Problem & Search

5	4	
6	1	8
7	3	2

Initial State

1	4	7
2	5	8
3	6	

Goal State

Problem

Farmer Cabbage Goat Wolf

Solution

Problem

The solution of many problems can be described by finding a sequence of actions that lead to a desirable goal. Each action changes the state and the aim is to find the sequence of actions and states that lead from the initial (start) state to a final (goal) state.

A well-defined problem can be described by:

Initial state

Operator or successor function - for any state x returns s(x), the set of states reachable from x with one action

State space - all states reachable from initial by any sequence of actions

Path - sequence through state space

Path cost - function that assigns a cost to a path. Cost of a path is the sum of costs of individual actions along the path

Goal test - test to determine if at goal state

State spaces

- A state space consists of
  - A (possibly infinite) set of states
    - The start state represents the initial problem
    - Each state represents some configuration reachable from the start state
    - Some states may be goal states (solutions)
  - A set of operators
    - Applying an operator to a state transforms it to another state in the state space
    - Not all operators are applicable to all states
- State spaces are used extensively in Artificial Intelligence (AI)

State Space Search: Playing Chess

- Each position can be described by an 8-by-8 array.
- Initial position is the game opening position.
- Goal position is any position in which the opponent does not have a legal move and his or her king is under attack.
- Legal moves can be described by a set of rules:
  - Left sides are matched against the current state.
  - Right sides describe the new resulting state.

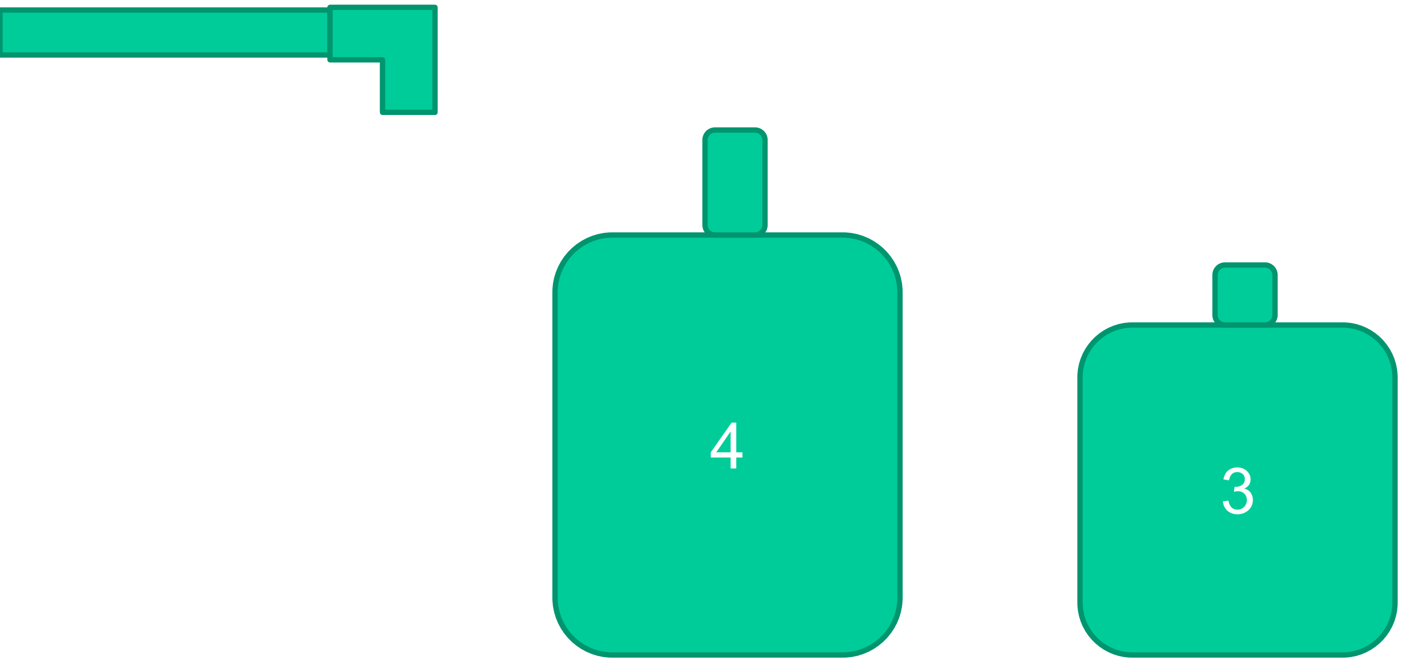
State Space Search

Problem solving = Searching for a goal state

State Space Search: Playing Chess

- State space is a set of legal positions.
- Starting at the initial state.
- Using the set of rules to move from one state to another.
- Attempting to end up in a goal state.

