Title: Local Search

Required reading: AIMA, Chapter 4 (Section 4.1)
LWH: Chapters 6, 10, 13 and 14.

Introduction to Artificial Intelligence

CSCE 476-876, Fall 2022

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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)

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

Iterative improvement search

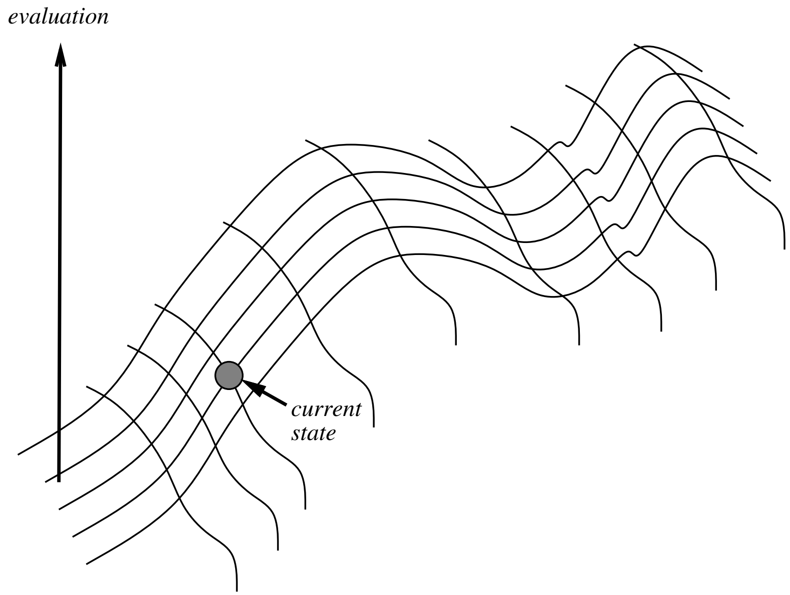
- choose a single current state, sub-optimal
- gradually modify current state
- generally visiting 'neighbors'
- until reaching a near-optimal state

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?

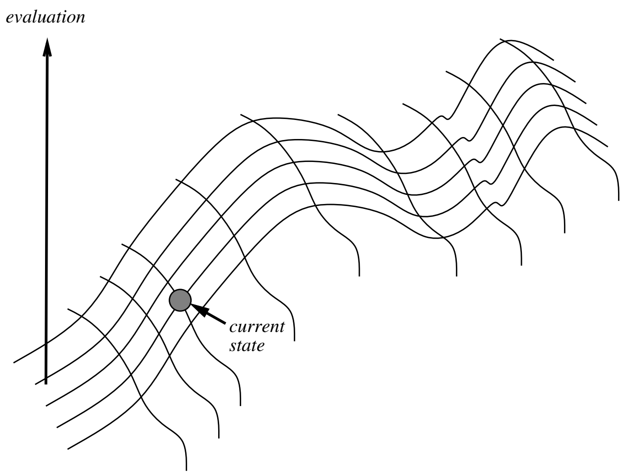
⟶ In practice, surprisingly good.. (eroding myth)

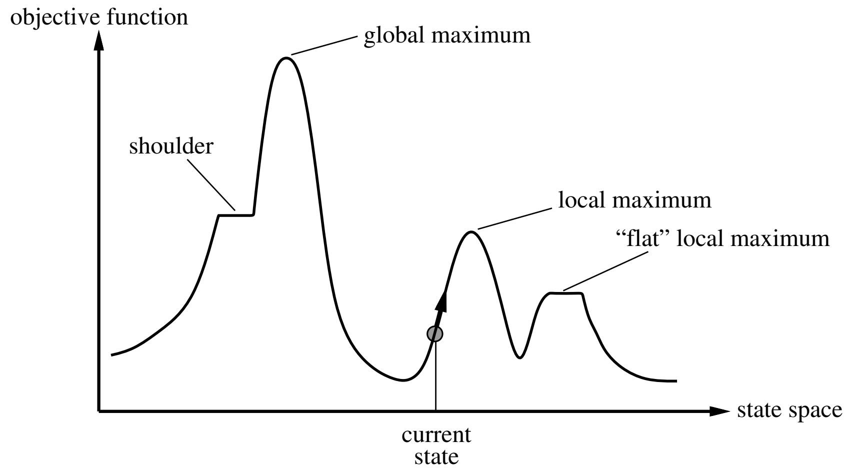
Hill climbing

Start from any state at random and loop:

