ANIMATion: A Predator-Prey Animat Model

C.J.Scogings and K.A.Hawick

c.scogings@massey.ac.nz, k.a.hawick@massey.ac.nz
Institute of Information and Mathematical Sciences, Massey University, Albany, North Shore 102-904, Auckland

Massey University

Introduction

ANIMATion is a predator-prey simulation that combines the replication rules of Conways Game of Life with the behavioural rules of Boids (Reynolds, 1987[1]), the evolutionary processes of Tierra (Ray, 1991[2]) and Avida (Adami, 1994[3]) and the agent behaviour of Echo (Holland, 1994[4]) to produce a unique and exciting world of animats (Wilson, 1991[5]) that eat, breed and interact to create fascinating emergent macro-behaviours. Two species of animat exist in an unbounded 2-dimensional plain the predators that must eat prey to survive; and the prey that must eat grass to survive. Every time step, each animat executes one of a small set of simple rules, e.g. move away from adjacent predator. The rules are placed in a priority order and by changing the order of priority, different rule sets (genotypes) can be evolved. Thousands of animats of both species interact and cluster together in a variety of formations. The most significant of these are distinct spiral patterns (Hawick et al., 2004[6]) which are an emergent behaviour (see figure 2) that can not be traced to any of the simple rules guiding the lives of individual animats.

Animats

Animats are spatial agents - simulated artificially intelligences in a computer generated world.

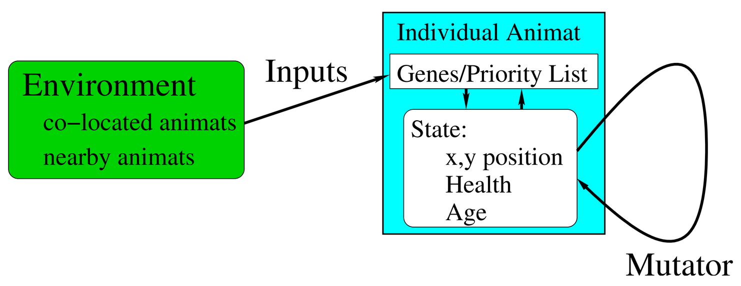

Figure 1: The spatial agent - "Animat" Machine.

Figure 1 shows the core animat machine concept. An animat agent has a simple internal state as well as a spatial position. It interacts with its environment (including other animats) to change its state.

One of the biggest problems facing ALife models is what we call the Hand of God effect in which a simulation contains numerous **global** parameters that are imposed on all animats equally, irrespective of any local situation. For example, many genetic algorithms use globally imposed fitness functions to decide which organisms live or die. Such global effects may constrain emergent behaviours. We have refined the ANIMATion system to ensure that animat behaviour is governed almost entirely by local criteria. Each animat eats, breeds or moves depending only on the proximity (and actions) of its neighbours. There is no global fitness function there is only life or death.

Each time step of the ANIMATion model, animats execute the first rule in their priority list for which the constraint conditions are satisfied. There are separate rules for different types of animat in the system.

Rules for Predators:

1. Breed if not hungry
2. Eat prey if hungry
3. Move towards mate if not hungry
4. Move towards prey if hungry
5. Move randomly

Rules for Prey:

1. Breed if not hungry
2. Eat grass if hungry
3. Move towards mate if not hungry
4. Move away from other prey
5. Move away from adjacent predator
6. Move randomly

We can arrange different subspecies by re-prioritising the rules, so it is possible to have "hungry rabbits" that eat in preference to breeding. In any given model run we can study which rules are actually executed the most by the whole population.

