Local Search

Computer Science cpsc322, Lecture 14

(Textbook Chpt 4.8)

Oct, 5, 2012

Announcements

- Assignment1 due now!

- Assignment2 out next week

Lecture Overview

- Recap solving CSP systematically
- Local search
- Constrained Optimization
- Greedy Descent / Hill Climbing: Problems

Systematically solving CSPs: Summary

- Build Constraint Network
- Apply Arc Consistency
  - One domain is empty → no sol
  - Each domain has a single value → unique sol
  - Some domains have more than one value → ?!

    may or may not have a solution

- Apply Depth-First Search with Pruning
- Split the problem in a number of disjoint cases
  - Apply Arc Consistency to each case

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- Recap
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Local Search motivation: Scale

- Many CSPs (scheduling, DNA computing, more later) are simply too big for systematic approaches
- If you have 10^5 vars with dom(var_i) = 10^4

- Systematic Search
- Constraint Network

$10^5 * 10^4$

$10^{10} * 10^8$

$10^{10} * 10^{12}$

- but if solutions are densely distributed…….

Local Search motivation: Scale

- Many CSPs (scheduling, DNA computing, more later) are simply too big for systematic approaches
- If you have 10^5 vars with $\mathrm{dom}(var_i) = 10^4$

- Systematic Search

  $b = 10^4$ (branching factor)

  $d = 10^5$ (depth)

  $(10^4)^{10^5}$

- Constraint Network

  $10^5 + 10^5 * 10^5$ (var nodes + constraint nodes)

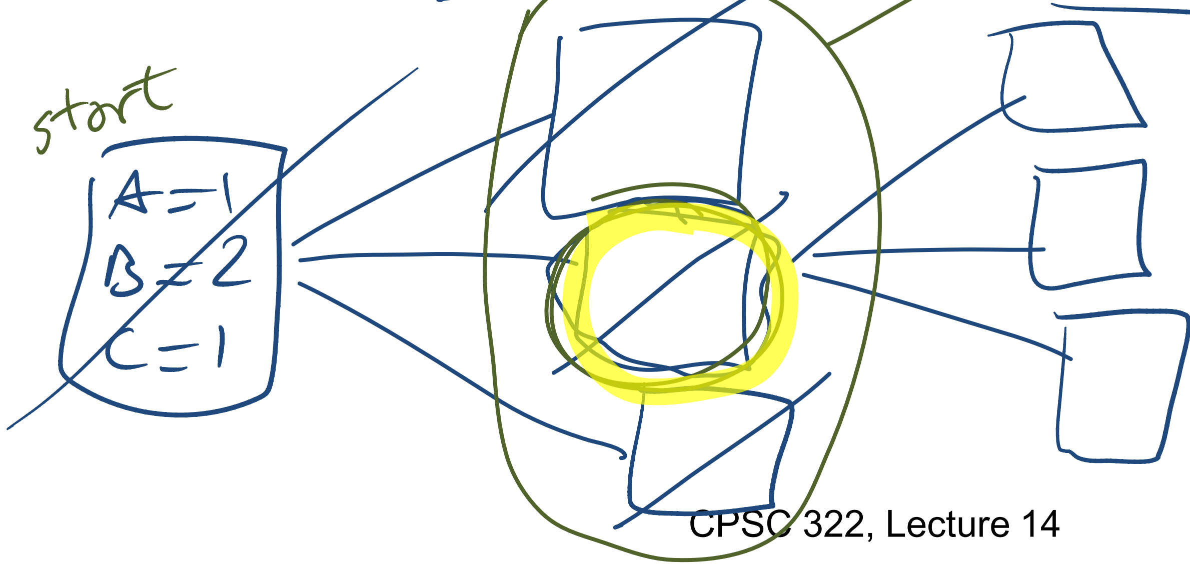
  10^{10} max # of nodes

- but if solutions are densely distributed…….

Local Search: General Method

Remember , for CSP a solution is..... a possible world (not a path)

- Start from a possible world
- Generate some neighbors (“similar” possible worlds)
- Move from the current node to a neighbor, selected according to a particular strategy
  - Example: A,B,C same domain {1,2,3}

