Replacing Sugarscape: A Comprehensive, Expansive, and Transparent Reimplementation

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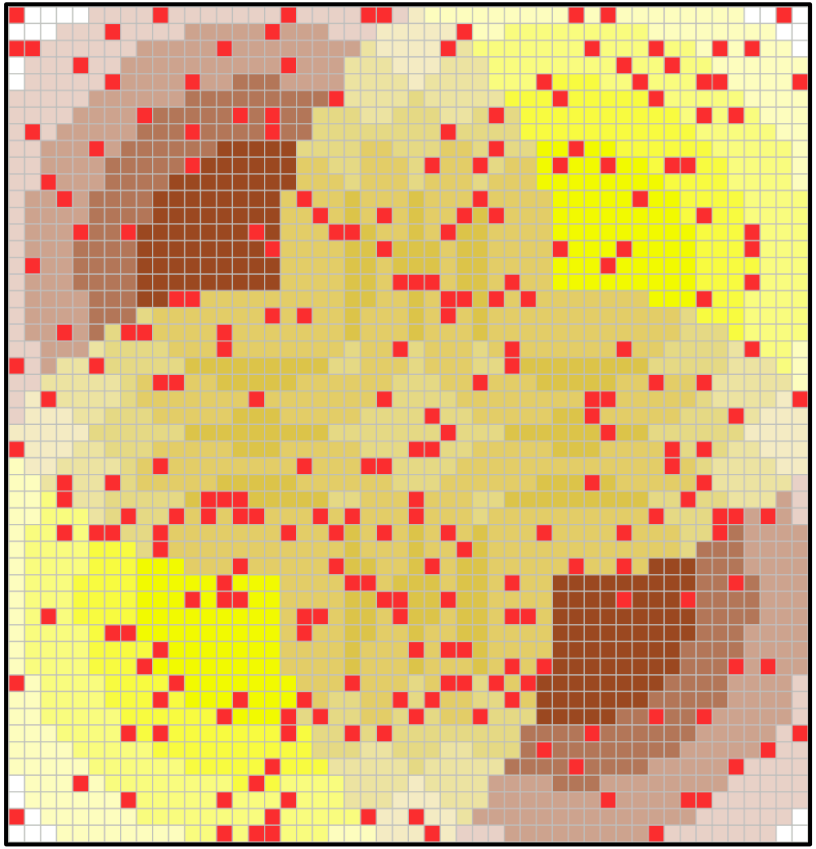
What Is Sugarscape?

- Agent-based simulation platform that explores societal behavior
  - Originally developed and evaluated in 1996 in *Growing Artificial Societies* by Epstein and Axtell (hereafter called **GAS**)
- Seminal work with wide reach across many disciplines
  - sociology, philosophy, and economics, to name a few
- Sugarscape supports many interesting interactions among agents.
  - Reproduction, trade, lending, culture, inheritance, disease, and pollution

Welcome to Sugarscape

- Two dimensional $n \times m$ torus (or grid if you prefer)
- Cells generate *sugar* and *spice*, which is consumed by agents according to their *metabolism*
- Agents move according to their *vision* to collect more resources
- Lots of simulation features (some mentioned before)

Demo: 500 Timesteps on Seed 12345



Current Status of Sugarscape

- Many versions of Sugarscape exist today
  - All prior publicly available implementations are incomplete

Implementation	Chapter 2	Chapter 3	Chapter 4	Chapter 5
NetLogo [13] Sugarscape	✓	X	X	X
Python 2 Sugarscape [7]	✓	✓	X	X
MASON-Sugarscape [1]	✓	✓[6]	✓	X
Our Implementation	✓	✓	✓	✓

