Introduction to Stochastic Search

Simulated annealing

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Today

When search spaces are too big, or undiscovered, what to do?

Recap

Looking to the origins: British Museum search

Types of search

Side story: Waddington’s canalisation

Stochastic search

Simulated annealing

The travelling salesman problem

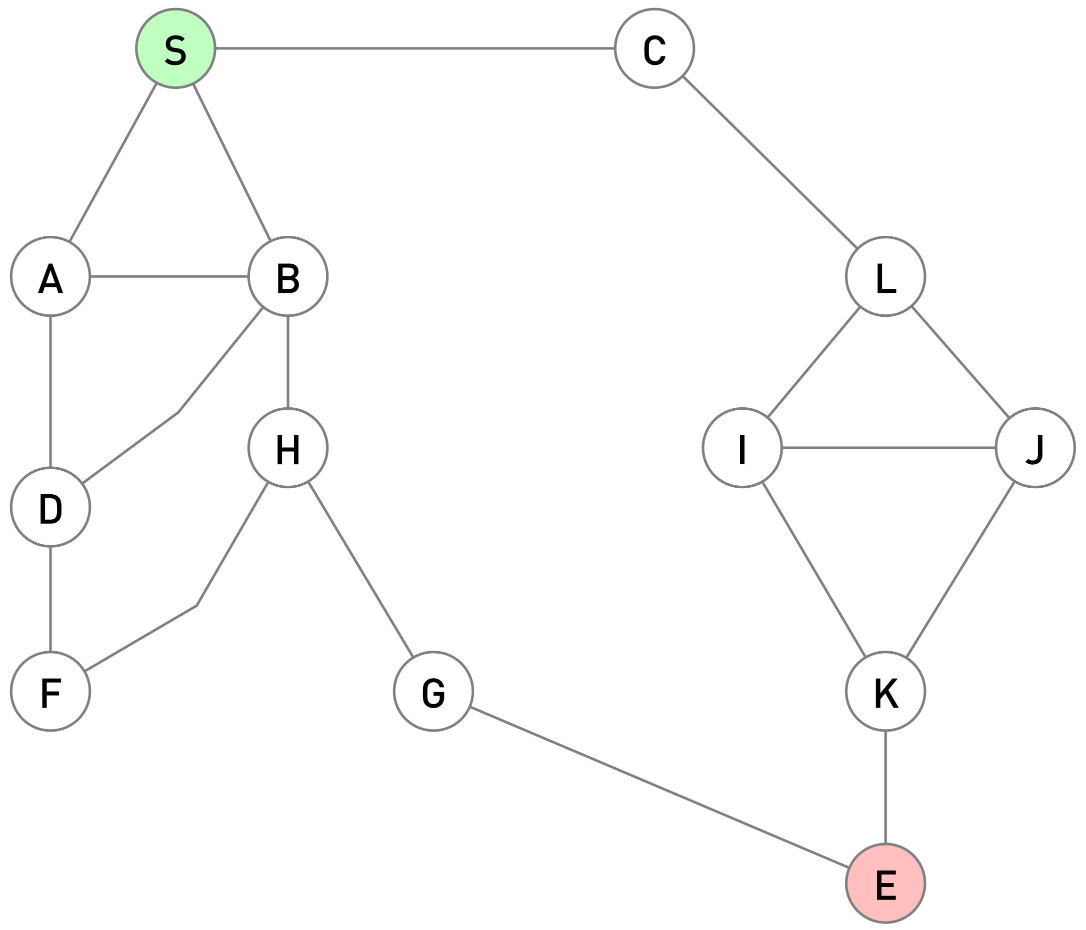
Recap

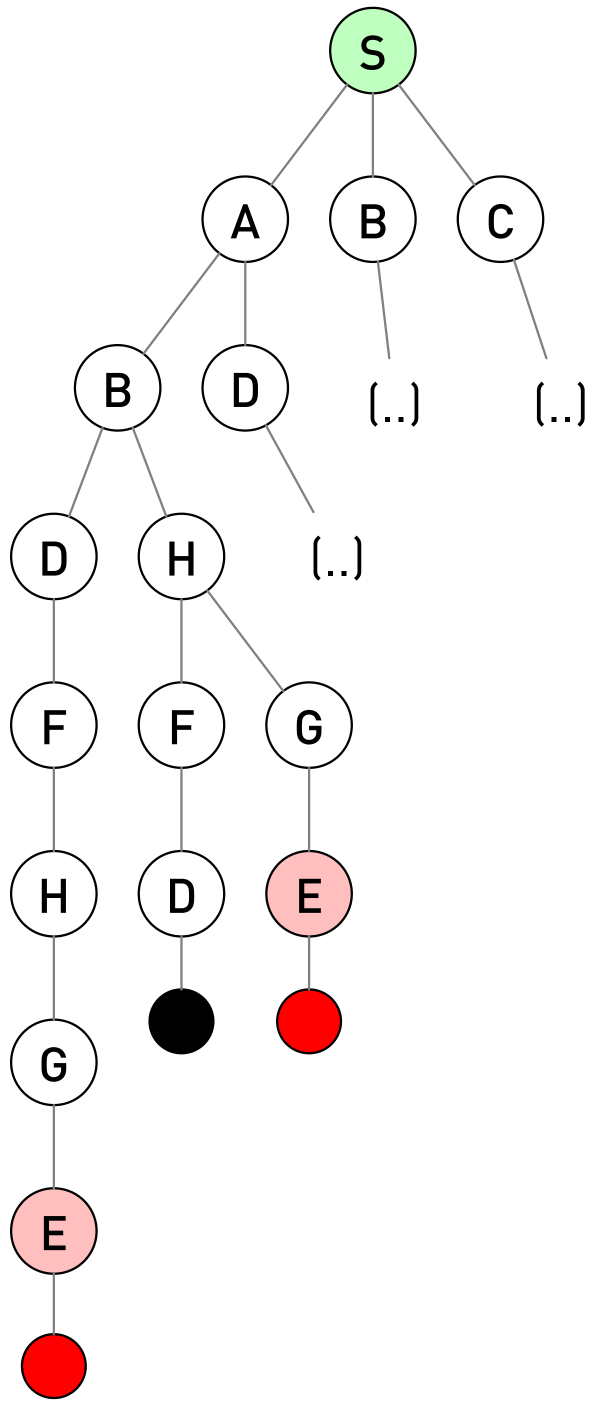
Uninformed and Informed Search

- States (nodes) + Actions (links) => **Search Graph** 🥰 Representation is so important!
- Want to **find a goal state** from an **initial state**
- This is easy by hand on small problems, but **hard for things like chess** and genetics
- **How can we make search be smart** when we have no information?
- **How stupid is our search** when we have no information?
- Before DFS and BFS, the British Museum (as you will play with in the practical)
- Poll time (if polling available)

Recap

Before DFS and BFS: The British Museum





- Just expand all paths from the start
- This quickly becomes impractical but it is a good tool to think with!
- What do we gain with DFS and BFS over British Museum?
- What do we gain with Dijkstra over Uninformed search?
- What do we gain with A* over Dijkstra?