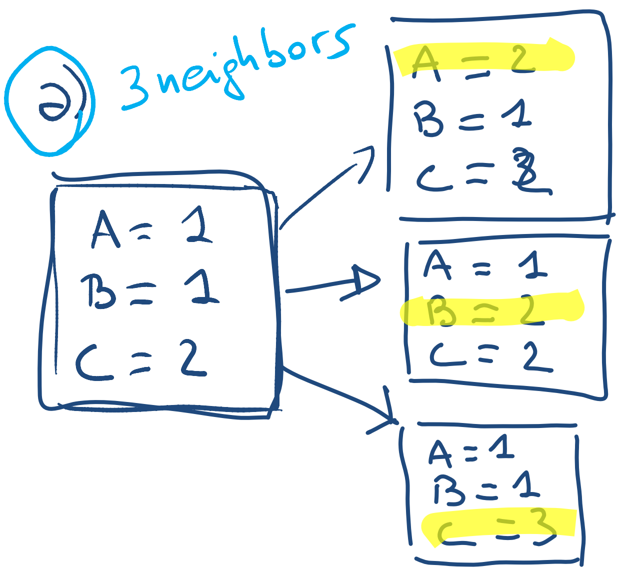


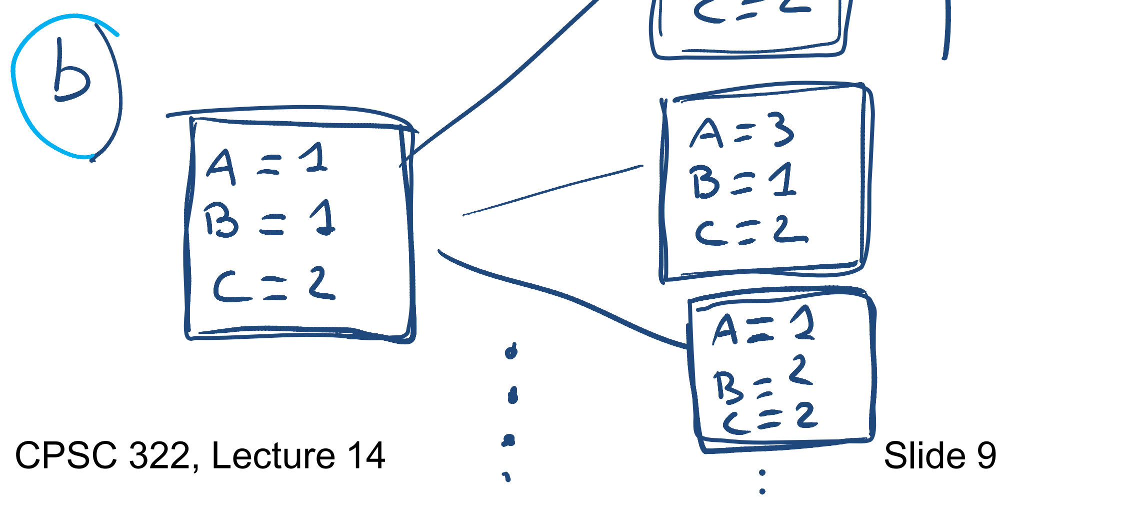
Local Search: Selecting Neighbors

How do we determine the neighbors?

- Usually this is simple: some small incremental change to the variable assignment
  a) assignments that differ in one variable's value, by (for instance) a value difference of +1
  b) assignments that differ in one variable's value
  c) assignments that differ in two variables' values, etc.

- Example: A,B,C same domain {1,2,3}





Iterative Best Improvement

- How to determine the neighbor node to be selected?
- Iterative Best Improvement:
  - select the neighbor that optimizes some evaluation function
- Which strategy would make sense? Select neighbor with …

Maximal number of constraint violations

Similar number of constraint violations as current state

No constraint violations

Minimal number of constraint violations

Iterative Best Improvement

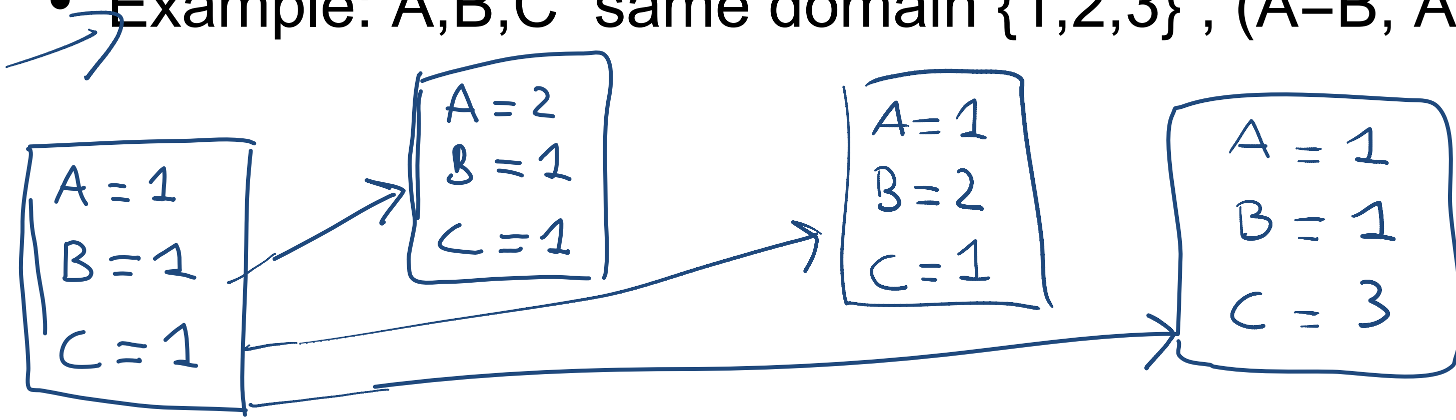
- How to determine the neighbor node to be selected?
- Iterative Best Improvement:
  - select the neighbor that optimizes some evaluation function
- Which strategy would make sense? Select