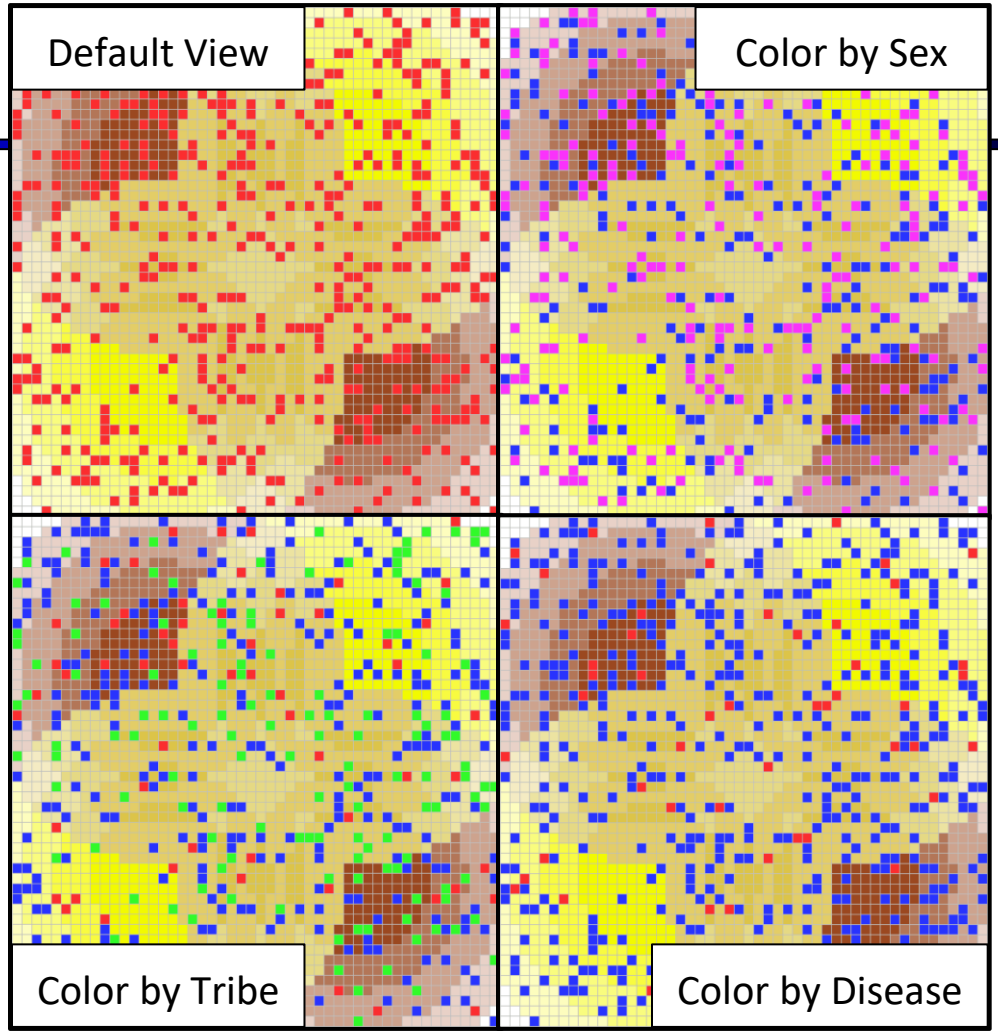
- We provide the first *complete* and *definitive* version of Sugarscape since its original implementation for **GAS**

Our Version of Sugarscape

- We provide the *full* functionality from **GAS**
- We use modern software development standards:
  - Modular code with built-in additional functionality
  - Transparent and reproducible results
  - Tested and validated *all* experiments in **GAS**
  - Freely accessible (for non-profit use) github repo
    - https://github.com/nkremerh/sugarscape
  - Highly extendable, configurable, and customizable

Sugarscape Agent Features

Demo: 200 Timesteps on Seed 98765



Emergent Behavior

- *Emergent behavior* corresponds to the collective actions of a group of agents (or a *society*) that transcend the available actions of any individual agent

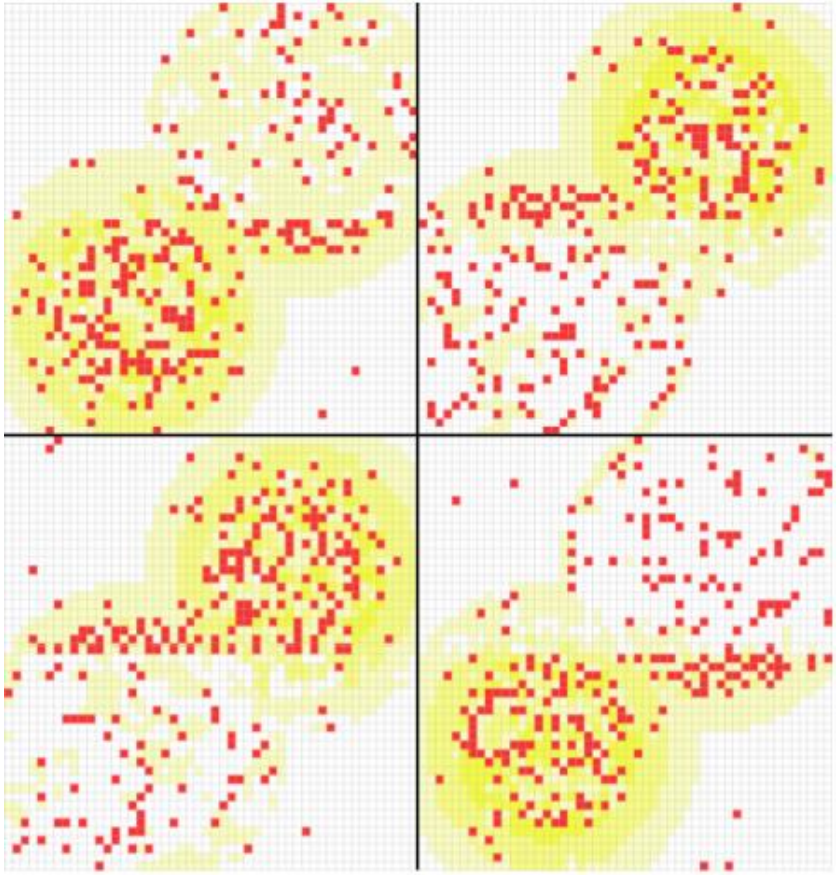
- Example: Agents cannot move diagonally. Societies that move in diagonal migratory patterns exhibit emergent behavior