Spirals & Battlefronts

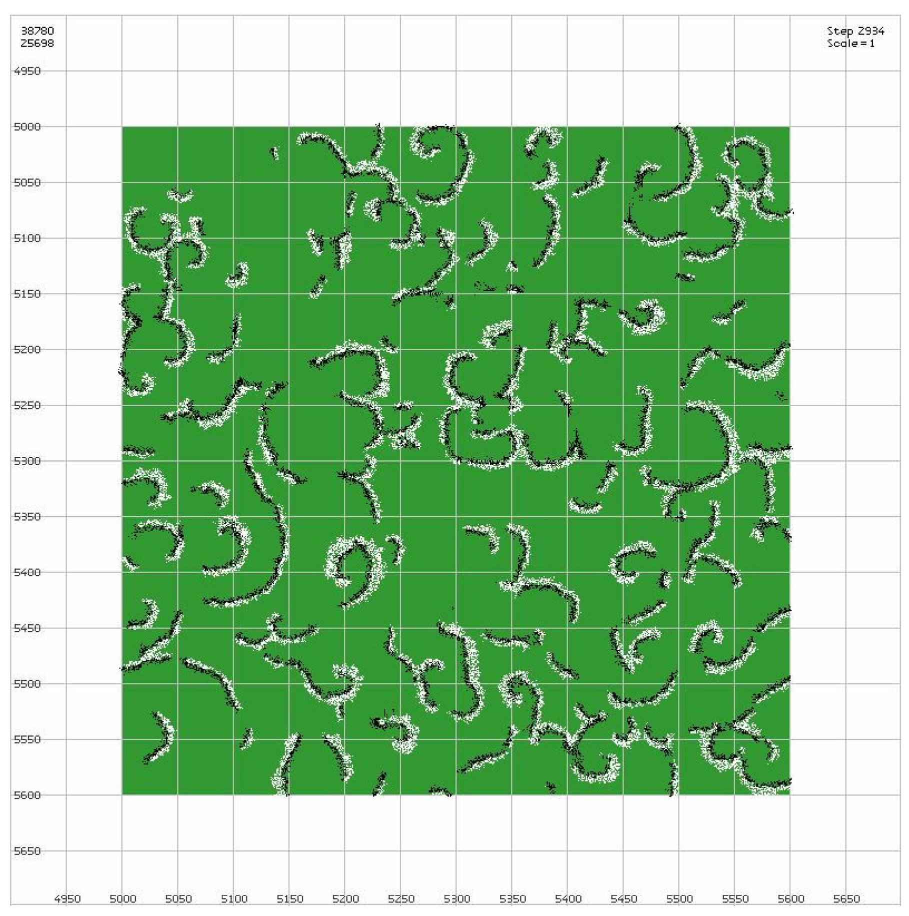

Figure 2: Battlefronts give rise to spiral patterns of animats: Green denotes grass; prey are white; predators are black.

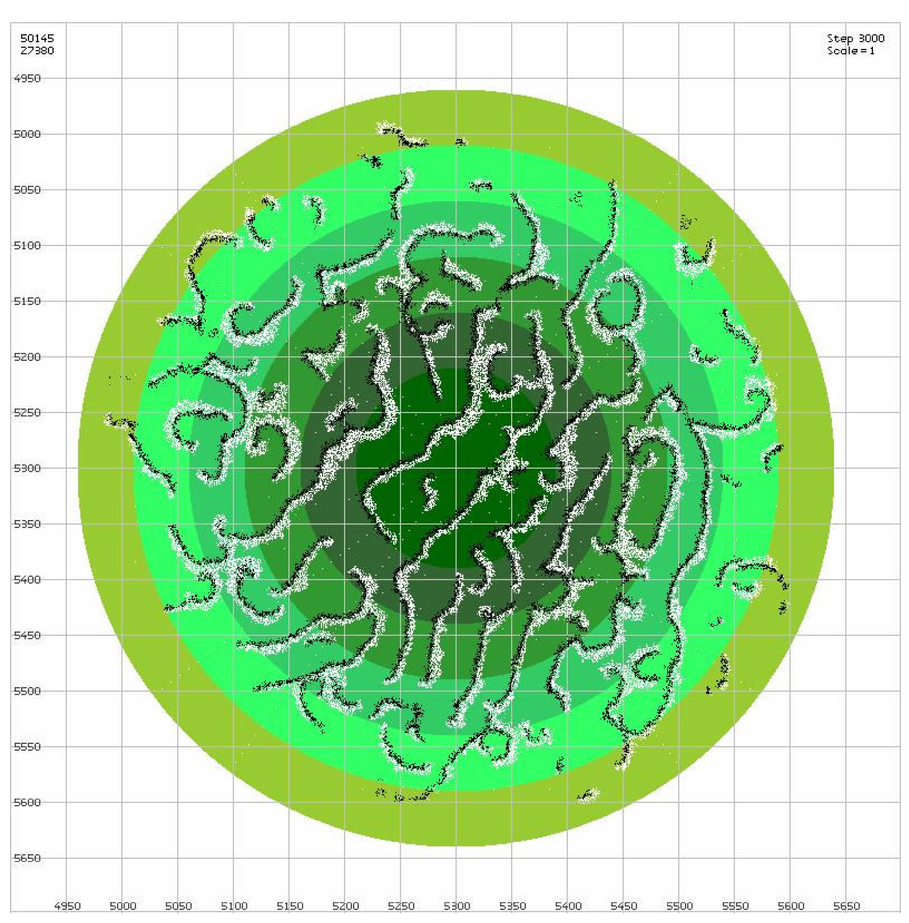

Figure 3: A Circular pattern of grass richness (dark green is richest) shows how animats arrange themselves across boundaries.