Minimal number of constraint violations

- Evaluation function:
  h(n): number of constraint violations in state n
- Greedy descent: evaluate h(n) for each neighbour, pick the neighbour n with minimal h(n)
- Hill climbing: equivalent algorithm for maximization problems
  - Here: maximize the number of constraints satisfied

Selecting the best neighbor

- Example: A,B,C same domain {1,2,3} , (A=B, A>1, C≠3)



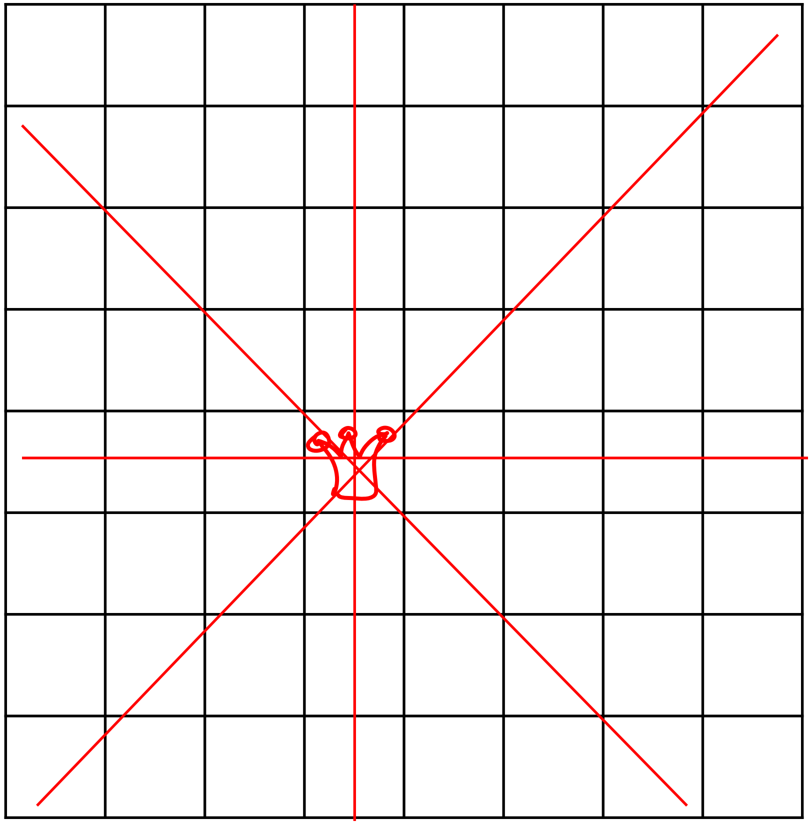
A common component of the scoring function (heuristic) => select the neighbor that results in the ……

- the min conflicts heuristics

Example: N-Queens

- Put n queens on an n × n board with no two queens on the same row, column, or diagonal (i.e attacking each other)

- Positions a queen can attack



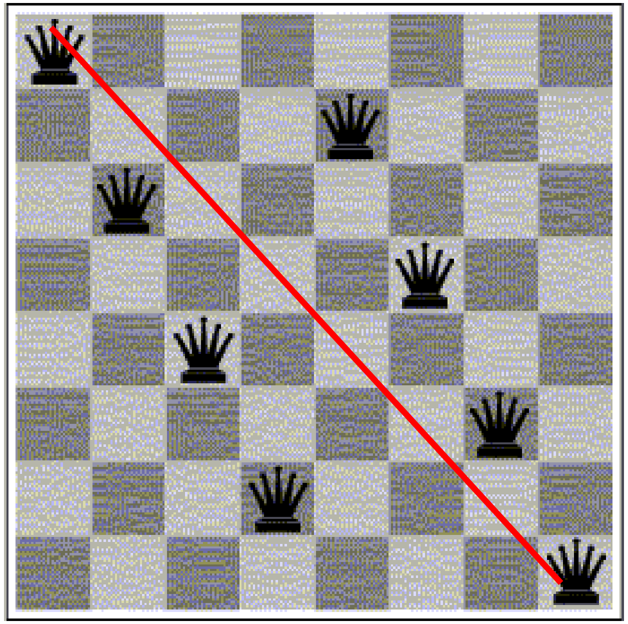
Example: N-queen as a local search problem

CSP: N-queen CSP

- One variable per column; domains {1,…,N} => row where the queen in the i^{th} column seats;
- Constraints: no two queens in the same row, column or diagonal

Neighbour relation: value of a single column differs

Scoring function: number of constraint violations (i..e, number of



Example: *n*-queens

Put *n* queens on an *n* × *n* board with no two queens on the same row, column, or diagonal (i.e attacking each other)

