

Advanced Search Algorithms I: Simulated Annealing

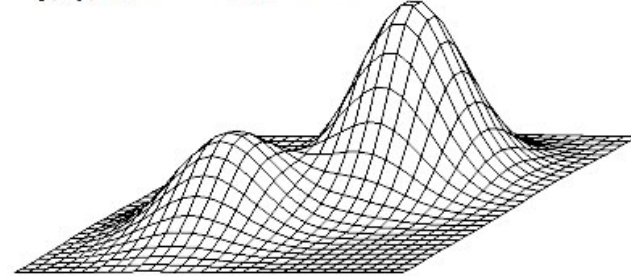
CSE 415: Introduction to Artificial Intelligence
University of Washington
Winter, 2018

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Hill Climbing

$$f(x,y) = e^{-(x^2+y^2)} + 2e^{-((x-1.7)^2+(y-1.7)^2)}$$



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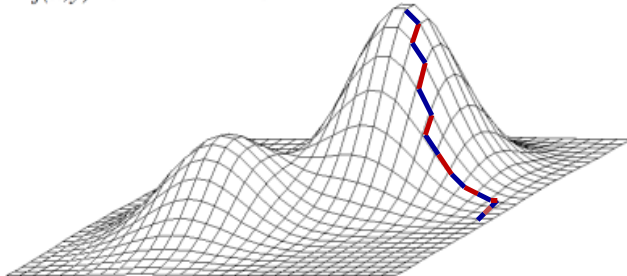
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Hill Climbing (cont.)

$$f(x,y) = e^{-(x^2+y^2)} + 2e^{-((x-1.7)^2+(y-1.7)^2)}$$



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Hill Climbing (cont.)

Assumptions:

Each state maps to a well-defined “height.”

Method:

At each step, choose the move that results in the state having the greatest height.

Similar to:

Greedy algorithms.

Gradient ascent or descent or steepest ascent or descent (in continuous state spaces)

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Hill Climbing (cont.)

Major limitation:

Can get stuck in a local optimum (e.g., a lesser peak).



Simulated Annealing

Like probabilistic hill climbing.
Allows for the possibility of escaping from local optima.

Optimum means “lowest potential energy” state.

S.A. is based on an analogy to a metallurgical process called annealing.



S.A. (cont.)

Problem structure for simulated annealing:

We have an energy function

$$E: S \rightarrow \mathbb{R}^+$$

that assigns to each state a nonnegative real number.



S.A. – The Method

In state s having energy z , randomly select an operator whose precondition is satisfied.

Apply it to create a state s' having energy z' . If $z' \leq z$, then accept s' as the new current state.

But if $z' > z$, randomly choose to accept s' with probability p , where

$$p = e^{-(z'-z)/kT}$$

T is the “temperature” which starts high and gradually is reduced to 0.

S.A. Typical Problem Structure

Problem structure for simulated annealing:

Often: the state space is a **cartesian product** of many subspaces each of which corresponds to a state variable.

S.A. Example

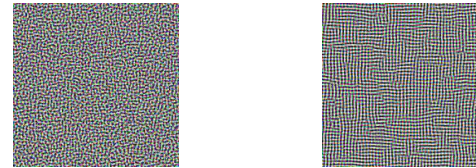
“Crystallization” in a digital image.

Each pixel corresponds to a separate state variable.

Start with a random image. Use an energy function that gives low energy to similar pixels being adjacent and low energy when pixels at a slight distance are different, but higher energy in the other situations.

http://en.wikipedia.org/wiki/Simulated_annealing

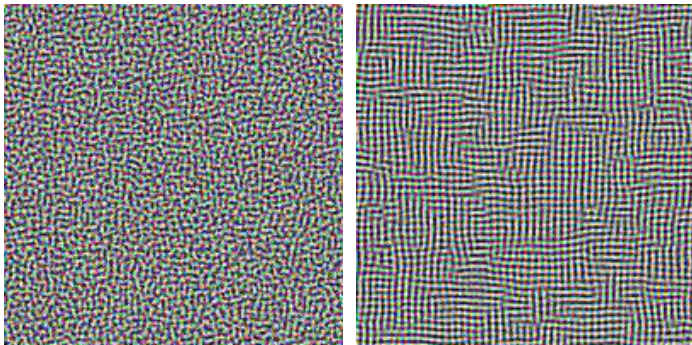
Results using fast and slow cooling schedules:



S.A. Example (enlargements)

Fast

Slow



S. A. Example 2

Travelling Salesman Problem

Demonstration applet at:

<http://www.heatonresearch.com/articles/64/page1.html>

