Introduction to Artificial Intelligence
COMP 3501 / COMP 4704-4
Lecture 3: Local Search

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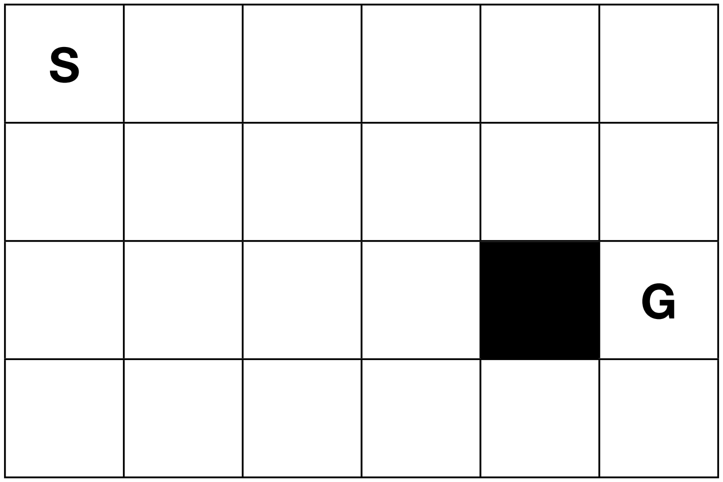
JGH 318

Today

- Finish up heuristics from last time
- Discuss homework
- Chapter 4:
  - Local search: hill climbing
  - Genetic Algorithms
  - Online search agents

A* Search

- Special case of best-first search
  - Best is by *f*-cost, where f(s) = g(s)+h(s)
  - Estimates total path cost through a node to the goal
- If heuristic is consistent, *f*-costs will be monotonically non-decreasing



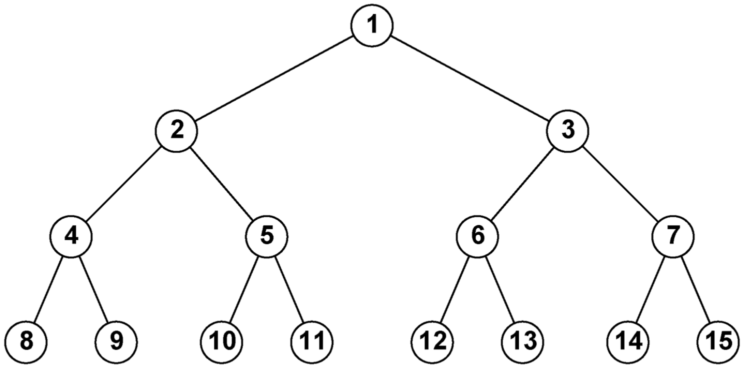
A* search

- Complete?
- Optimal?
- Time complexity?
- Space complexity?

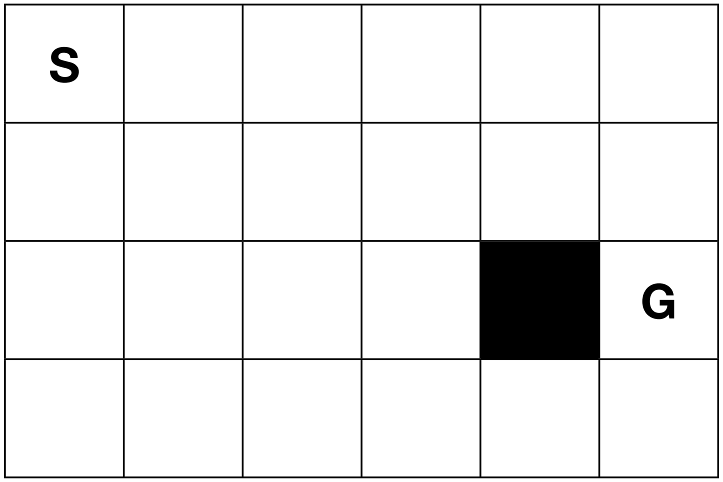
- Can we do better than A*?

Iterative-Deepening A*

- Perform depth-first iterative deepening on *f*-costs instead of *g*-costs
  - How do we update the bounds?
  - How do we get our initial bound?