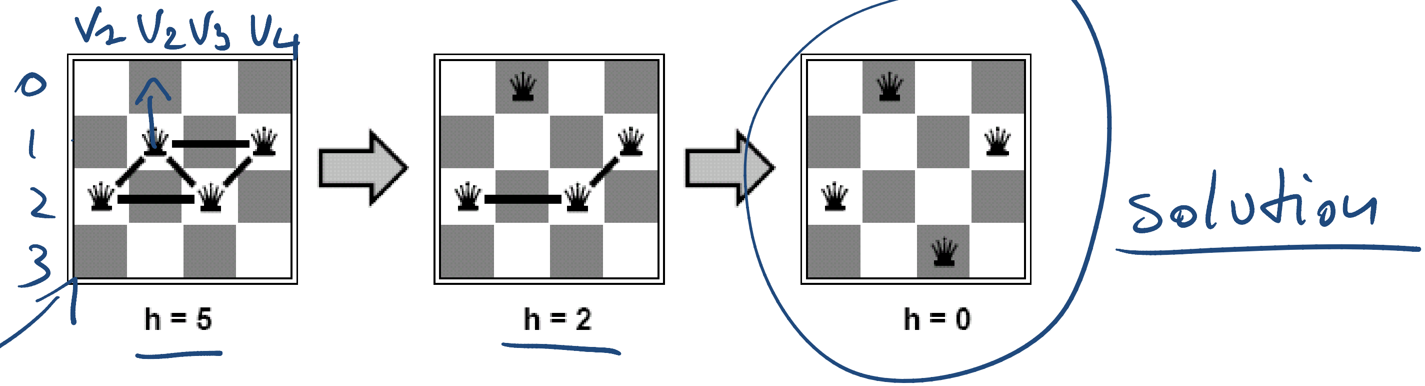
Example: 4-Queens

States: 4 queens in 4 columns ($4^4 = 256$ states)

Operators: move queen in column (to generate neighbors)

Goal test: no attacks

Evaluation: $h(n)$ = number of attacks



$V_1 = 2$
$V_2 = 1$
$V_3 = 2$
$V_4 = 1$

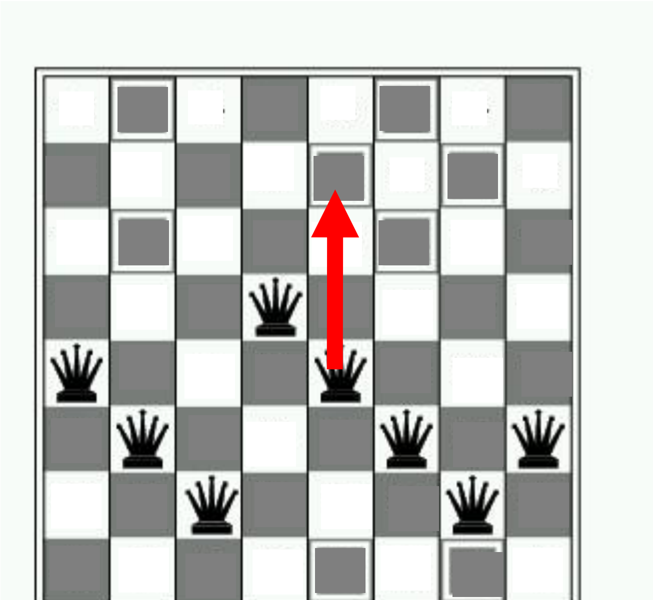
Example: Greedy descent for N-Queen

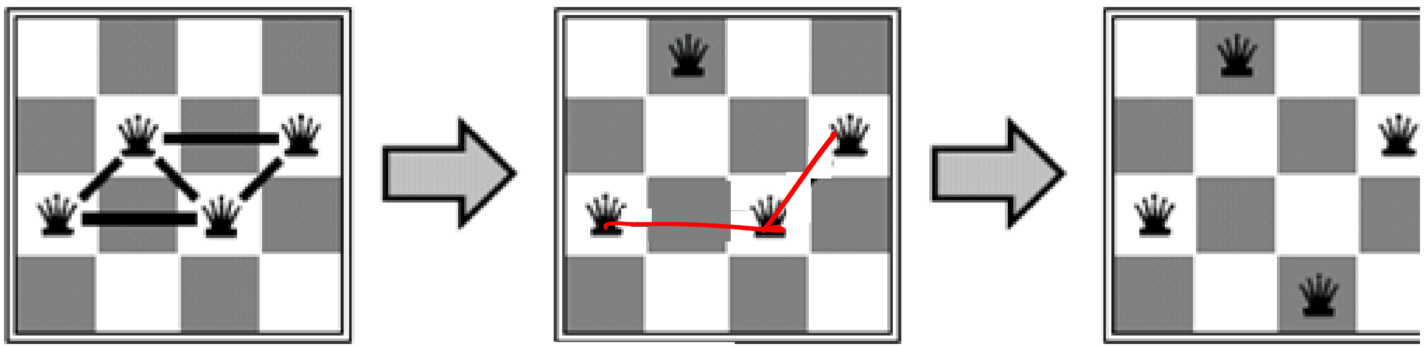
For each column, assign randomly each queen to a row (a number between 1 and N)

Repeat

- For each column & each number: Evaluate how many constraint violations changing the assignment would yield
- Choose the column and number that leads to the fewest violated constraints; change it

