

Title: Local Search
Required reading: AIMA, Chapter 4
LWH: Chapters 6, 10, 13 and 14.

Introduction to Artificial Intelligence
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Outline Iterative improvement search:

- Hill-climbing
- Simulated annealing
- ...

Types of Search (I)

- 1- Uninformed vs. informed
- 2- Systematic/constructive vs. iterative improvement

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Iterative improvement (a.k.a. local search)

→ Sometimes, the 'path' to the goal is irrelevant
only the state description (or its quality) is needed

Iterative improvement search

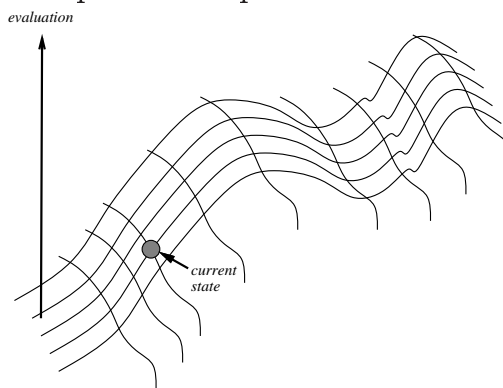
- choose a single current state, sub-optimal
- gradually modify current state
- generally visiting 'neighbors'
- until reaching a near-optimal state

Example: complete-state formulation of N -queens

Main advantages of local search techniques

1. Memory (usually a constant amount)
2. Find reasonable solutions in large spaces
where we cannot possibly search the space exhaustively
3. Useful for optimization problems:
best state given an objective function (quality of the goal)

Intuition: state-scape landscape



- All states are layed up on the surface of a landscape
- A state's location determines its neighbors (where it can move)
- A state's elevation represents its quality (value of objective function)
- Move from one neighbor of the current state to another state until reaching the highest peak

Two major classes

1. Hill climbing (a.k.a. gradient ascent/descent)
 - try to make changes to improve quality of current state
2. Simulated Annealing (physics)
 - things can temporarily get worse

Others: tabu search, local beam search, genetic algorithms, etc.

→ Optimality (soundness)? Completeness?

→ Complexity: space? time?

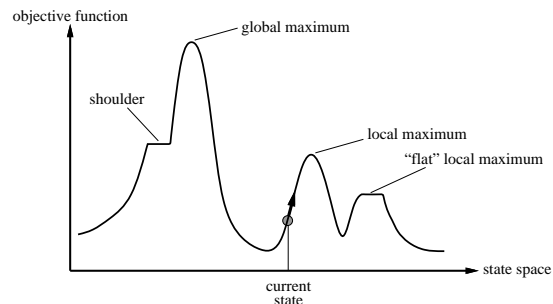
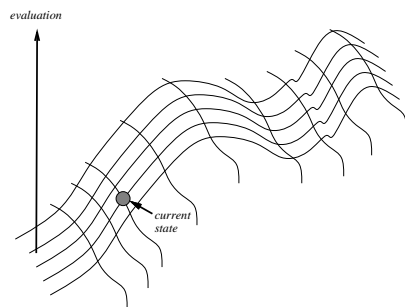
→ In practice, surprisingly good.. (eroding myth)

Hill climbing

Start from any state at random and loop:

Examine all direct neighbors

If a neighbor has higher value then move to it else exit

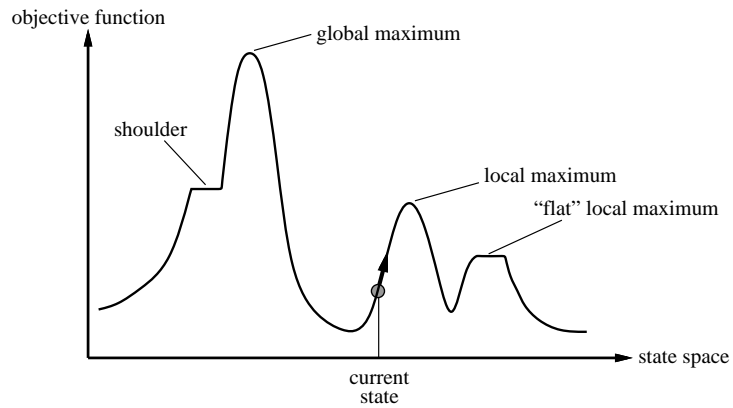


Problems: {

- Local optima: (maxima or minima) search halts
- Plateau: flat local optimum or shoulder
- Ridge