Examine all direct neighbors

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

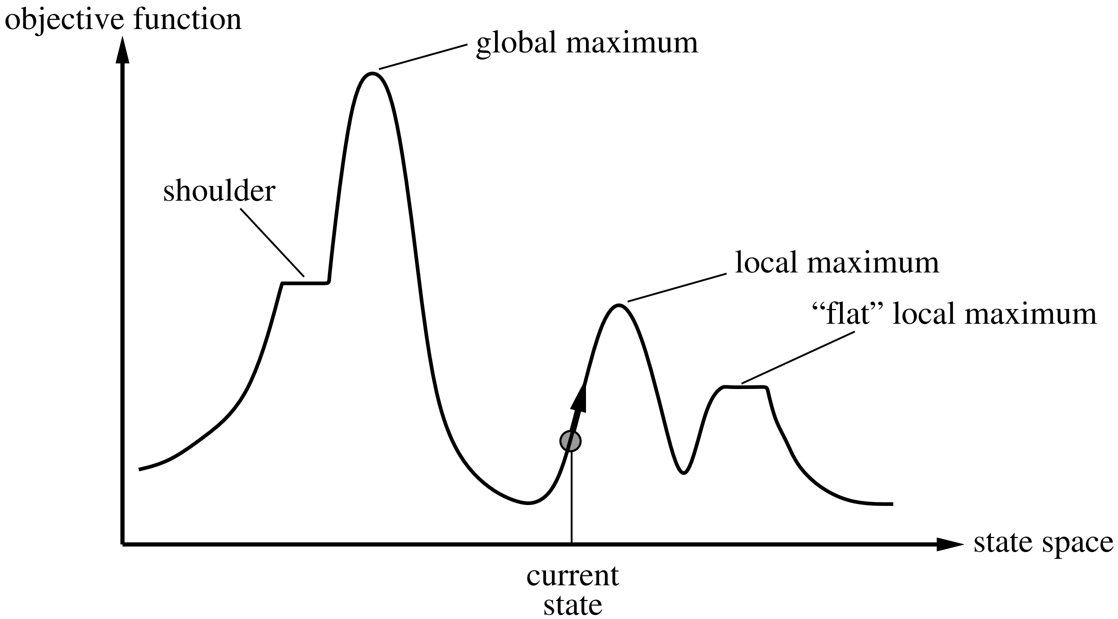




Problems:
- Local optima: (maxima or minima) search halts
- Plateau: flat local optimum or shoulder
- Ridge

Plateaux

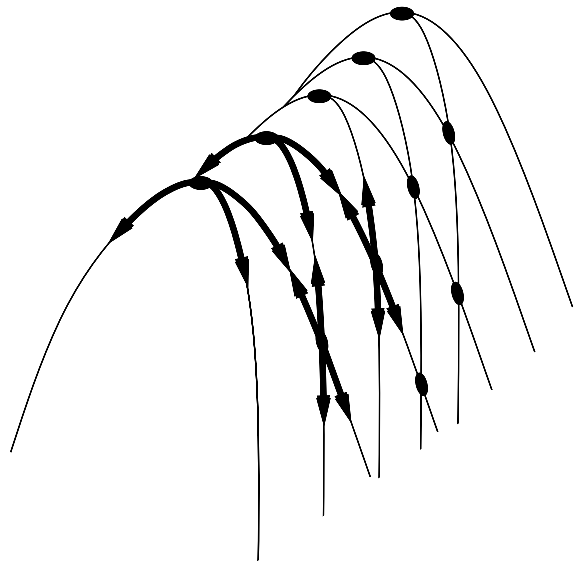
Allow sideway moves



- 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



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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 <u>random</u>

Set ΔE = value(neighbor) - value(current state)

If ΔE>0 (neighbor is better)

then move to neighbor

else ΔE<0 move to it with probability < 1

Transition probability $\simeq e^{\Delta E/T}$ $\begin{cases} \Delta\text{E is negative} \\ \text{T: count-down time} \end{cases}$

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?