- Example: Agents trade sugar and spice but cannot set prices. Societies that establish a stable economy exhibit emergent behavior

Validating Vanilla Sugarscape (from **GAS**)

- Not easy to validate
  - Documentation in **GAS** is sparse and incomplete
    - No way to know the initial configuration of most experiments
    - No known seeds or easy way to replicate results
  - Most observations in **GAS** are *qualitative*
    - "Results" are largely observational and represent majority trends
      - Trying to match minority trends too much risks overfitting **GAS** experiments
- Too many experiments to show in this talk, but we will walk through a few

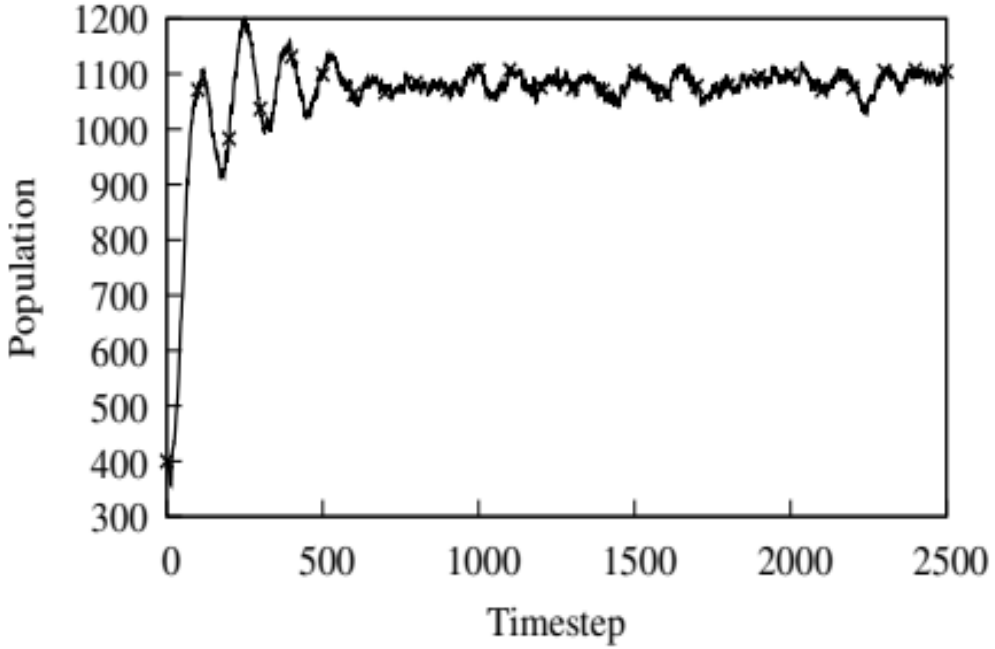
Seasonal Migration -- Validation



- The *seasons* feature oscillates resource production in Sugarscape
- Societies discover and travel to high concentrations of sugar (emergent behavior)
- Agent types: migrators, hibernators, and scavengers
- Matches the results from **GAS**