Assume heuristic is distance from leaves



IDA*

- Complete?
- Optimal?
- Time complexity?
- Space complexity?

Where do heuristics come from?

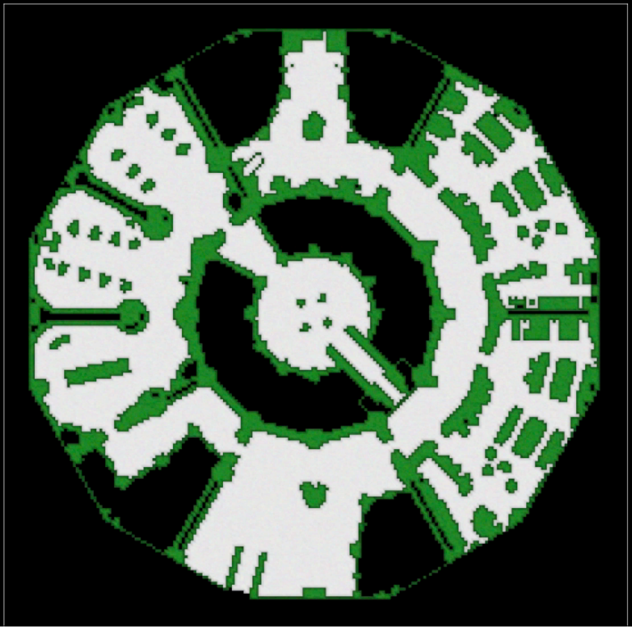
- Exact solution to relaxed version of original problem

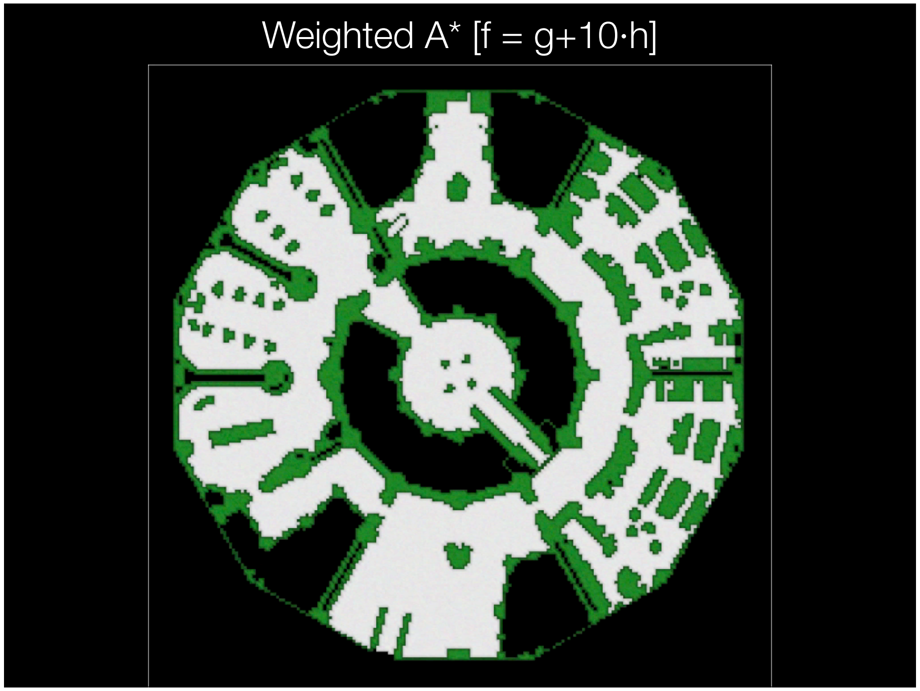
- Relax the constraints in the original problem to make it easier to solve
- Use solution as heuristic in original problem

Heuristics for pathfinding & tsp

- Pathfinding
  - Normally constrained to move on grid/graph
  - Cannot move through obstacles
  - Relax by allowing straight-line movement
- Traveling Salesman Problem
  - Must visit all cities in a tour
  - Relax by visiting all cities in minimum spanning tree