Water Jug Problem



State Space Search: Water Jug Problem

"You are given two jugs, a 4-litre one and a 3-litre one. Neither has any measuring markers on it. There is a pump that can be used to fill the jugs with water. How can you get exactly 2 litres of water into 4-litre jug."

State Space Search: Water Jug Problem

- State: (x, y)

  x = 0, 1, 2, 3, or 4 y = 0, 1, 2, 3

- Start state: (0, 0).
- Goal state: (2, 0)
- Attempting to end up in a goal state.

State Space Search: Water Jug Problem

1. current state = (0, 0)
2. Loop until reaching the goal state (2, 0)
   - Apply a rule whose left side matches the current state
   - Set the new current state to be the resulting state

(0, 0)
(0, 3)
(3, 0)
(3, 3)
(4, 2)
(0, 2)
(2, 0)

State Space Search: Summary

1. Define a state space that contains all the possible configurations of the relevant objects.
2. Specify the initial states.
3. Specify the goal states.
4. Specify a set of rules:
   - What are unstated assumptions?
   - How general should the rules be?
   - How much knowledge for solutions should be in the rules?

Solve this now…

Farmer Cabbage Goat Wolf


FCGW

Search Strategies

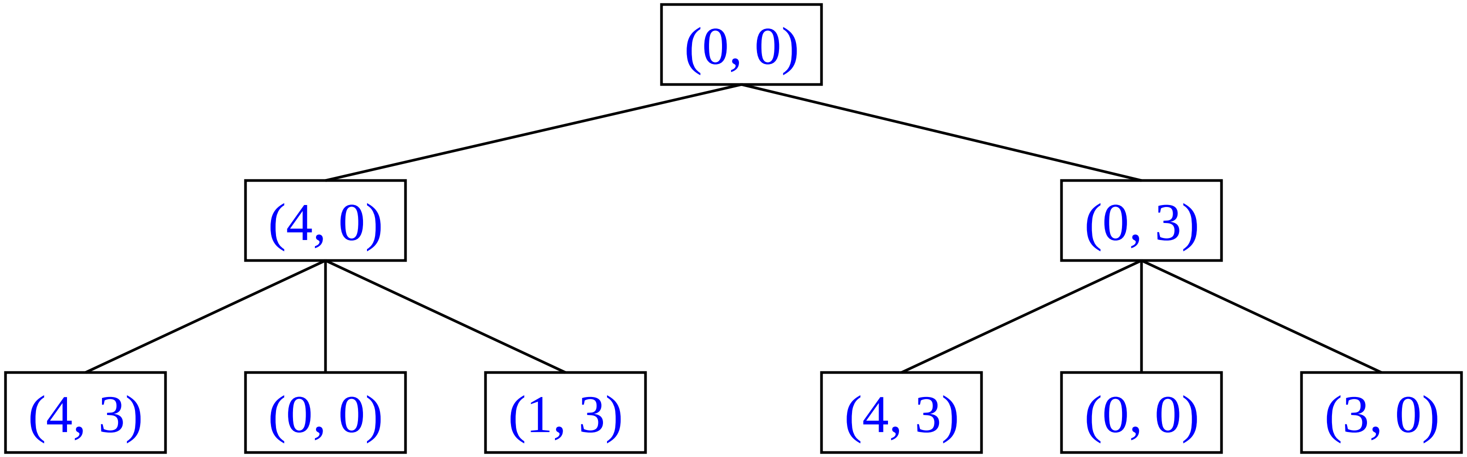
1. Uninformed search (blind search)

   Having no information about the number of steps from the current state to the goal.

2. Informed search (heuristic search)

   More efficient than uninformed search.

