

# Complexity in Socially-Inspired Simulation

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- ❖ Social systems are sources of complexity in themselves. The interactions between individuals can give rise to unexpected and unpredictable behaviour at the system level.
- ❖ Agent-based social simulation (ABSS) allows us to analyse such systems, by capturing individual behaviour in the agents and observing the system-level behaviour that emerges. This leads to a better understanding of which interactions lead to critical system-level behaviours.
- ❖ In turn, the lessons learned from ABSS can be applied to other areas involving networks of interacting autonomies.

## Food Web Evolution

Evolutionary processes naturally result in complex food chains involving spontaneous specialisation. In conjunction with our NANIA colleagues at the Physics Department of the University of Manchester we are attempting to relate different approaches to dynamic food web modelling. Whereas our colleagues take a population dynamics (that is, equation-based) approach, we take an agent-based approach.

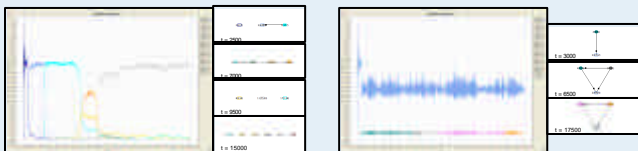
Our model attempts to replicate the results of the equation-based model, which can then be extended to incorporate other factors (Norling 2006). Following the equation-based model:

- There are  $M=500$  possible abstract features representing things like "sharp teeth" or "nocturnal." An  $M \times M$  anti-symmetric matrix defines the score of any feature against any other feature.
- Each species is defined by a subset  $N=10$  of these features.
- The score of one species against another is determined by the sum of the relevant feature scores. If the resulting score is positive, there is a predator-prey relationship.

At each time step:

- Each individual selects a potential prey. If the potential prey is edible, it is eaten, with the predator gaining a fraction of the prey's resources.
- Of the remaining live individuals, those that have sufficient resources will reproduce, sharing their resources with their offspring. There is a small chance of mutation (change of a single feature) during reproduction.

Initial results, as shown below, demonstrate plausible food webs emerging, although there is not yet a direct match to the population dynamics model.



Two short runs of the non-spatial food web model, showing the population dynamics and the food web at various stages. In the first, a relatively benign environment means that all species are able to feed off the environment, and most do in preference to feeding off other species. In the second, only one species has evolved that can feed off the environment, and new predators successively kill off their rivals.

One issue in this model is that of discrete versus continuous values: in the equation-based model, the values are continuous (and number of resources in species is seen as equivalent to number of individuals in a species), whereas in the individual-based model they are by nature discrete. While it might make sense to talk of some individuals (e.g. a plant) in fractional terms, for others it is less clear what this would mean.

In addition to the model here, an alternative spatially-explicit model has been developed. This model is less closely related to the equation-based model. Instead, it starts to tie the food web dynamics to the concept of tag-based cooperation that is introduced in the adjacent panel.

## Cooperation between Selfish Individuals

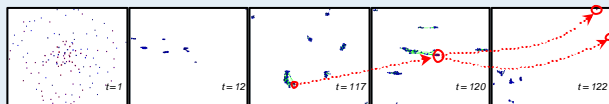
Tags are properties of an agent that are observable to others but not hard-wired to its behaviour. Initially suggested by John Holland in 1992 they allow (under suitable conditions) the self-organisation of selfish agents to maintain relatively high levels of cooperation.

*Production World* is a model in which agents require assistance in order to maximise their performance:

- Each agent is assigned a particular skill, but may be required to complete tasks involving other skills.
- If an agent does not have the skill required for a task, it can request any neighbour to complete a task for them, and will receive the reward for their task if successful.
- The neighbour who assists will incur a (smaller) penalty for their efforts.
- The network of any agent is limited to at most  $N$  agents.

SLAC is a very simple algorithm for managing this network that has been shown to produce high levels of performance at the system level (Hales 2005). To update its network, an agent randomly selects another individual from the population and looks at its performance score. If that agent is performing better, the agent will copy that agent, as follows:

- Links to current neighbours are removed
- A link is established to the agent in question
- Links and behaviour of other agent are copied
- With low probability links and behaviour are mutated



The evolution of networks using the SLAC algorithm in *Production World*. From an initial population of isolated individuals, clusters of altruistic agents form. As the cluster grows, cheating agents can profit from the altruistic agents in their network, so other agents copy their success (and cheating nature). Eventually this subgroup is rejected.

The main problem with this algorithm is that it can lead to a disconnected network, which for many applications (e.g. peer-to-peer applications) is undesirable. SLACER is a variant on the above algorithm that probabilistically maintains existing links, resulting in slightly lower performance but a "small world" network (Hales *et al.* 2005). It has been demonstrated in the P2P domain (Edmonds and Hales 2005). A further "smart" variant attempted to reason about which links should be dropped, but was shown to have catastrophic outcomes (Norling and Edmonds 2006).



Percentage of altruism and percentage of jobs complete using the SLAC, SLACER and "smart" algorithms respectively.

A variant of the *Production World* model is currently under development, in which a series of skills are required to complete a task, yet each agent still has only a single skill. This model will be used to explore further networking algorithms, related to those seen in supply chains.

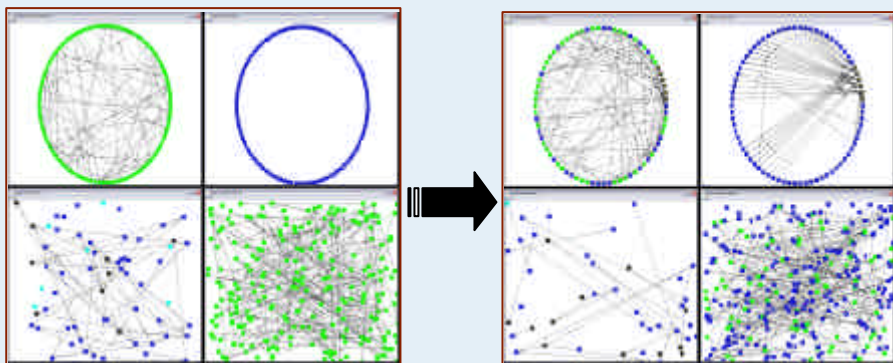
## Modelling the Impact of HIV/AIDS in South Africa

(Part of the EU-funded CAVES project)

The aim of this project is to determine the socio-economic impact of HIV/AIDS in a rural community of South Africa, using knowledge of typical behaviours of and interactions between individuals and households.

In this model:

- Individuals are modelled as agents, which
  - are born during simulation, age, and die,
  - require nutrition (changing amount depending on age and health),
  - (may) engage in farming and/or do labour,
  - receive pensions and grants,
  - can have friends and may marry,
  - have a HIV/AIDS status and health status (largely affected by HIV/AIDS status)
- Households (composed of agents) are created and dissolved over time. They
  - have a head who is responsible for key decisions
  - have extended family and social links
  - mutually help neighbours
  - dissolve if all adults die; orphans are accommodated by nearest relatives
- Social clubs, both formal and informal, add another layer to the interactions. In particular, we focus on
  - savings clubs: informal clubs established by innovative household heads.
  - funeral clubs: formal burial societies joined by households, providing support for funeral costs.



Interplay of dynamic social networks at individual and household levels. Snapshots at  $t=0$  and at  $t=t-\Delta t$ .

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