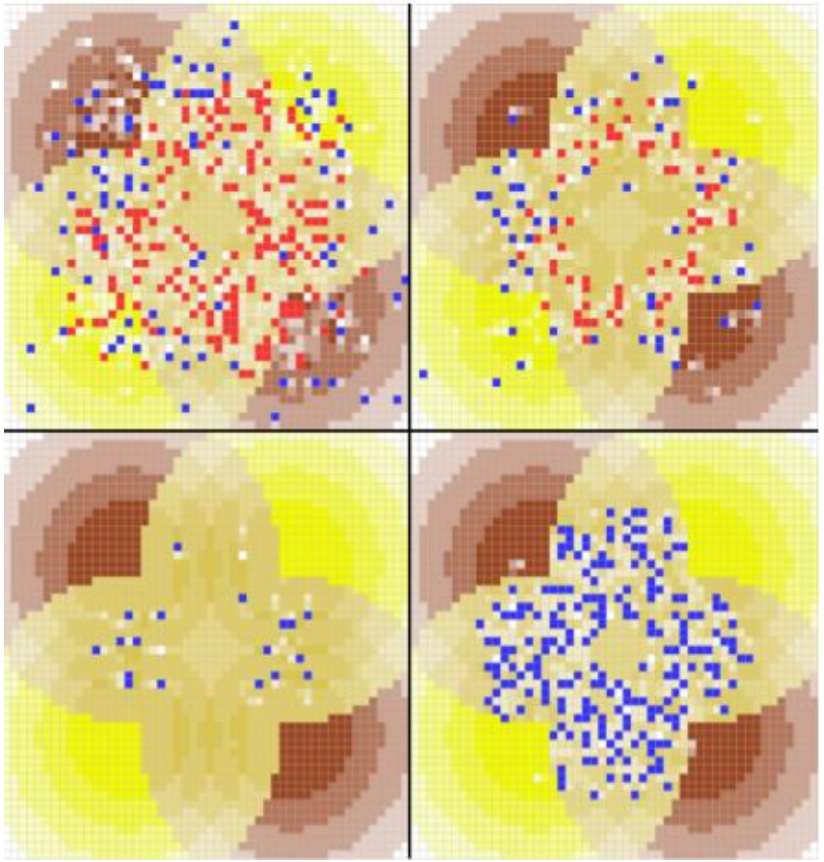
Short Fertile Window -- Validation

- Agent reproduction costs resources and must happen during their fertile window
- **GAS** explored the impact of reducing an agent's fertile window
- Boom-bust cycle eventually stabilizes
- Matches the results from **GAS**



Disease Transmission -- Validation

- The *disease* feature reduces an agent's metabolism, vision, or impairs reproduction, etc.
- Disease is also highly contagious
- We replicate the results from **GAS** with 10 diseases
  - Population craters, but recovers once the remaining agents have isolated or built up immunity
- Matches the results from **GAS**



Validation Across Many Seeds

- Not all seeds will behave the same
- We tested many more (but here are 20 and their results)
- TLFADT (Too Long, Fell Asleep During Talk)
  - Welcome back. Glad you enjoyed the nap!
  - We mostly replicated **GAS**
    - Our paper is great, and now you know it too!

Seed	Seasons	Reproduction	Disease
14133	✓	✓	✓
5172	✓	✓	✓
32209	✓	X	✓
23128	✓	✓	✓
15362	✓	✓	✓
12881	✓	✓	X
1484	✓	X	✓
19522	✓	✓	✓
23231	✓	✓	✓
24022	✓	✓	✓
5568	✓	✓	✓
13461	✓	X	✓
31844	✓	✓	✓
8885	✓	X	✓
21500	✓	✓	✓
28307	✓	✓	✓
28548	✓	✓	✓
22744	✓	✓	X
27167	✓	✓	✓
26341	✓	✓	✓

Deviations from Sugarscape

- **GAS** suggests that trading and lending resources increases the *carrying capacity*, the number of agents an environment can support
  - 10-25% increases reported

- We could not find a single seed that shows more than a 5% increase in carrying capacity, and many seeds decreased!

“Under the Hood” Improvements

- Nearly all agent features use a numeric range, rather than a single value
- Added new configurable parameters such as aggressionFactor, which indicates the likelihood that an agent will engage in combat
- Detailed logs of all agents throughout the simulation
- We consider resources as real numbers rather than integers

Conclusions

- We provide the definitive version of Sugarscape
  - https://github.com/nkremerh/sugarscape (bleeding edge repo)
- Our implementation verifies prior work to the extent possible
- Increase transparency and reproducibility of results
- Provide a modern, modular software design
  - Allows customization and flexibility
- We hope that users of Sugarscape will adopt our version for their future work

Questions?

Example	Book Page Number(s)
Resource Collection with Immediate Growback	21–26
Resource Collection with Constant Growback	28–30
Seasonal Migration	43–45
Pollution	45–50
Reproduction	55–58
Constrained Reproduction	64–66
Inheritance	67–68
Cultural Tagging	72–79
Combat with Unlimited Reward	82–83
Combat with Limited Reward	86–90
Sugar & Spice	96–99
Trading	101–107
Trading & Agent Replacement	120–122
Trading & Pollution	127–129
Agent Foresight	129–130
Lending	131–133
Disease Transmission	141–147