Counting Coup

ANIMATion has been designed to allow evolution of the animats using genetic algorithms. Each rule is supplied as a string of digits in order to maximise the scope for mutation and crossover. However, we have adopted a cautious approach, preferring to edit one small aspect of the model at a time and then measure the effect that this change has on the model. Thus far we have not used genetic algorithms although we have evolved various sub-tribes with different rule priorities (Hawick et al., 2007, [7]).

Grass is allocated a "nutritional value" such that a high value means that prey will be well fed. Thus grass can be used to limit population growth and prevent a significant slow down of the simulation. Figure 3 shows concentric rings of grass from a value of 20 on the edge changing to a value of 80 in the centre. Note how the prey population increases with higher grass values. However, cluster formations and spirals continue to form.

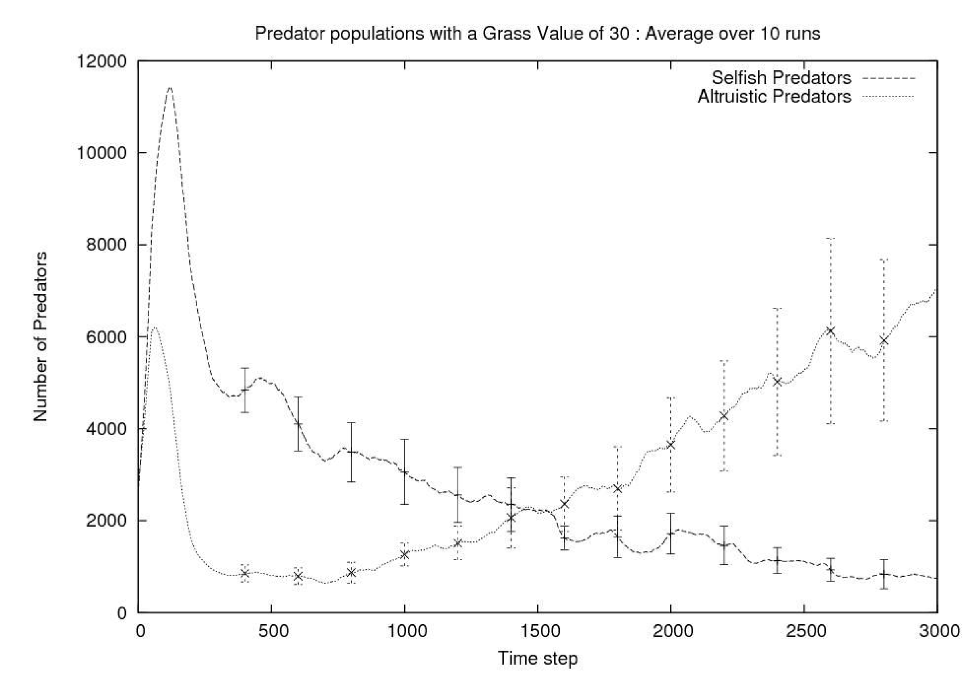

Figure 4: Time evolution of selfish and altruistic predators over a typical model run.

We found that selfish predators will replace altruistic predators if resources are easily obtainable but that altruistic predators will dominate if resources are scarce. Figure 4 shows predator populations when the grass value is low (30) and thus the altruistic population is increasing.

The data shown in figure 4 represents an average over several independent runs. Each will have the same rules and parameters but different (random) microscopic animat starting conditions. The ANIMATion mnodel seems remarkably robust against microscopically different configuration changes and the emergent statistical effects we find are present irrespective of starting conditions.

There is a typical phase-lag between fluctuations in the total number of predators and prey, whereby a boom in prey population is followed by a boom in predators and a subsequent drop in prey. This effect is well known and is also found in equation based predator-prey models such as the Lotka-Volterra[8] equations as well as in real population data.

Summary & Conclusions

The system can manage significant numbers of animats. A typical run contains hundreds of thousands and the code has been tested with over a million animats. These high population figures enable emergent macro-behaviours that would not be possible with lower numbers. ANIMATion has both a parallel implementation and a sequential implementation. We have also developed and incorporated a number of general techniques for managing large-scale simulations and increasing efficiency in the model (Scogings et al., 2006[9]).

The ANIMATion model enables research into far more complex emergent behaviours than many previous ALife models because it simulates higher-order animals. Further work is planned to study the interactions of different types of animats within the same community, e.g. workers and soldiers. Our latest research project is to demonstrate that altruism can evolve naturally among animats and that it benefits both the group and the individual (Scogings and Hawick, 2008[10]).

More information on the Animat model embodied in ANIMATion is given in Technical Notes: CSTN-007; 009; 010; 015; 017; 020; 022; 028; 031; 033; 035; 038; 040; 041; 044; 045; 047; and 050 – see `www.massey.ac.nz kahawick/cstn`.

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