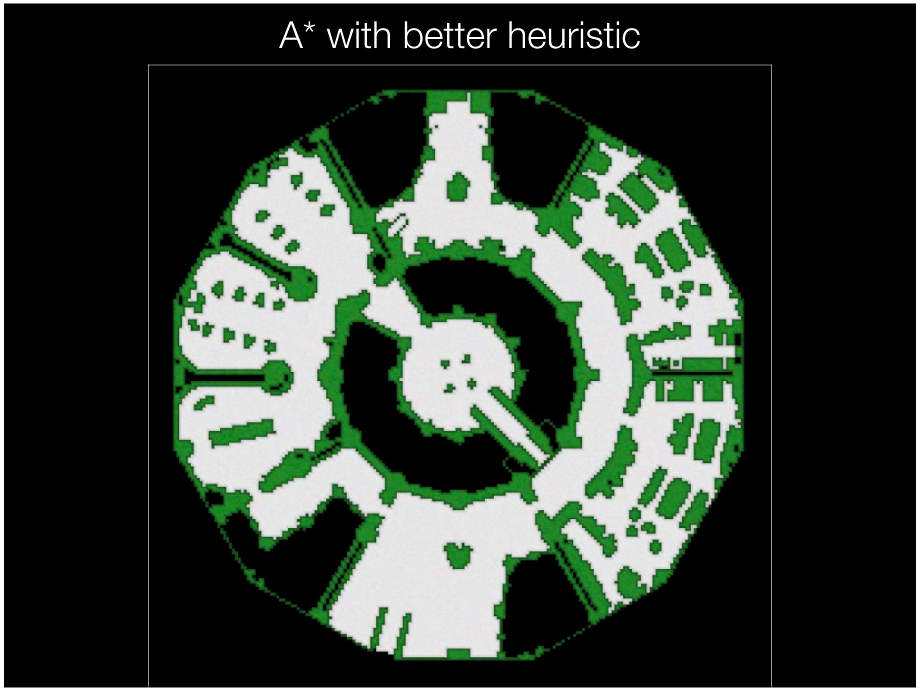
Regular A*





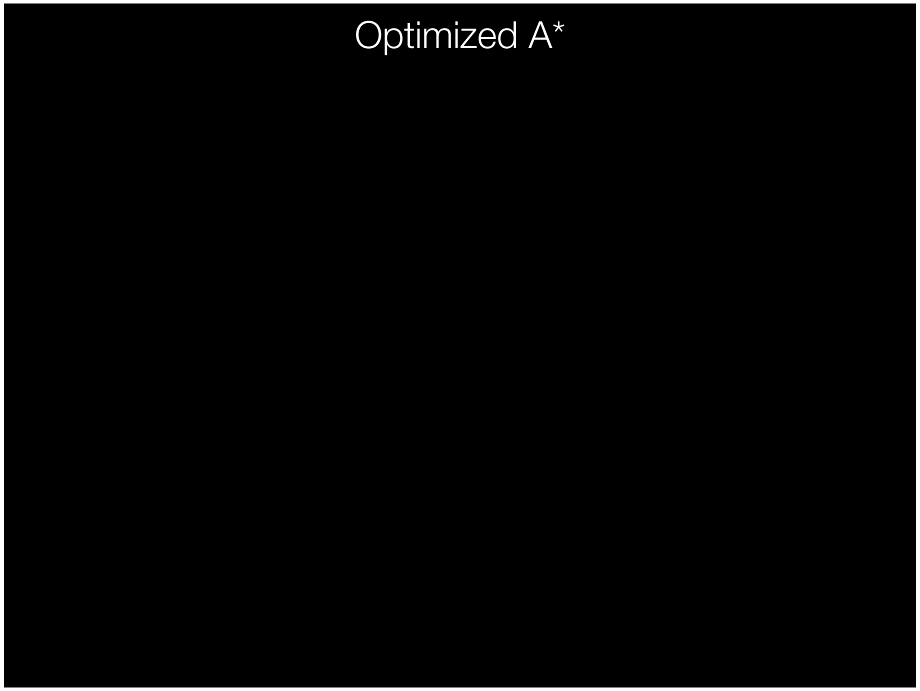
Weighted A* [f = g+10·h]

