

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 2023

**URL:** [www.cse.unl.edu/~choueiry/F23-476-876](http://www.cse.unl.edu/~choueiry/F23-476-876)

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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

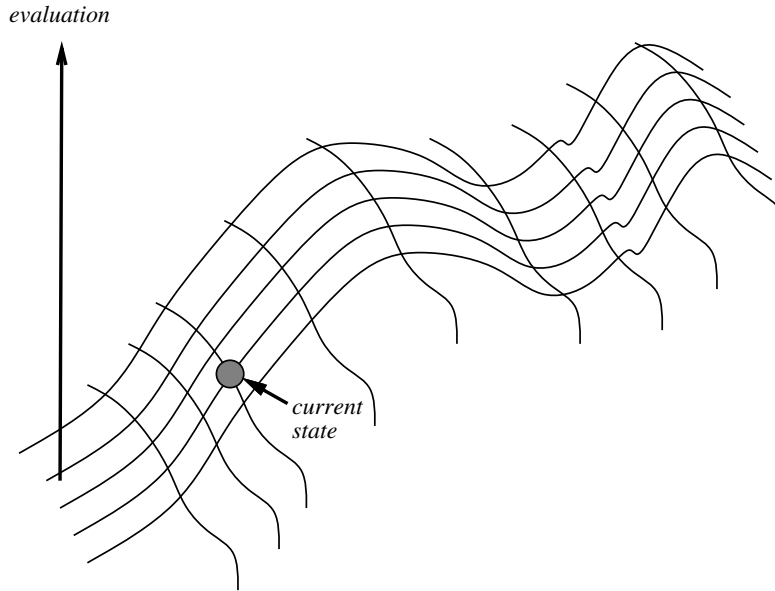
- choose a single current state, sub-optimal
- gradually modify current state
- generally visiting ‘neighbors’
- until reaching a near-optimal state

**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)

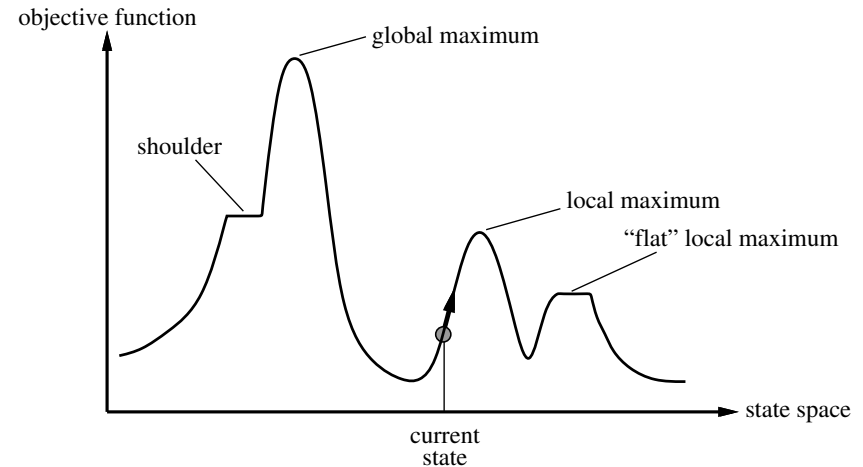
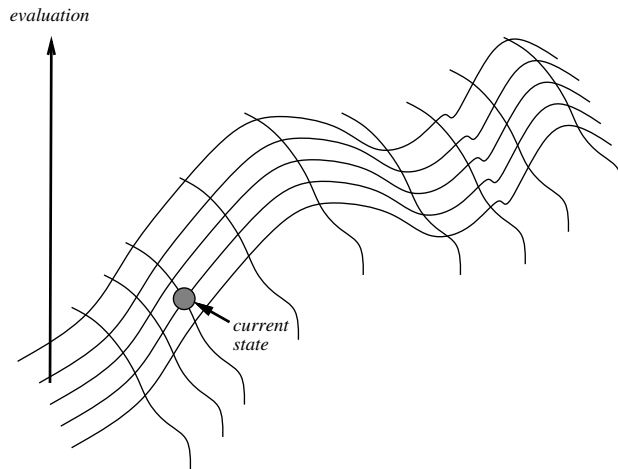
# Hill climbing

Start from any state at random and loop:

Examine all direct neighbors

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

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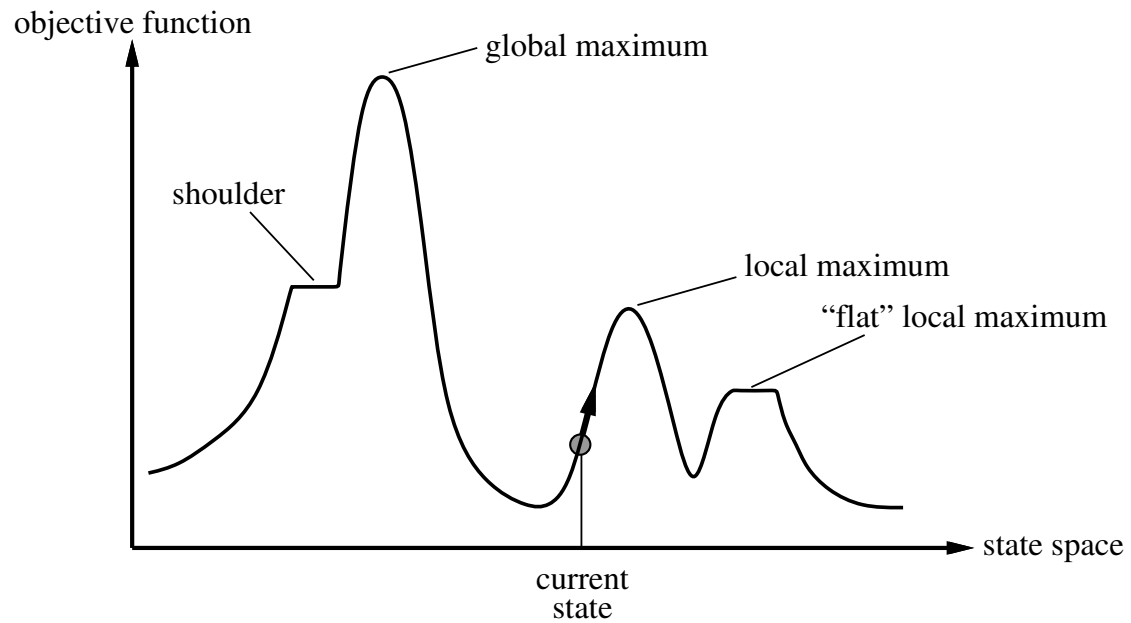
Problems: {