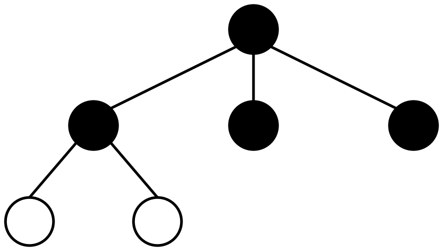
Search Strategies



Search Strategies: Blind Search

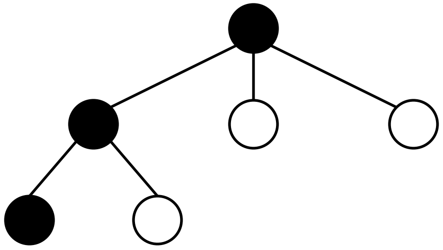
- Breadth-first search

  Expand all the nodes of one level first.



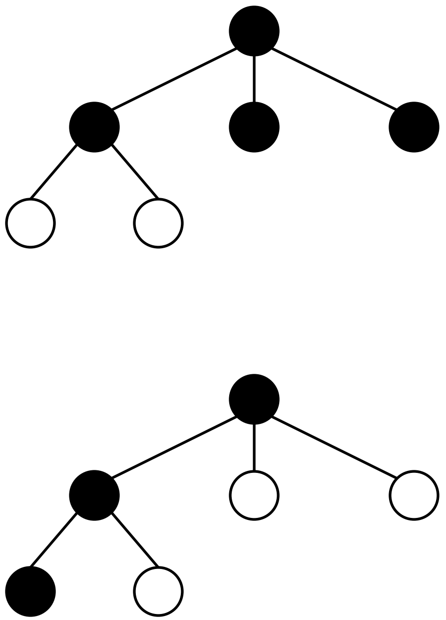
- Depth-first search

  Expand one of the nodes at the deepest level.



Search Strategies: Blind Search

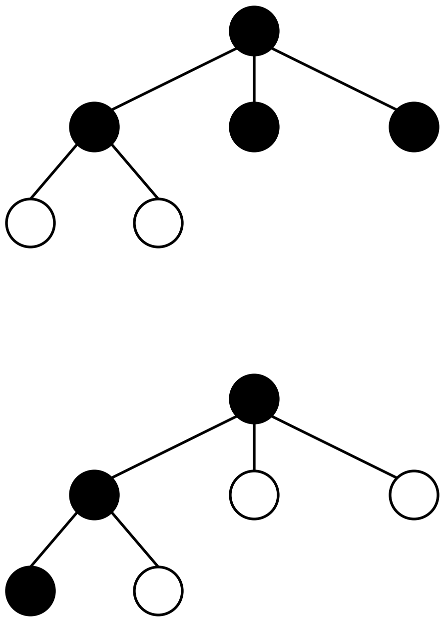
Criterion	Breadth-First	Depth-First
Time		
Space		
Optimal?		
Complete?		



b: branching factor d: solution depth m: maximum depth

Search Strategies: Blind Search

Criterion	Breadth-First	Depth-First
Time	b^d	b^m
Space	b^d	bm
Optimal?	Yes	No
Complete?	Yes	No



b: branching factor d: solution depth m: maximum depth

Daughter & Dad Story

Search Strategies: Heuristic Search

- Heuristic: involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and-error methods.

- Heuristic technique improves the efficiency of a search process, possibly by sacrificing claims of completeness or optimality.

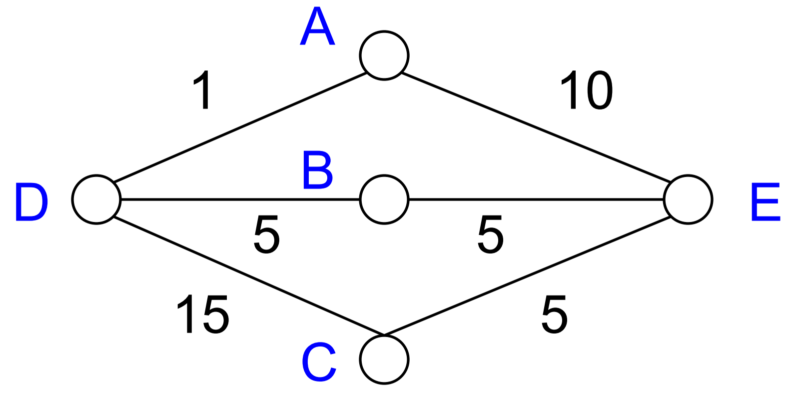
Search Strategies: Heuristic Search

- Heuristic is for combinatorial explosion.
- Optimal solutions are rarely needed.