Until solved

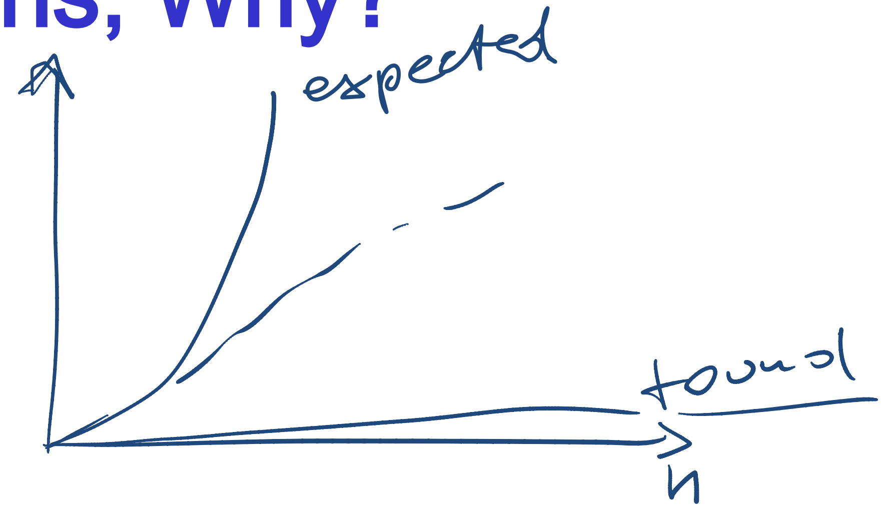




h = 5 h = ? h = ?

1 0 2 3

n-queens, Why?



Why this problem?

Lots of research in the 90' on local search for CSP was generated by the observation that the run-time of local search on n-queens problems is **independent of problem size!**

Given random initial state, can solve n-queens in almost constant time for arbitrary n with high probability (e.g., $n = 10,000,000$)

Lecture Overview

- Recap
- Local search
- **Constrained Optimization**
- Greedy Descent / Hill Climbing: Problems

Constrained Optimization Problems

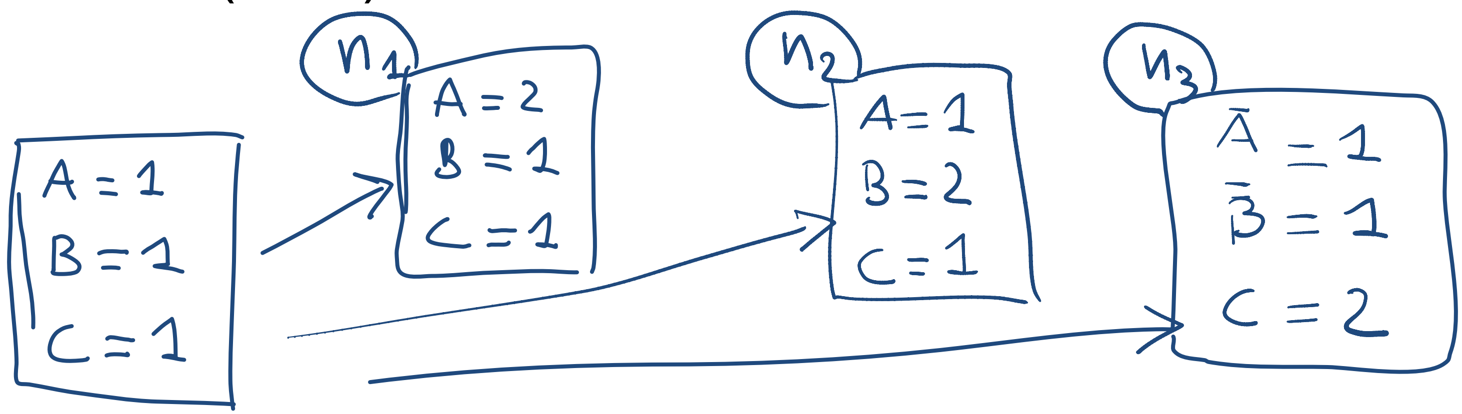
So far we have assumed that we just want to find a possible world that satisfies all the constraints.

But sometimes solutions may have different values / costs

- We want to find the optimal solution that
  - maximizes the value or
  - minimizes the cost

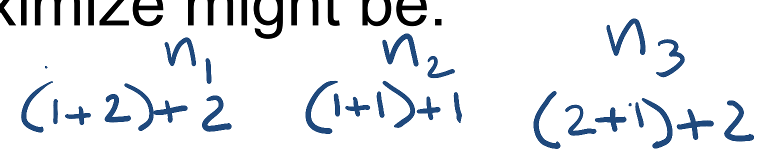
Constrained Optimization Example

- Example: A,B,C same domain {1,2,3} , (A=B, A>1, C≠3)
- Value = (C+A) so we want a solution that maximize that



The scoring function we'd like to maximize might be:

f(n) = (C + A) + #-of-satisfied-const



Hill Climbing means selecting the neighbor which best improves a (value-based) scoring function.