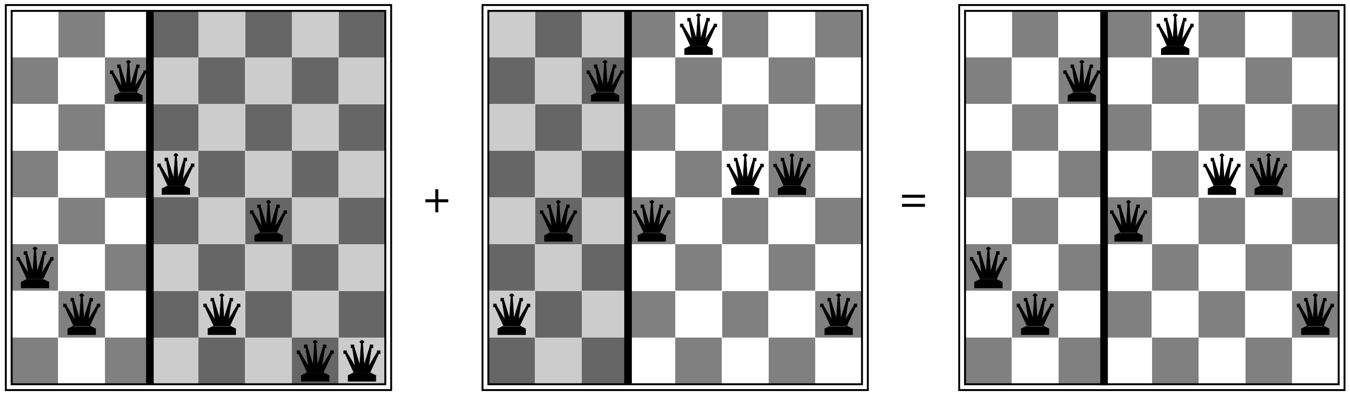
Optimization problems		Decision problems
Iterative improvement	$\longleftrightarrow$	Iterative repair
State value	$\longleftrightarrow$	Number of constraints violated
Sub-optimal state	$\longleftrightarrow$	Inconsistent state
Optimal state	$\longleftrightarrow$	Consistent state

Local beam search

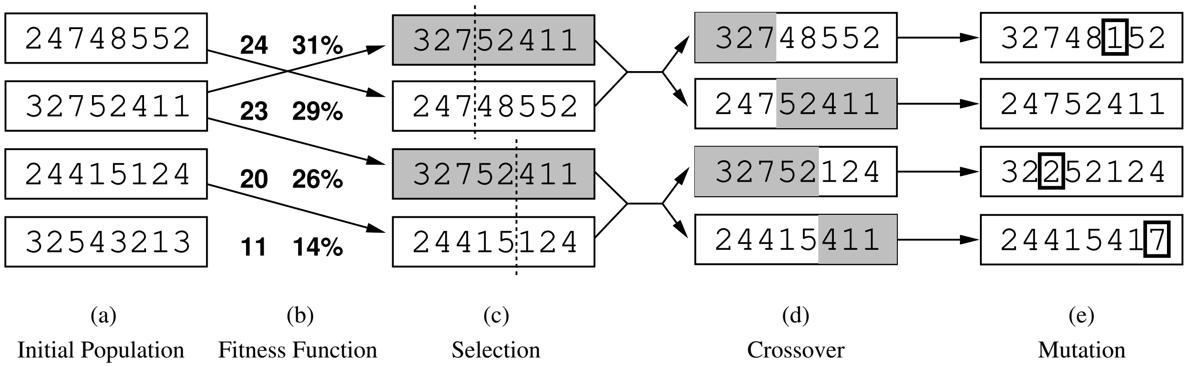
- Keeps track of k states
- Mechanism:
  Begins with k states
  At each step, all successors of all k states generated
  Goal reached? Stop.
  Otherwise, selects k best successors, and repeat.
- Not exactly a k restarts: k runs are not independent
- Stochastic beam search increases diversity

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