

## AIMA Sections 4.3–4.4, Lecture 2, 22 September 2006

A. Discuss readings and homework: Ch. 4.1–4.2.

1. Question #13 from Day 1 handout: anyone have a graph?
2. Are these heuristics admissible?
  - a. In 8-puzzle,  $h_2(n)$  = number of tiles out of place
  - b. In missionaries & cannibals  $h_3(n)$  = number of m&c on other bank
3. Assignment for Monday: Finish reading Chapter 4, beyond what I'll do today.  
See course website for exploration.

B. In 8-puzzle, the Manhattan or taxi-cab distance function can also be used as a heuristic:

1. **Demo** the Java code at `q:\InstructorFiles\Chase_Gene\ai\...`  
for (Greedy | A\*) and (ManhattanHeuristic | MisplacedTileHeuristic)
2. Are Greedy and A\* algorithms or are they each a collection of algorithms?

C. **Local methods:** Remember only current state, not whole unfolding state tree.

1. Can be used to solve **pure optimization** problems

We call the evaluation function an **objective function** to emphasize that unlike other evaluation functions, it has neither goal test nor path cost, we want (often) to maximize it instead of minimize it, and it is (often) continuous rather than discrete.

- a. **Calculus:** Maximize a function by setting (partial) derivative(s) of a function = 0.

Problem: You may end up finding only local maximum.

What solution to this problem do you suggest?

Problem: You don't have a differentiable function.

Solution: [I'll discuss Section 4.4 about heuristic gradients another day.]

- b. **Simulated annealing:** Easiest to think about as minimizing an objective function.

We assign a random next state based on a variable that we call T, temperature, and cool the temperature slowly (according to some schedule, a **parameter** to adjust). Simulated annealing is again a collection of algorithms.

[Look at Java code for 8-queens, while looking at the general algorithm on p. 116.]

Why do we choose the successor with probability  $\exp(\Delta E/T)$ ?

Answer: That's how real annealing works, and we are simulating it! In fact, the change in the value function,  $\Delta E$ , is the free energy in the analogy, so an appropriate letter.

- c. **Linear programming:** Maximize a linear function on a polygonally bounded area by checking vertices. [homework Question #13]

Problem: Unlike derivatives which can be approximated by discrete steps, doing linear programming with discrete steps (called "integer programming") is not able to be correctly approximated. To see an example, here is a link:

[mat.gsia.cmu.edu/orclass/integer/node12.html#SECTION00041000000000000000](http://mat.gsia.cmu.edu/orclass/integer/node12.html#SECTION00041000000000000000)

#### d. Genetic algorithms:

- We represent each problem **state** as a string over a finite alphabet, usually  $\{0,1\}$ .
- To promote an analogy with genetics, we call the evaluation function the **fitness function**, as if the states were competing for survival. The fitness function is to be maximized.

Example: In 8 Queens problem,  $f(n)$  = number of non-attacking pairs of queens.

- We remember a **population** of  $k$  current states to start with.
- These choices give a parametrized family of algorithms.

Different encodings into an alphabet give different results! [Important!]

Example: In 8 Queens problem, a state could be a string of 8 digits in range  $[1,8]$ , one for each column telling where the queen is.

Or, more compactly, a state could be a string of 8 binary numbers each of length 3 in the range  $[0,7]$ ; that is, the range  $[000_2, 111_2]$ .

- We randomly select 2 **parents** (pairs of strings).
- We randomly cut them at the same corresponding place (**crossover point**) and swap their halves to get two children. [See Fig. 4.15.]
- We then **mutate** with small probability some of the children string locations.

[The algorithm in Fig. 4.17 uses *child* to mean pair of children. That's how I'm making it agree with Fig. 4.15, but in fact we could modify Fig. 4.15 to agree with the algorithm if we wanted to. Both work, another free choice to decide what GA we'll use.]

- **Demo** the Java code.