THE THEORY BEHIND ECOBOTS

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The key to simulating life in Ecobots is the combination of these dynamics:

- Self replication within population limits

- Randomness

- Destruction

- Feedback loops

In combination these can give rise to a system which is semi-stable in size yet is constantly adjusting itself, and will mostly likely end up circling around an attractor state to which the system is drawn... which is pretty much what life on planet Earth does.

REPLICATION AND LIMITS

The key equation in Ecobots is this:

$p = mr - d$

Where:

p = the population limit at which replication is stopped

m = how many times larger than the radius the population can grow

r = the radius around each bot which counts as being within its population

d = the dispersal radius, i.e. how far away a new bot can be spawned from its parent.

This seems to be the threshold between stasis and exponential growth. Below the threshold structures grow to a set size then become locked, or end up with a single growing point (depending on m). Too far above the threshold and new bots are able to spread into new areas and grow exponentially.

EXAMPLE:

This is a fully grown structure:

	A2	A	B	C	D	
		A1	B1			
		A1'				

This image shows how the structure grew until every block hit its population limit and stopped.

Each cell represents a possible block. Coloured cells are blocks. The letters represent lines of descent starting from block A. The colour represents the generation.

A through D is our main line of growth. A1 is a sibling from A, and A1' is a child of A1 and so on.

In this example blocks are placed clockwise into empty cells, at right angles. Each block continues creating offspring until it hits it's local population limit.

This example used $r = 4$, $m = 2$, $d = 1$

Therefore

$p = mr - d$

$p = 2 \times 4 - 1$

$p = 7$

If we look at this in table form we can see when each block hit $p = 7$. In this case they all reached it after three generations. (with other set ups some will stop early, and sometimes one single block continues forever)

Generation	**A**							
0	1	**B**						
1	2	2	**A1**	**C**				
2	4	4	4	4	**A2**	**A1'**	**B1**	**D**
3	8	8	8	8	8	8	8	8

Therefore we are able to use replication but keep it under strict control. But a locked structure is hardly alive.

We need more...

RANDOMNESS

Let’s add some randomness. This is the same as above, but now instead of rigidly going clockwise, blocks go in a random place.

			B1				
				B			
		A2	A		C	D	
		A1					
	A1'						

T	**A**							
0	1	**B**						
1	2	2	C	A1				
2	4	4	4	4	D	A2	B1	A1'
3	8	8	8	8	7	8	8	7

Again the structure locked itself up in the same amount of time, but it was not guaranteed.

Let’s run it again...

						D	
					C		
				B			
			A	B1			
	A1'	A1					
	A2						

T	**A**							
0	1	**B**						
1	2	2	**C**	**A1**				
2	4	4	4	4	**D**	**A2**	**B1**	**A1'**
3	8	8	6	7	5	6	8	6

This time four of the blocks are still below their population limits. They will keep growing.

It is easy to imagine that if we we're to try this again and again that sometimes they would spread out and get further, and sometimes they would clump up and halt early.

Randomness adds variability and unpredictability to our structure. Yet, these will still lock themselves up into a static shape. They run out of luck, choose a bad shape, and stop.

We need something else...

DESTRUCTION

It's a cliché that destruction is necessary for creation. In this case it is also true.

If we were to take a locked up structure from our examples above and destroy a few blocks it would release some of them to replicate again. They would be able to roll the dice again, possibly choose a better shape and keep on growing.

However, once the structure has recovered from the damage, it will still end up static eventually.

We need something more...

FEEDBACK LOOPS

We can do two things. Either we keep damaging the structure, or better yet, we tie growth and destruction together.

If growth can be made to cause destruction then the structure can get caught in a loop. New growth will lead to destruction which will lead to new growth which will lead to destruction....

So long as growth and destruction are kept in balance the system will exist in a state of constant rearrangement. It will randomly try all the possible states in which it can exist.

The likely outcome of all this is that the system will gravitate towards some attractor state. The nature of this attractor state will then govern what the system spends most of its time doing.

That attractor will probably be whatever state enhances the total number of blocks in the system. Those states that enhance the structure's ability to survive and grow will get locked into the system, while those that don't will die out. The structure will be at a basic level adaptive.

With all of these components put together the structure behaves as a truly complex system. It embodies a few of the basics of what allows life to be alive.

ECOLOGY

Ecobots uses the above to simulate an ecosystem. Instead of one structure it produces dozens, or hundreds, of interacting structures which then together make a much larger complex system which embodies the same ability to change, grow, and adapt.

Here's what each of the blocks does in the system:

Trees and the Pioneer:

> All ecosystems are open systems, that is they take in matter and energy from the outside. Plants are the doorway in.
>
> They limit all the other populations by controlling everything's food supply. They add matter to the system, and ultimately control it's physical shape, light conditions, quantity of soil and so on.
>
> Why not just have trees? The pioneer allows for ecological succession, the means by which ecosystems repair themselves with fast growing "weeds". It makes the system stronger. It is also an easy way to allow us to simulate competition, which is interesting for its own sake. In the extreme this may lead to alternative stable states for the system - an open grassland or a dense forest.

Herbivores:

> They clear old plant growth thereby stimulating new plant growth (the destruction aspect), and they redistribute plant matter dispersing it to new areas (by making it fall), and sending it to the forest floor to feed the decomposers.

Dead Matter and Decomposers:

> The dead matter and wood feeds the decomposers who break down all the mass which the plants are adding to the system. They stop the overall system from accumulating enormous amounts of mass. However they do create some persistent soil - this enables the ecosystem to do terraforming, coating even bare rock in soil.

The Predators (apex, and detritivore):

> The predators should add stability. They create negative feedback loops on the growth of their prey populations. Without this there is the potential for plague like explosions of herbivores killing all the trees, or outbreaks of fungus eating all the wood, both of which could make the system collapse.

In combination these components capture the bare basics of how ecosystems work. Ecobots should experience numerous things resembling real ecological phenomena , like trophic cascades, and succession.

Real ecosystems are of course orders of magnitude more complicated, containing dozens to thousands to even millions of species (if you count all the bacteria!). Even the most sophisticated computer simulation will only ever capture the smallest slice of all this wondrous complexity.