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



# Plateaux

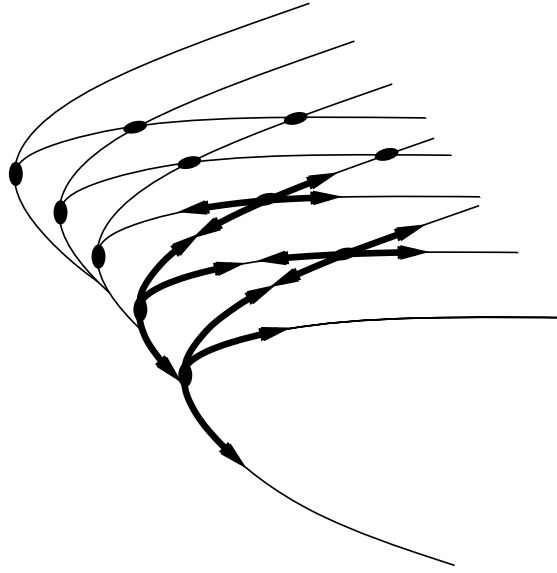
Allow sideway moves



- 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 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



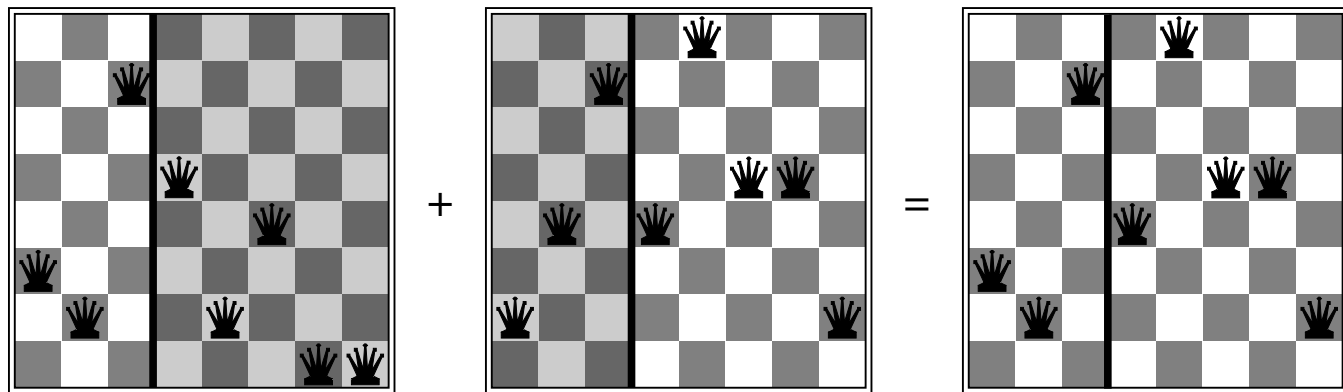
# Genetic algorithms

- Basic concept: combines two (parent) states
- Mechanism:

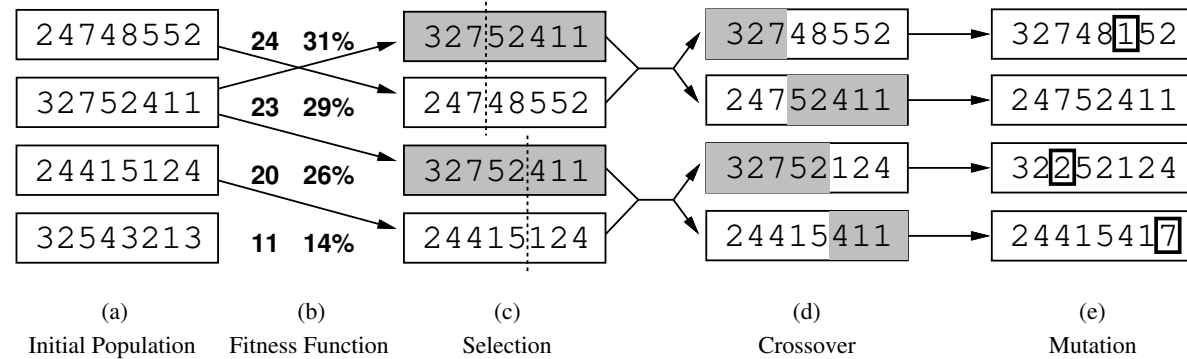
Starts with  $k$  random states (population)

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