Search Strategies: Heuristic Search

The Travelling Salesman Problem

"A salesman has a list of cities, each of which he must visit exactly once. There are direct roads between each pair of cities on the list. Find the route the salesman should follow for the shortest possible round trip that both starts and finishes at any one of the cities."



Search Strategies: Heuristic Search

Nearest neighbour heuristic:

1. Select a starting city.
2. Select the one closest to the current city.
3. Repeat step 2 until all cities have been visited.

Search Strategies: Heuristic Search

Nearest neighbour heuristic:

1. Select a starting city.
2. Select the one closest to the current city.
3. Repeat step 2 until all cities have been visited.

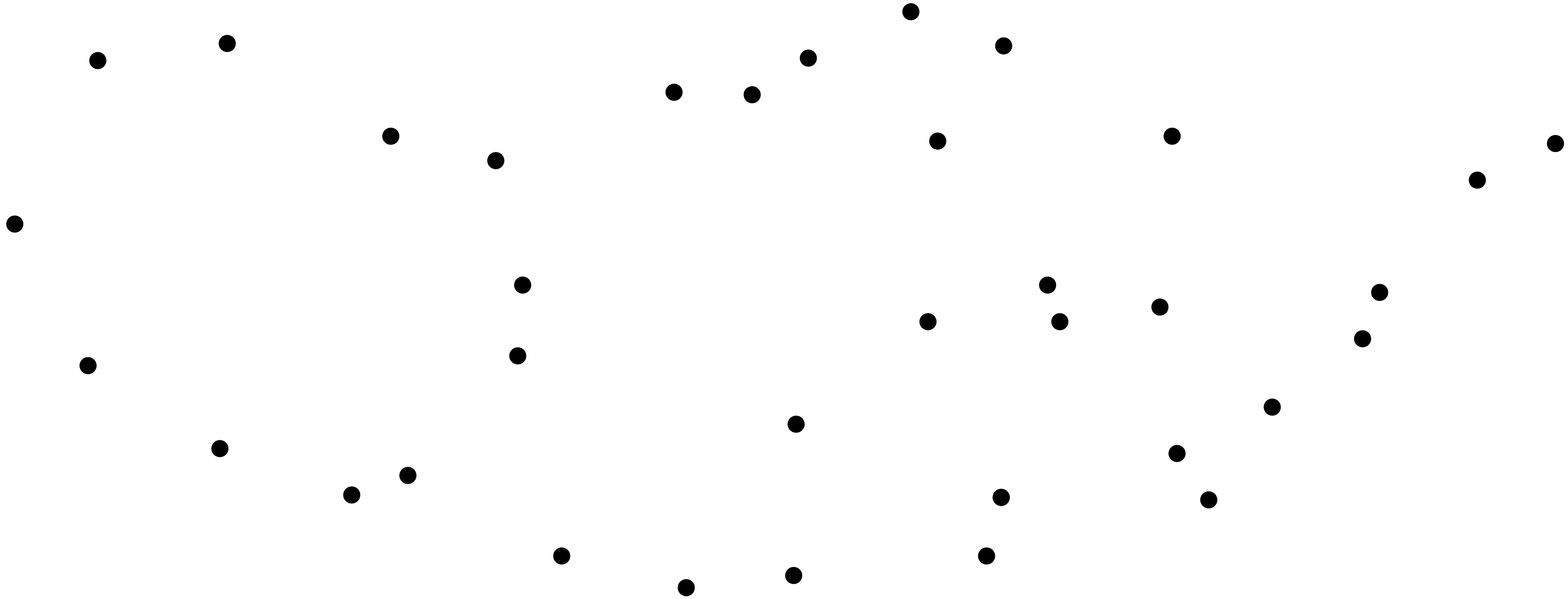
$O(n^2)$ vs. $O(n!)$

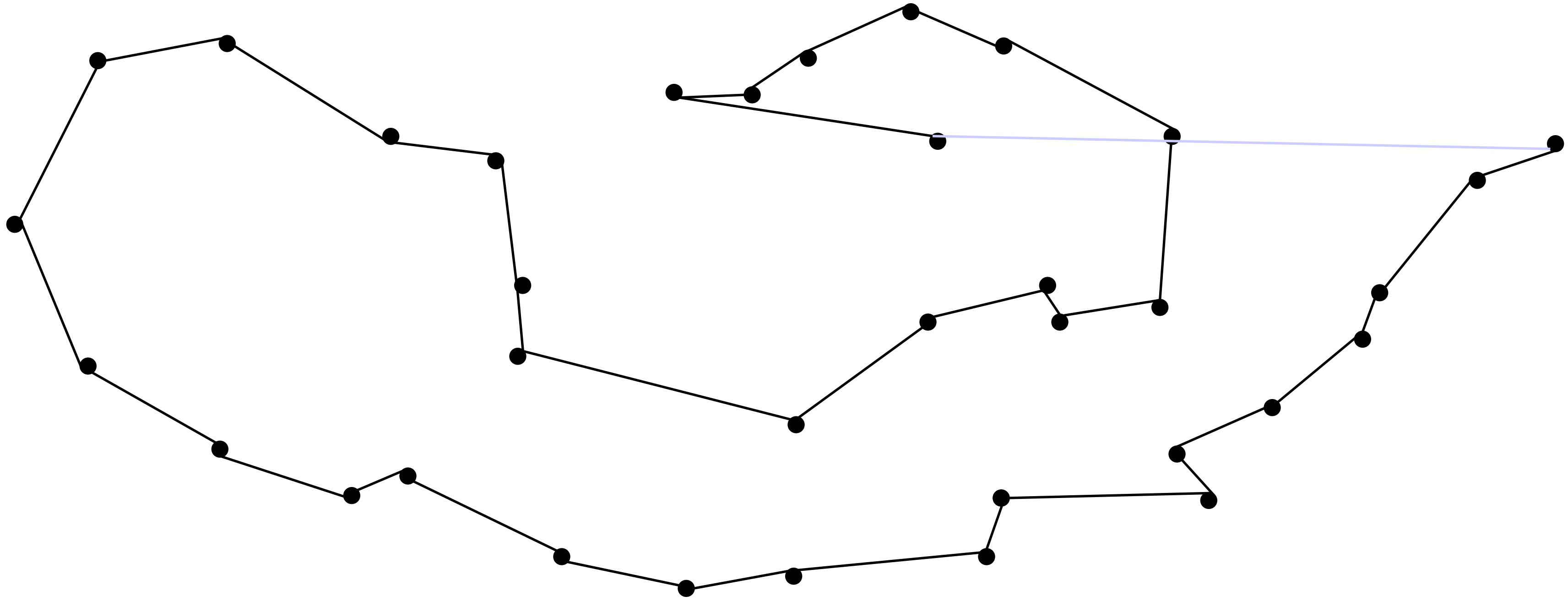
Search Strategies: Heuristic Search

- Heuristic function:

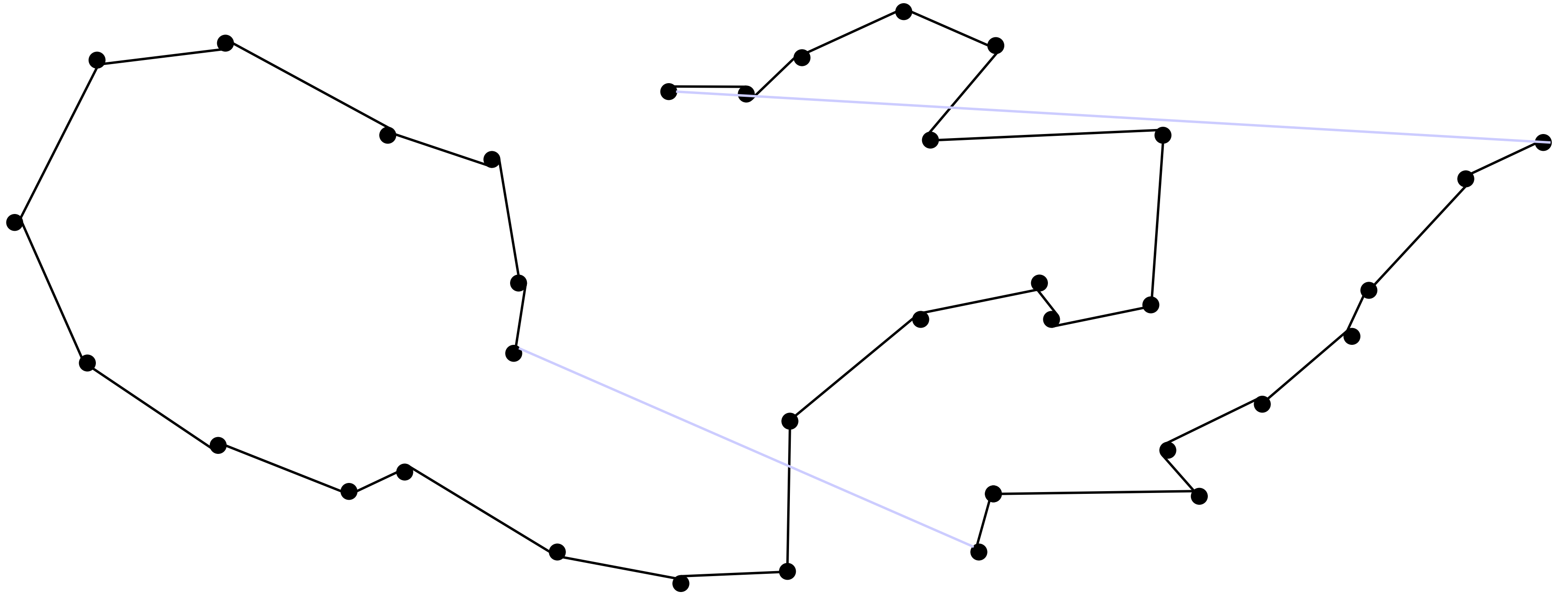
  state descriptions $\rightarrow$ measures of desirability

