6.836 Embodied Intelligence
Research Assignment 2
Massachusetts Institute of Technology
Due: Friday, March 8, 2002

For this research assignment you will be designing artificial chemistries to control the behavior of simple bacteria in simulation. We recommend that you first familiarize yourself with the Artificial Chemistry (AC) concepts discussed in the Dittrich et al. and Ziegler & Banzhaf papers.

The bacteria live in a 2D toroidal grid world. Each bacterium contains an internal AC metabolism to guide its navigation, food consumption, and reproduction. Each cell in the grid world can hold chemicals that the bacteria can sense and consume. The chemicals in the world diffuse across the grid over time. A bacterium reads the chemical intensity of its surroundings by sensing the cells 45 degrees to the right and 45 degrees left of front center. Specific chemicals in the metabolism can actuate the bacteria by energizing thrusters to go forward or by changing the bacteria orientation.

The metabolism uses a stochastic reactor to apply chemical reaction rules. Refer to the supplied code for further explanation of its function.

We have provided a basic simulator for you to use. See the class webpage for download and details. If you choose not to work with the simulator we have developed, it is up to you to develop a simulator on the platform of your choice. Analysis of the AC will require a visualization of the 2D world. A clever command line display may suffice if you don't want to develop a GUI. In our simulation, the AC is coded in generic C and should provide a good starting point for a working system that can already follow a chemical gradient, though poorly. We are not supporting this code so it is up to you to adapt, compile, port or write your own.

We will need quantitative proof of your conclusions - screenshots, hand drawn depictions, and graphs to analyze your answers in each problem. Furthermore, if you DO write your own simulator, please give us a brief description of its major components (see the comments in our code for guidance).

2.1 Use the provided simulator or your own to get a bacterium to roughly follow a gradient of chemical food, consuming food in the environment as it moves. Assume the world is initially populated with a finite amount of food.

a. What are the necessary reaction rules and why do you believe them to work? Draw the reaction graph.

b. Describe how a few of the simulation parameters, such as diffusion rate, affect the bacterium's behavior.

c. What happens to the environment after a long run? (Again, be sure to give us quantitative proof that you got this to work.)

2.2 Now modify the previous reaction rules to prevent the bacterium from overshooting an area of highest chemical density when it gets there. You may need to incorporate reactions such as catalysis and disintegration.

a. What are the new reaction rules? Describe the simulation performance.

b. How can you make one reaction more probable than another at compile time?

c. How can you dynamically modify this probability through other reactions?

2.3 Modify the simulation to contain multiple bacteria using the world and reaction rules of problem 2.1.

a. What, if any, group behavior emerges?

b. How does population size affect the global behavior?

2.4 If the food supply is scarce enough, the bacteria should stop moving. Add a fat-store chemical to the metabolism so that in times of scarcity, the bacteria can locomote long enough to find food. Assume that each bacterium has an initial fat-store that must be replenished by metabolizing food from the environment.

a. First, design (by hand) a set of reaction rules that you think should work here. Describe your reasoning for them and include any other details of a fat molecule that you think should be included in the simulator.

b. Now describe the performance of these rules in the simulation. Did they work to your expectations. Why or why not? What simulation parameters are critical to their performance?

2.5 Change the bacteria so that they die under dire metabolic conditions yet still adhere to conservation of mass. Allow a dead bacterium to release its metabolic chemicals into the environment so that the dead matter can be consumable by other bacteria.

a. Under what conditions does one of your bacterium die?

b. How does bacteria death affect the long-term outcome of the environment?

c. Does an equilibrium between food supply and population size occur?

2.6 Modify the bacteria to asexually reproduce (i.e., split into two). Again, we leave it up to you as to when, why, and how this should occur.

a. Describe the reaction rules and methodology you used (when, why, how).

b. Can you achieve a population equilibrium that includes the effects of mitosis and organism death? If not, why?

DISCLAIMER: We want to stress that the probabilistic nature of AC means some of these questions don't have clear cut answers (e.g., just how directly a bacterium must move to demonstrate that it is following an increasing chemical gradient may be somewhat open to interpretation.)

This also means you can still get an A on this homework even though you might think your answers fall slightly short absolutely correct. We are mainly trying to see your effort, thought processes, and ingenuity, so focus on keeping those up to par if you get panicky. We understand.