Greedy Descent means selecting the neighbor which minimizes a (cost-based) scoring function. cost + # of conflicts

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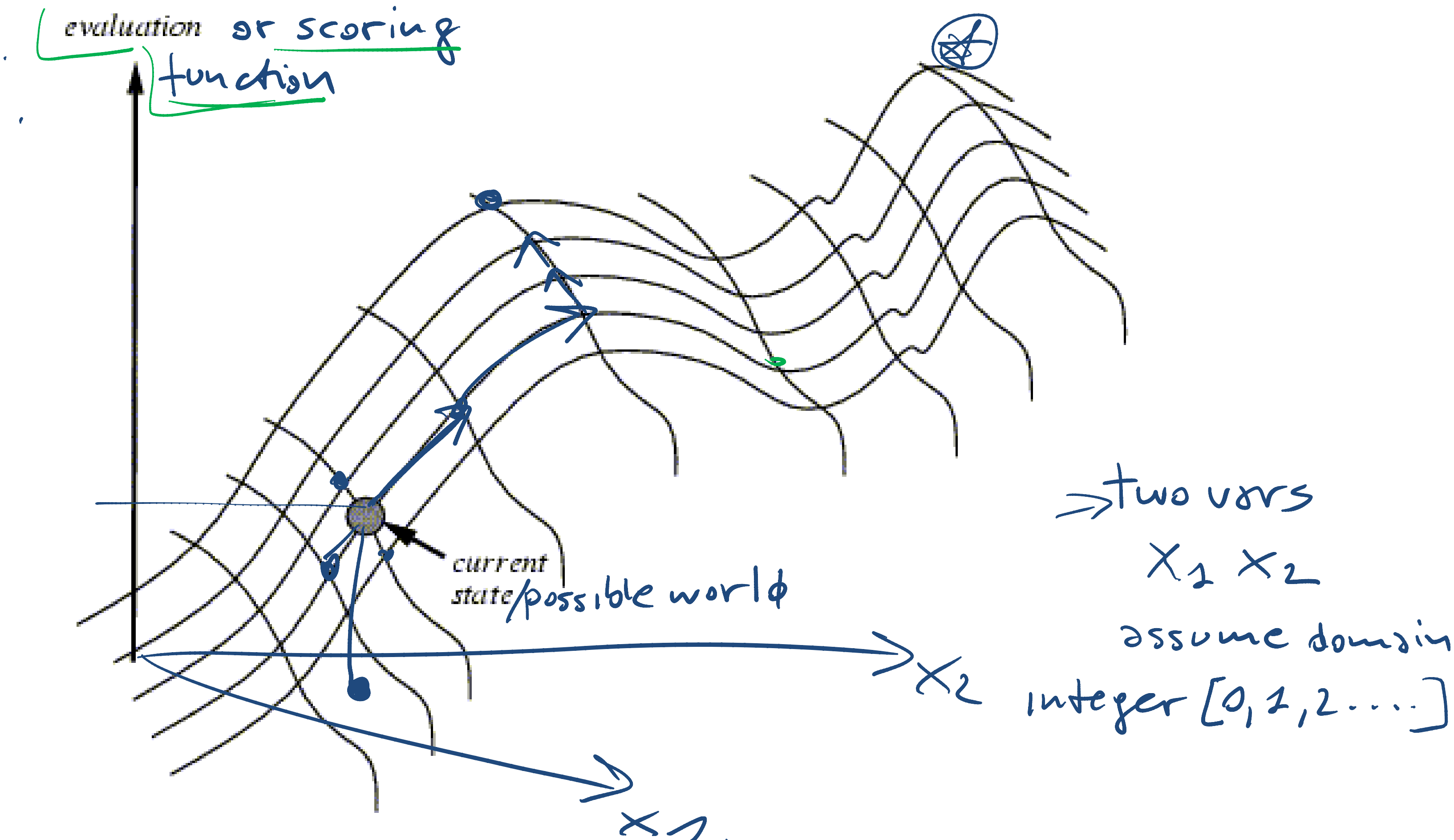
Hill Climbing