Building a new TS tour from scratch

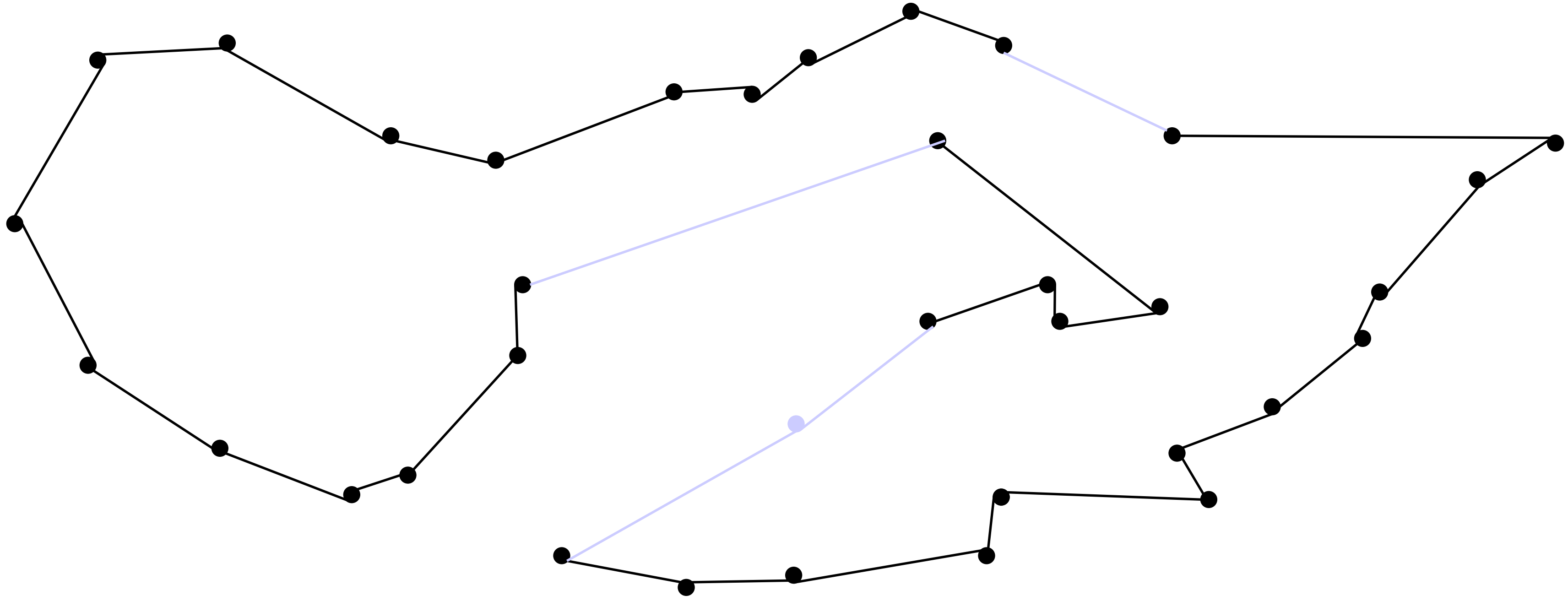




Nearest Neighbor heuristic (greedy, order dependent, some neighbors not so near)



A different greedy, multi-fragments heuristic



Savings heuristic

Heuristics

- Mean distance to the optimum
  - Savings: 11%
  - Multi-fragments: 12%
  - Nearest Neighbor: 26%

Is the problem decomposable?

- Can the problem be broken down to smaller problems to be solved independently?

- Decomposable problem can be solved easily.

Is the problem decomposable?

- $\int(x^2 + 3x + \sin^2x.\cos^2x)dx$
  - $\int x^2dx$
  - $\int 3xdx$
  - $\int \sin^2x.\cos^2xdx$
    - $\int(1 - \cos^2x)\cos^2xdx$
      - $\int \cos^2xdx$
      - $-\int \cos^4xdx$

Can solution steps be ignored or undone?

Theorem Proving

A lemma that has been proved can be ignored for next steps.

Ignorable!

Can solution steps be ignored or undone?

The 8-Puzzle

2	8	3
1	6	4
7		5

➡

1	2	3
8		4
7	6	5

Moves can be undone and backtracked.

Recoverable!

Can solution steps be ignored or undone?

Playing Chess

Moves cannot be retracted.

Irrecoverable!

Can solution steps be ignored or undone?

- Ignorable problems can be solved using a simple control structure that never backtracks.
- Recoverable problems can be solved using backtracking.
- Irrecoverable problems can be solved by recoverable style methods via planning.

Is the universe predictable?

The 8-Puzzle

Every time we make a move, we know exactly what will happen.

Certain outcome!

Is the universe predictable?

Playing Bridge

We cannot know exactly where all the cards are or what the other players will do on their turns.

Uncertain outcome!

Is the universe predictable?

- For certain-outcome problems, planning can used to generate a sequence of operators that is guaranteed to lead to a solution.
- For uncertain-outcome problems, a sequence of generated operators can only have a good probability of leading to a solution.

  Plan revision is made as the plan is carried out and the necessary feedback is provided.

Is a good solution absolute or relative?

The Travelling Salesman Problem

We have to try all paths to find the shortest one.

Is the solution a state or a path?

The Water Jug Problem

The path that leads to the goal must be reported.

Is the solution a state or a path?

- A path-solution problem can be reformulated as a state-solution problem by describing a state as a partial path to a solution.

- The question is whether that is natural or not.

What is the role of knowledge

Playing Chess
Knowledge is important only to constrain the search for a solution.

Reading Newspaper
Knowledge is required even to be able to recognize a solution.

Does the task require human-interaction?

- Solitary problem, in which there is no intermediate communication and no demand for an explanation of the reasoning process.
- Conversational problem, in which intermediate communication is to provide either additional assistance to the computer or additional information to the user.

Problem Characteristics

To choose an appropriate method for a particular problem:

- Is the problem decomposable?
- Can solution steps be ignored or undone?
- Is the universe predictable?
- Is a good solution absolute or relative?
- Is the solution a state or a path?
- What is the role of knowledge?
- Does the task require human-interaction?

Today Task

Given:

1. a five gallon jug
2. a seven gallon jug
3. a way to fill up the jugs
4. a way to pour out water

End up with:

exactly 1 gallon of water in one of the jugs.

Today Task

Given:

1. a five gallon jug
2. a seven gallon jug
3. a way to fill up the jugs
4. a way to pour out water

End up with:

exactly 1 gallon of water in one of the jugs.