13



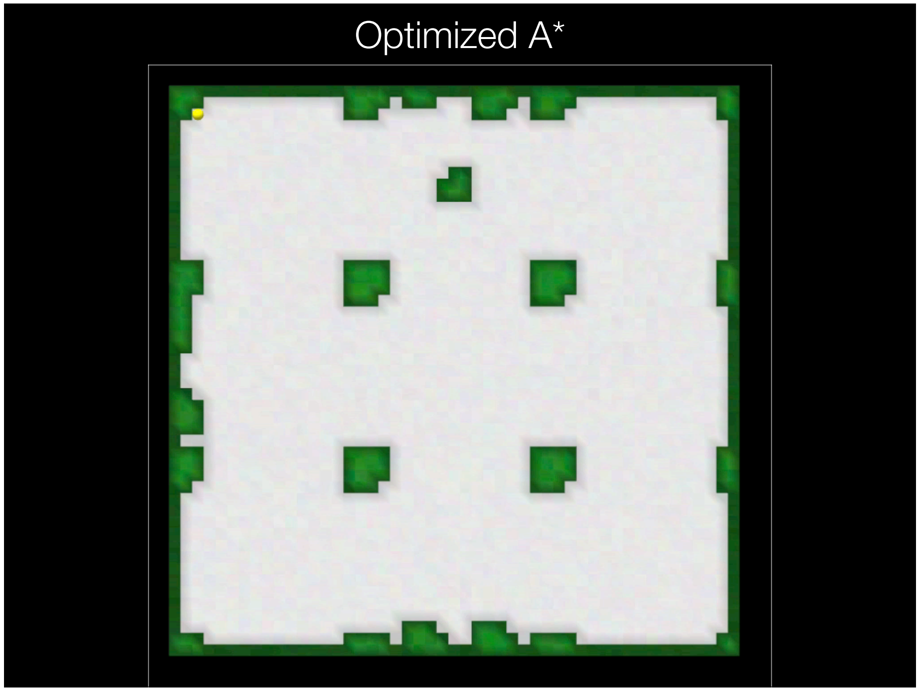
A* with better heuristic

14



Optimized A*

15



Optimized A*

15

A*: Break ties towards lower g-costs

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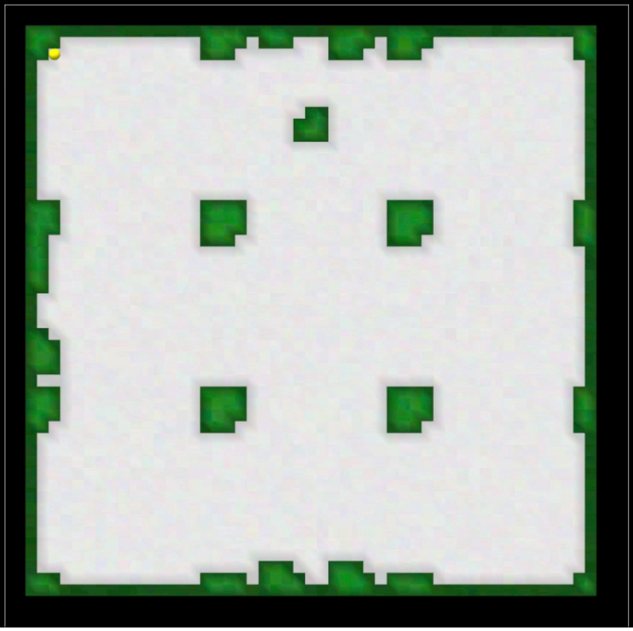
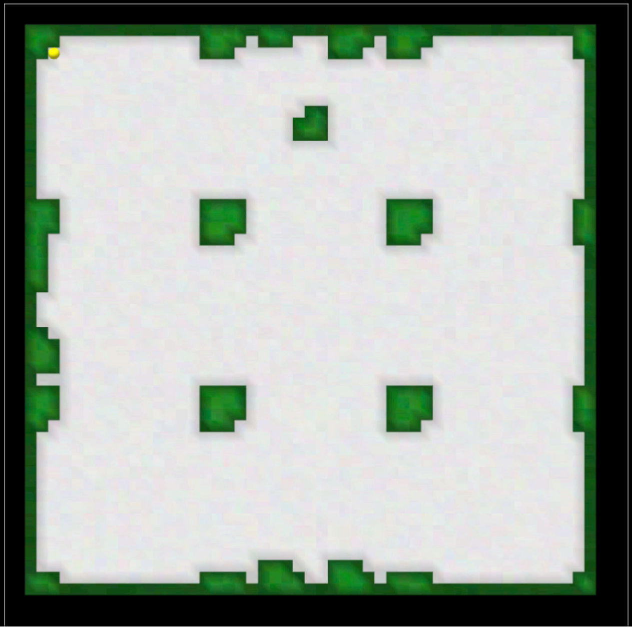


