’ structures of interest
- agent: the individual of an artificial society; has internal states and behaviour rules
- environment: can be a landscape (as a lattice of resource-bearing sites), a communication network, ...
E&A Definitions

- rules
  - agent-environment rules: look around as far as possible, find best food, ...
  - environment-environment rules: governs resource regrowth etc (cellular automata)
  - agent-agent rules: mating, combat, trade, ...
Sugarscape

- a landscape that agents live in
- landscape contains resources: first sugar, then spice
- agents have attributes
  - vision
  - metabolism
  - ...
- agents move around the sugarscape
  - go to largest sugar deposit with vision range
  - burns sugar when moving
- die when all sugar is burnt
Sugarscape Aims

- observe behaviour and compare against empirical data
  - what happens when seasons are introduced?
  - under what conditions does the distribution mimic the real world?
  - under what conditions do selection pressures lead to change over generations in agent attributes (vision, metabolism)?
  - under what conditions (for example, rules of agent behaviour) will local prices converge to a market clearing (general equilibrium) price?
  - are there different effects with neoclassical and non-neoclassical economic agents?
  - what happens when disease is introduced?
Artificial Societies vs Traditional

- heterogeneous agent populations
- space distinct from agent population
- no global information
  - cf. Walrasian auctioneer
- dynamics vs statics
Artificial Societies vs ALife

- one strand: cellular automata
  - fixed spatial relationship
  - landscape in sugarscape is modelled as CA

- another strand: agents in a space-less environment
  - change through social interaction
  - parametric vs structural adaptation
Basic Sugarscape

- 2D lattice
  - each point has sugar level, sugar capacity
  - can have a range of possibilities for sugar regrowth
  - chosen $G_\alpha$: sugar grows back at $\alpha$ units per turn until capacity is reached

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Basic Sugarscape

- agents
  - so far just move around and eat sugar

- agent states
  - location
  - sugar metabolism: agent needs to eat $m$ units of sugar per turn
  - vision: agent can see $v$ units in the four principal directions
  - sugar holding $h$: store of sugar (with some initial value)
Basic Sugarscape

- agent movement
  - rule $M$: look as far as possible, find a site with most sugar, move there and eat sugar
  - sugar holding is incremented by sugar eaten, decremented by sugar used by metabolism
- agent dies if $h \leq 0$
Initial Experiments

- what happens if the rule $G_\infty$: instant regrowth is used?
  - cluster on edges of terraces
  - some deaths

- what happens if the rule $G_1$: gradual regrowth is used?
  - more concentrated on peaks
  - some deaths

- can study various features of simulation
  - carrying capacity of Sugarscape: for given average $m$ and $v$
  - selection: compare change in average $m$, $v$
Wealth and Death

• introduce death
  – each agent has a random lifetime
  – replacement rule $R_{[a,b]}$: dead agent replaced by new random
    one with max age in range $[a, b]$

• measure wealth
  – begins equal, ends up skewed
  – true for large range of parameters
  – this skewness is emergent structure
Measuring Economic Inequality

- want a summary measure of wealth skewness

- in economics, the Gini coefficient is used
  - based on Lorenz curve
  - plots cumulative population vs cumulative wealth
  - perfectly equally distributed wealth would give a straight line of gradient 1
  - the further the curve from this line, the more skewed wealth distribution, and the larger the Gini coefficient

- in this simple society, Gini coefficient for wealth less than for income
Measuring Economic Inequality

- Gini coefficient the ratio of the divergence from straight line to total area of triangle, given by

\[ \frac{2}{n^2 \bar{x}} \sum_{i=1}^{n} ((i - \frac{n + 1}{2})x_i) \]

- in Sugarscape, ranged from 0.230 to 0.503 over time

- real world data (USA):

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Social Networks

- can also measure social networks
  - each agent has a set of sets of neighbours, one for each turn when movement occurs
  - want to see how these spread (like “six degrees of separation”)
  - useful in other situations (e.g. spread of language change)
Migration

- emergent behaviour: diagonal migration through Sugarscape (plus “bald spots”)