Plateaux

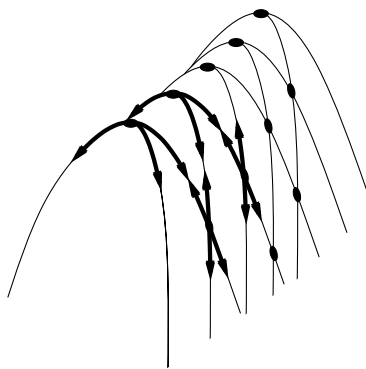
Allow sideways moves



- For shoulder, good solution
- For flat local optima, may result in an infinite loop
Limit number of moves

Ridges

Sequence of local optima that is difficult to navigate



Variants of Hill Climbing

- Stochastic hill climbing: random walk
Choose to disobey the heuristic, sometimes
Parameter: How often?
- First-choice hill climbing
Choose first best neighbor examined
Good solution when we have too many neighbors
- Random-restart hill climbing
A series of hill-climbing searches from random initial states

Random-restart hill-climbing

- When HC halts or no progress is made
re-start from a different (randomly chosen) starting
save best results found so far
- Repeat random restart
 - for a fixed number of iterations, or
 - until best results have not been improved for a certain
number of iterations

Simulated annealing (I)

Basic idea: When stuck in a local maximum allow few steps towards less good neighbors to escape the local maximum

Start from any state at random, start count down and loop until time is over:

Pick up a neighbor at random

Set $\Delta E = \text{value}(\text{neighbor}) - \text{value}(\text{current state})$

If $\Delta E > 0$ (neighbor is better)

then move to neighbor

else $\Delta E < 0$ move to it with probability < 1

Transition probability $\simeq e^{\Delta E/T}$ $\left\{ \begin{array}{l} \Delta E \text{ is negative} \\ T: \text{count-down time} \end{array} \right.$
as time passes, less and less likely to make the move towards 'unattractive' neighbors

Simulated annealing (II)

Analogy to physics:

Gradually cooling a liquid until it freezes

If temperature is lowered sufficiently slowly, material will attain lowest-energy configuration (perfect order)

Count down \longleftrightarrow Temperature

Moves between states \longleftrightarrow Thermal noise

Global optimum \longleftrightarrow Lowest-energy configuration

How about decision problems?

Optimization problems

Iterative improvement

State value

Sub-optimal state

Optimal state

↔

↔

↔

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Decision problems

Iterative repair

Number of constraints violated

Inconsistent state

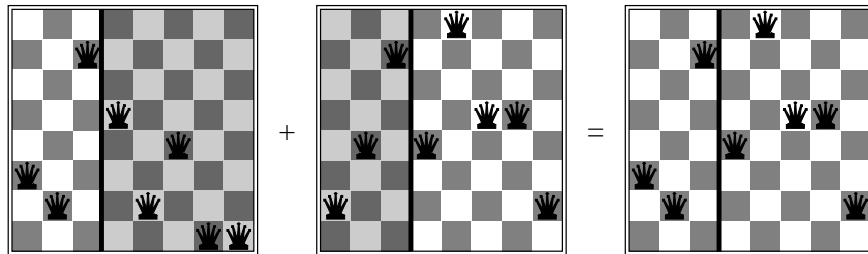
Consistent state

Local beam search

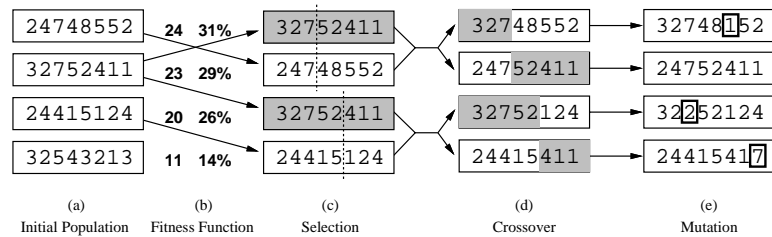
- Keeps track of k states
- Mechanism:
 - Begins with k states
 - At each step, all successors of all k states generated
 - Goal reached? Stop.
 - Otherwise, selects k best successors, and repeat.
- Not exactly a k restarts: k runs are not independent
- Stochastic beam search increases diversity

Genetic algorithms

- Basic concept: combines two (parent) states
- Mechanism:
 - Starts with k random states (population)
 - Encodes individuals in a compact representation (e.g., a string in an alphabet)
 - Combines partial solutions to generate new solutions (next generation)



Important components of a genetic algorithm



- Fitness function ranks a state's quality, assigns probability for selection
- Selection randomly chooses pairs for combinations depending on fitness
- Crossover point randomly chosen for each individual, offsprings are generated
- Mutation randomly changes a state