A*: Straight-line heuristic



Heuristics for sliding-tile puzzle

- What heuristic would you use for the sliding-tile puzzle?
  - Manhattan distance
- Domain abstraction for pattern databases
  - See Figure 3.30

Heuristics for pathfinding & tsp

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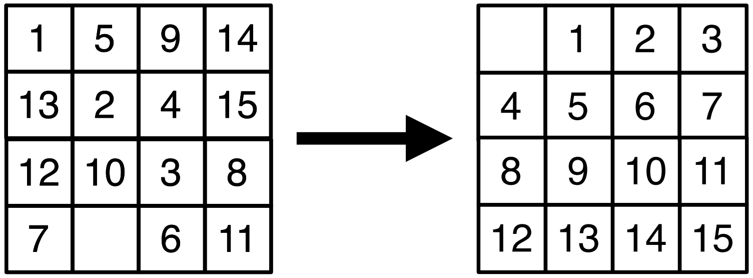
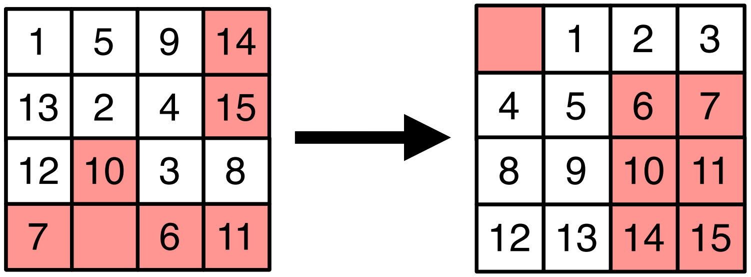


1	5	9	14
13	2	4	15
12	10	3	8
7		6	11

	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15



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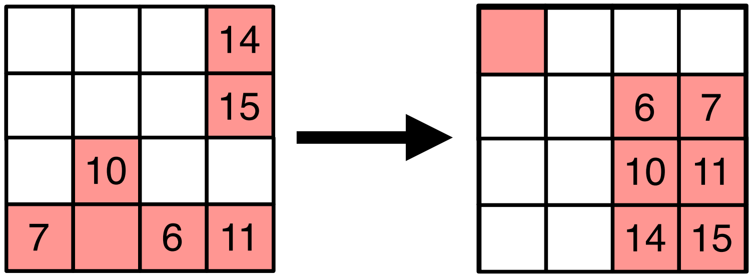


			14
			15
	10		
7		6	11

		6	7
		10	11
		14	15

Homework

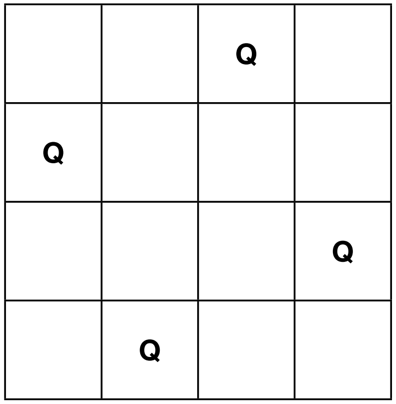
- 3.14(a) DFS always expands as many states as A*.
- 3.14(b) h(n) = 0 is an admissible heuristic
- 3.14(c) A* is of no use in robotics with continuous actions/states
- 3.14(d) BFS is complete even with 0-cost actions
- 3.14(e) If a rook can move across the board in one step, is Manhattan distance admissible?