- introduce seasonal growback rule $S_{\alpha\beta\gamma}$: sugar grows back at a rate of $\alpha$ in the summer, $\beta$ in the winter, with seasons changing every $\gamma$ turns

- result
  - migrators (high vision)
  - also hibernators (low vision, low metabolism)
  - hibernators don’t move: form separate groups
Pollution

- pollution introduced as negative externality in landscape
- pollution generated proportional to sugar metabolisation
- agents move to squares with best sugar-to-pollution ratio
- results
  - more diffuse population
  - lower carrying capacity
Sex

- in Ch 2, there’s only death, no birth
- does having a reproducing population change any of the results in Ch 2?
- what patterns arise, purely in terms of demographics, from particular models of agent reproduction?
- do we find patterns that match real world observations
  - e.g. natural selection
Reproduction Requirements

- define notion of ‘childbearing age’
- define minimum sugar endowment for reproduction
  - child needs some initial endowment
- sex rule $S$: select a neighbouring agent at random; if it’s fertile and of the opposite sex and at least one of the agents has an empty neighbouring site, then a child is born
- for each attribute, a child has an equal likelihood of inheriting the value of either of its parents
- agents are thus heterogeneous wrt genetics and environment, homogeneous wrt behaviour rules
A Particular Run

- the following parameters are set:
  - for both men and women, childbearing begins between 12 and 15;
  - for women, childbearing ends between 40 and 50;
  - for men, childbearing ends between 50 and 60;
  - for men and women, age of natural death is between 60 and 100;
  - members of the initial population have initial endowments of sugar between 50 and 100 units
- produces stationary population (pp58-9)
- however, population characteristics not stationary
Evolution and Selection

- agents evolve towards higher vision
  - reason: high vision yields more sugar income, which leads to more children
- similarly, agents evolve to lower metabolism
  - high metabolism tend to die off more, not reproduce
- rate of change:
  - average metabolism falls faster than average vision rises
  - evolution isn’t monotonic
- note there’s no explicit fitness function (cf. genetic algorithms etc)
  - fitness also a function of environment
Dynamics of Population Levels

- previous rules give stationary population (Fig III-1)
- can use sex rule $S'$ (women’s childbearing terminates between 30 and 40, men’s between 40 and 50) to produce oscillating population levels (Fig III-3)
  - cf. predator-prey models from week 1
  - oscillation can be produced by changing other parameters also
- question: the need for external shocks?
  - cf. discussion from last week
Inheritance

- want to investigate interaction of economics (social convention) and biology (selection)

- previously, when an agent died its wealth disappeared

- new inheritance rule $I$: when an agent dies, its wealth is spread equally among its children

- result:
  - inheritance retards selection (Fig III-7)
  - inheritance increases inequality, as represented by the Gini coefficient (Ani III-4)
Cultural Processes

- give agents extra attributes: ‘cultural tag’
  - all cultural attributes represented by string of 0s and 1s
  - not a functional attribute in the same way as vision, metabolism
  - could represent e.g. “follows rugby” (0) vs “follows AFL” (1)

- culture is transmitted among neighbours

- cultural transmission rule: for each neighbour a tag is randomly selected; if tags agree, no change, but if tags disagree, neighbour’s is flipped

- in initial simulation, an agent belongs to group Blue is the majority of its cultural tags are 0, to group Red otherwise
Cultural Processes

- question: is this set of rules enough to generate geographical groupings by cultural tags?

- result: agents converge to either all Blue or all Red (Ani III-6, Fig III-8)

- note that pattern of convergence isn’t monotonic, or any other interesting pattern

- also friendship networks (but this isn’t something of primary interest in modelling: there’s no empirical data to compare this to)
Combat

- combat can be between agents of different tribes
  - fight over resources
  - win resource fought over, plus some of enemy’s resources;
    defined by combat rule $C_\alpha$
- attacks can only occur when agent is ‘invulnerable to retaliation’
  - agent targeted has fewer resources (less sugar)
  - there’s no other potential enemy nearby
- results
  - $C_\infty$ leads to blitzkrieg attacks
  - $C_2$ leads to stable battlefronts
Combat and Culture

- in previous scenario, winner takes all resources; can lead to unstoppable agents
- can combine with culture, so individual agents can be converted