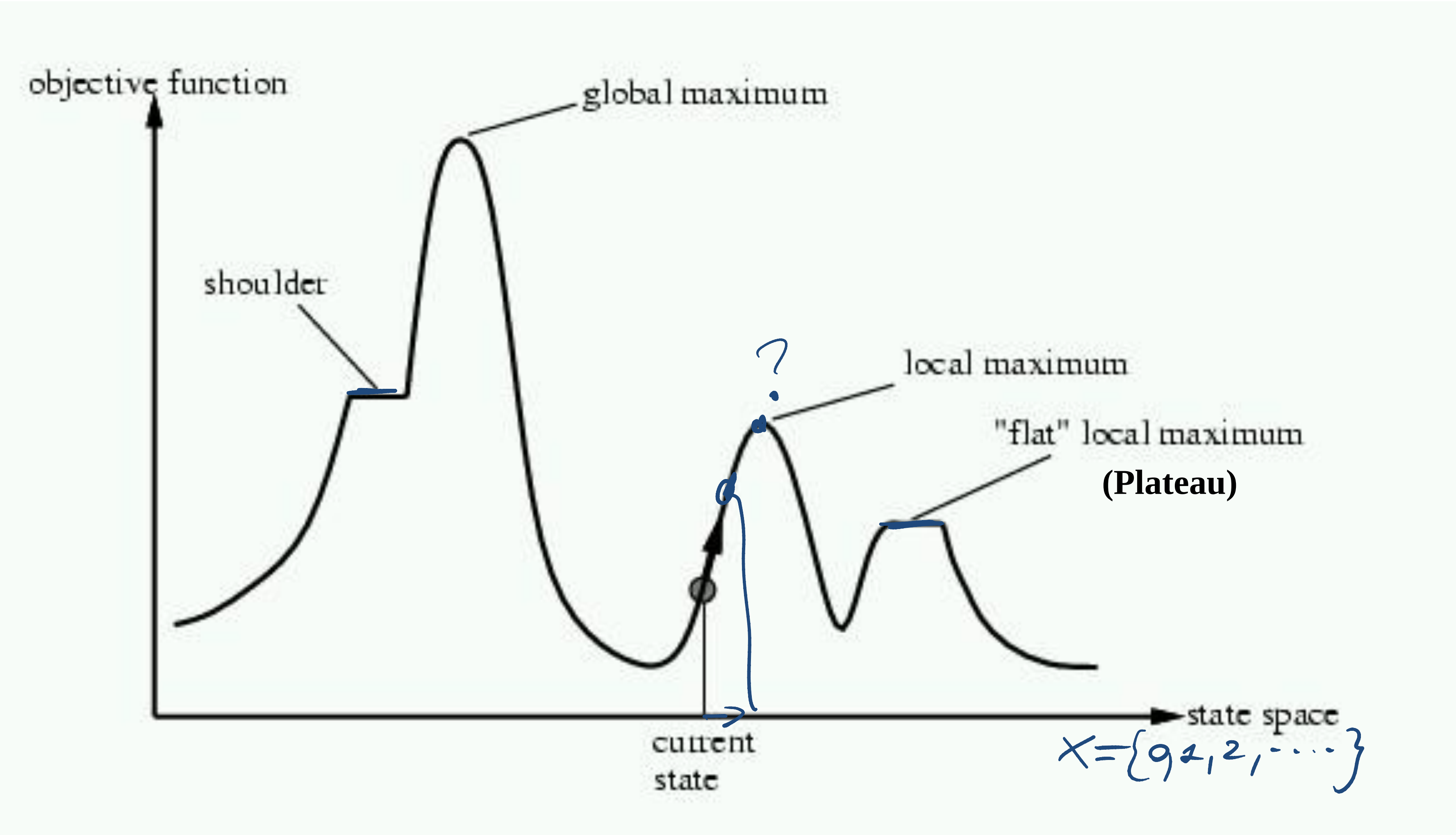
NOTE: Everything that will be said for Hill Climbing is also true for Greedy Descent



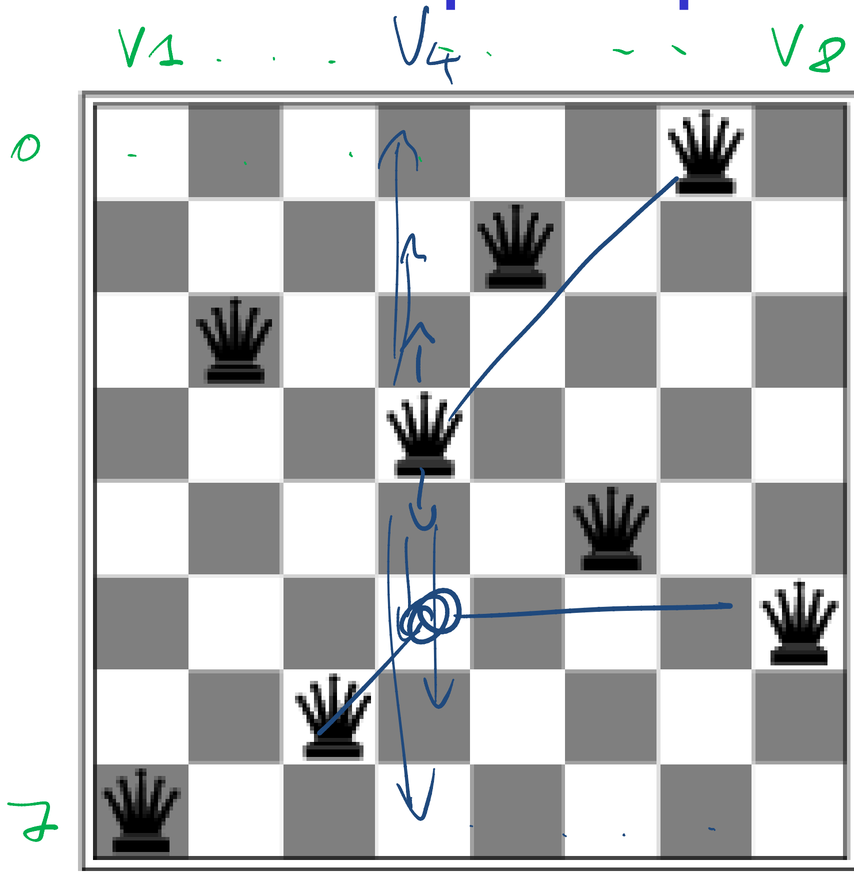
Problems with Hill Climbing

Local Maxima.