Local search

- Not all problems require a path as output
  - Examples?

N-queens problem

- Place *n* queens on a chess board in a manner such that no queen can capture another queen in a single move
- Possible problem defns?



		Q	
Q			
			Q
	Q		

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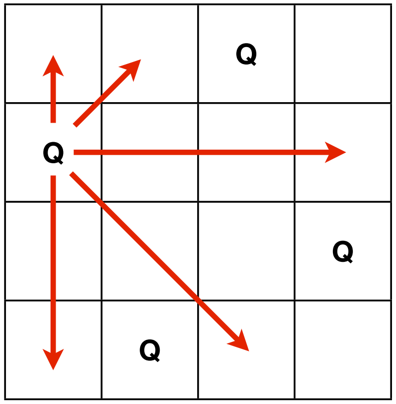
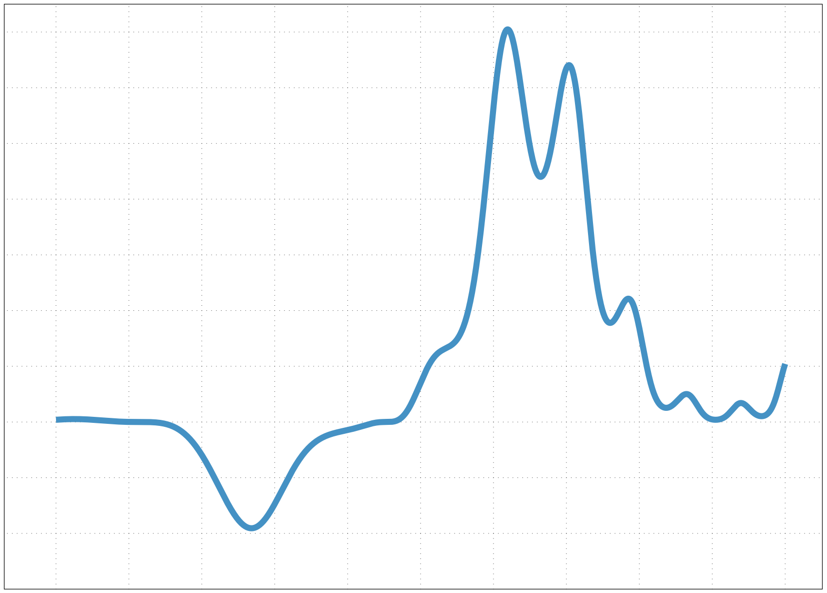


Local search

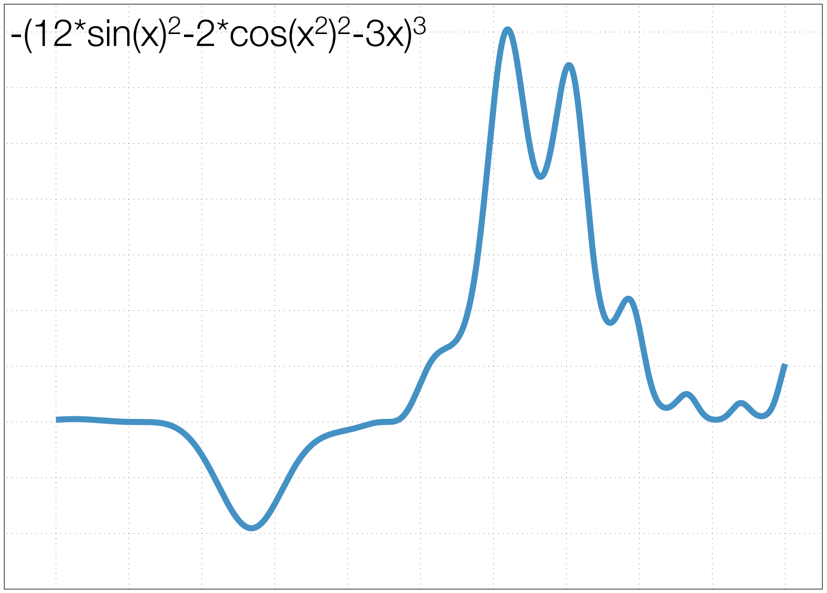
- Chapter 3 algorithms all find paths
- If a path is not required, there is more flexibility in the types of algorithms that can be considered