Plateau - Shoulders



Corresponding problem for GreedyDescent
Local minimum example: 8-queens problem



for all the moves (neighbors)

h > 1

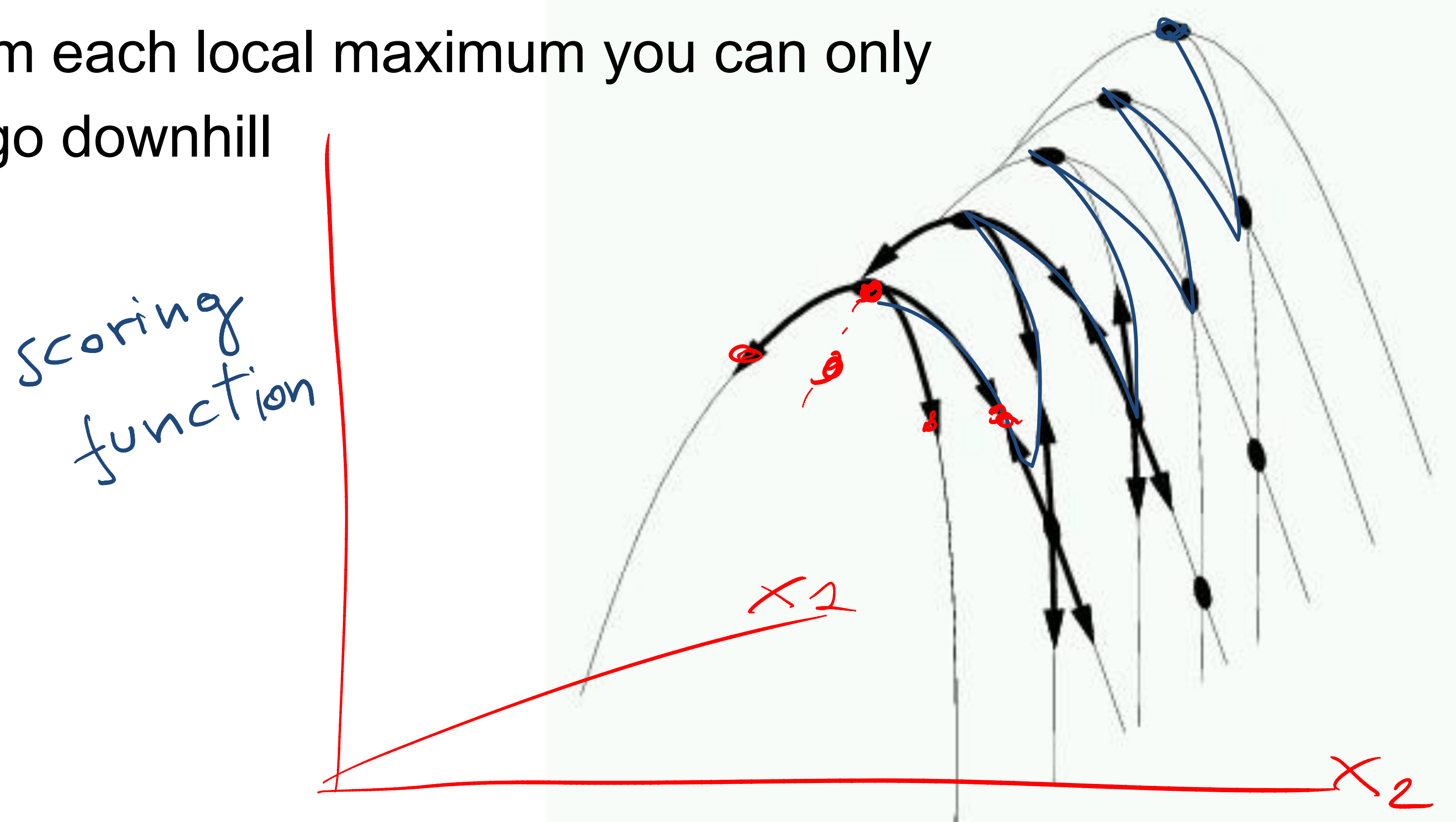
A local minimum with *h = 1*

h = 0
for solution

Even more Problems in higher dimensions

E.g., Ridges – sequence of local maxima not directly connected to each other

From each local maximum you can only go downhill



Local Search: Summary

- A useful method for large CSPs
  - Start from a possible world (randomly chosen)
  - Generate some neighbors (“similar” possible worlds)

    e.g. differ from current poss. world only by one variable's value
  - Move from current node to a neighbor, selected to minimize/maximize a scoring function which combines:
    - ✓ Info about how many constraints are violated
    - ✓ Information about the cost/quality of the solution (you want the best solution, not just a solution)

Learning Goals for today's class

You can:

- Implement local search for a CSP.
  - Implement different ways to generate neighbors
  - Implement scoring functions to solve a CSP by local search through either greedy descent or hill-climbing.

Next Class

- How to address problems with Greedy Descent / Hill Climbing?

Stochastic Local Search (SLS)

322 Feedback ☺ or ☹

- Lectures
- Slides
- Practice Exercises
- Assignments
- AIspace
- ……
- Textbook
- Course Topics / Objectives
- TAs
- Learning Goals
- ……