Local Search

- Don't necessarily need a open/closed list
  - Don't need an order to visit states
  - Don't (usually) need to worry about duplicate states
- State space might be infinite
- May only care about solution quality
  - No goal test or path cost
- Can consider "landscape" of objective function



How would you solve this problem?

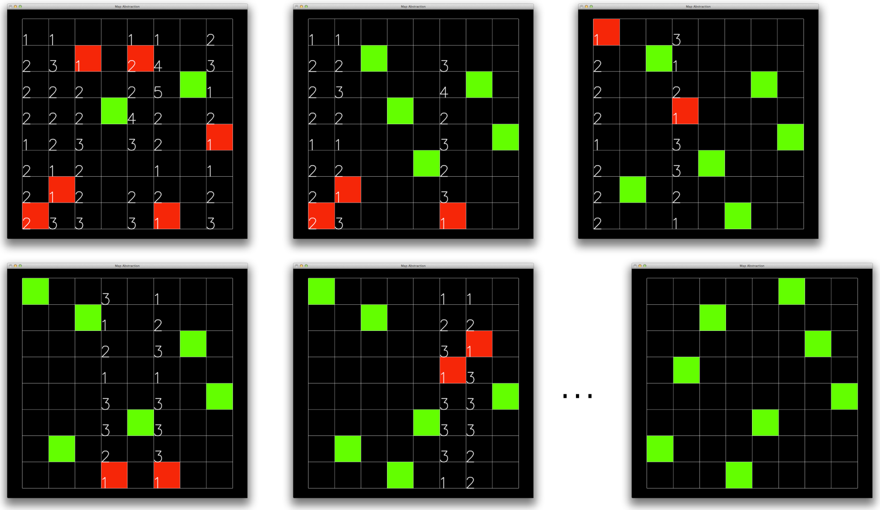

$-(12*\sin(x)^2-2*\cos(x^2)^2-3x)^3$

How would you solve this problem?

Hill Climbing / Greedy local search

- Find best *neighbor* of current state
  - Move to *neighbor*
- Repeat
- What is the best neighbor?

Example: Local search in 8-queens problem



Failure

- What does it mean for hill-climbing to fail?
- What should we do when hill-climbing fails?

Variations on simple hill climbing

- Act stochastically
- Don’t generate all successors
- Restart from a random state

What about SAT?

- Satisfiability
  - Find set of variables to satisfy a boolean formula
  - $(x_1 \lor \neg x_2 \lor \neg x_3) \land (\neg x_1 \lor \neg x_2 \lor \neg x_3) \land (x_1 \lor x_2 \lor \neg x_3)$
- WalkSat (http://www.cs.rochester.edu/u/kautz/walksat/)

Simulated Annealing

- Combine hill-climbing with random walks
  - Choose a random move
    - If it’s better, always follow it
  - Otherwise, according to current temperature, randomly choose whether to take move

Genetic Algorithms

- Genetic algorithms attempt to simulate populations of creatures in order to solve problems
- Several variations:
  - Describe creatures with a “genome”
    - Genome is “executed” to find fitness
  - Creatures directly represent solutions
    - Fitness is evaluated directly

Genetic Algorithms

- Start with population of individuals
- Instead of taking local actions, the representations "breed" leading to:
  - Cross-over between representations
  - Random mutation of states
- Breeding only occurs between:
  - Best individuals from population
  - Or randomly according to fitness

8-queen example

- What is the genome / representation?
- What is the fitness function?
- How does representation matter?

Homework for next class: 5.18

Optional Exercise: Modified problem 4.3
Do not implement; just describe:

- 4.3 (a) How would you use hill-climbing to solve TSPs?
- 4.3 (b) How would you use genetic algorithms to solve a TSP?