- What is A* with all heuristic values set to zero?
- What makes search hard?

Different search situations

There are different contexts, different search problems

- Deterministic, fully observable
  - Search agent always knows what state it is, and can expand (often offline)
- Non-deterministic, partially observable
  - Search may be in a set of states, future is probabilistic. Follow a policy (offline/online)
- Unknown search space
  - Search agent always knows what state it is, and can expand but locally (online)
  - It may also be that there is a search space but it is too large to generate a graph for it

Side story, but not really

Conrad Waddington and canalisation in genetics

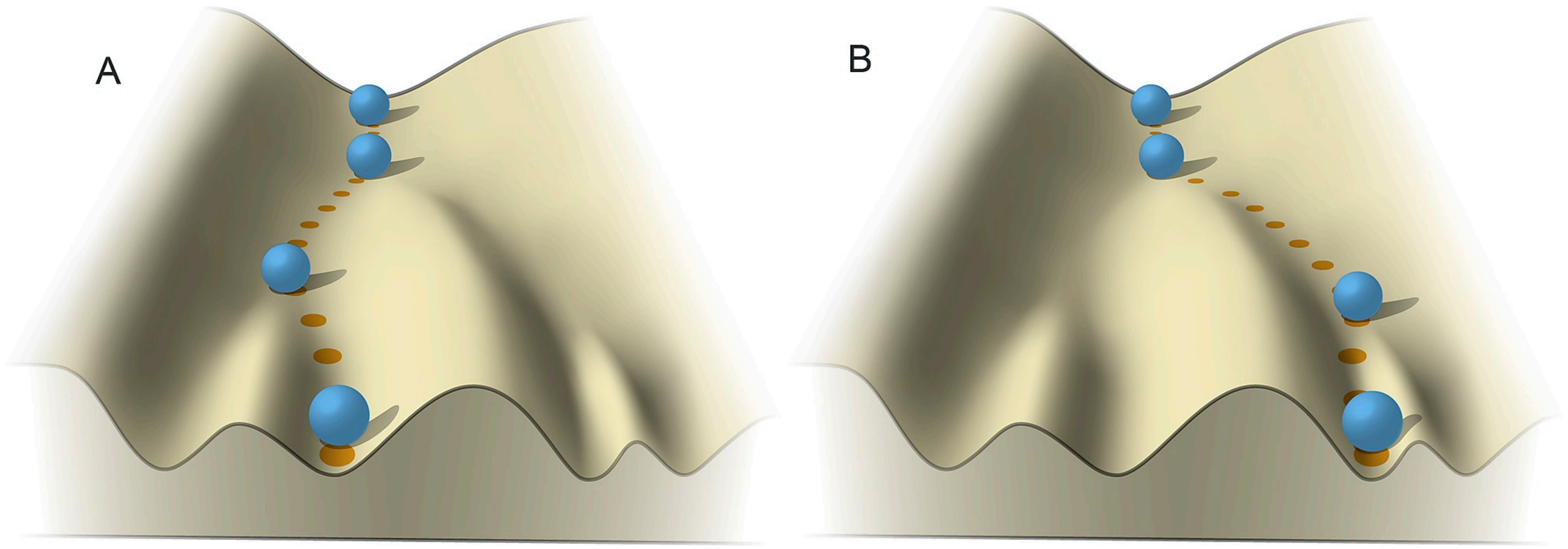
- **Conrad Waddington was born on November 8th, 1905, died in 1975**
- **British Developmental Biologist**
- **Father of a whole scientific field called Epigenetics**

> We are part of nature, and our mind is the only instrument we have, or can conceive of, for learning about nature or about ourselves.
>
> **Conrad Waddington**

Epigenetic Canalisation

How do cells decide be nail cells, neurones or hair?

- Our genetic program, the DNA, is complex
- There are many changes, variability inside and outside. Yet we keep our forms. Why?



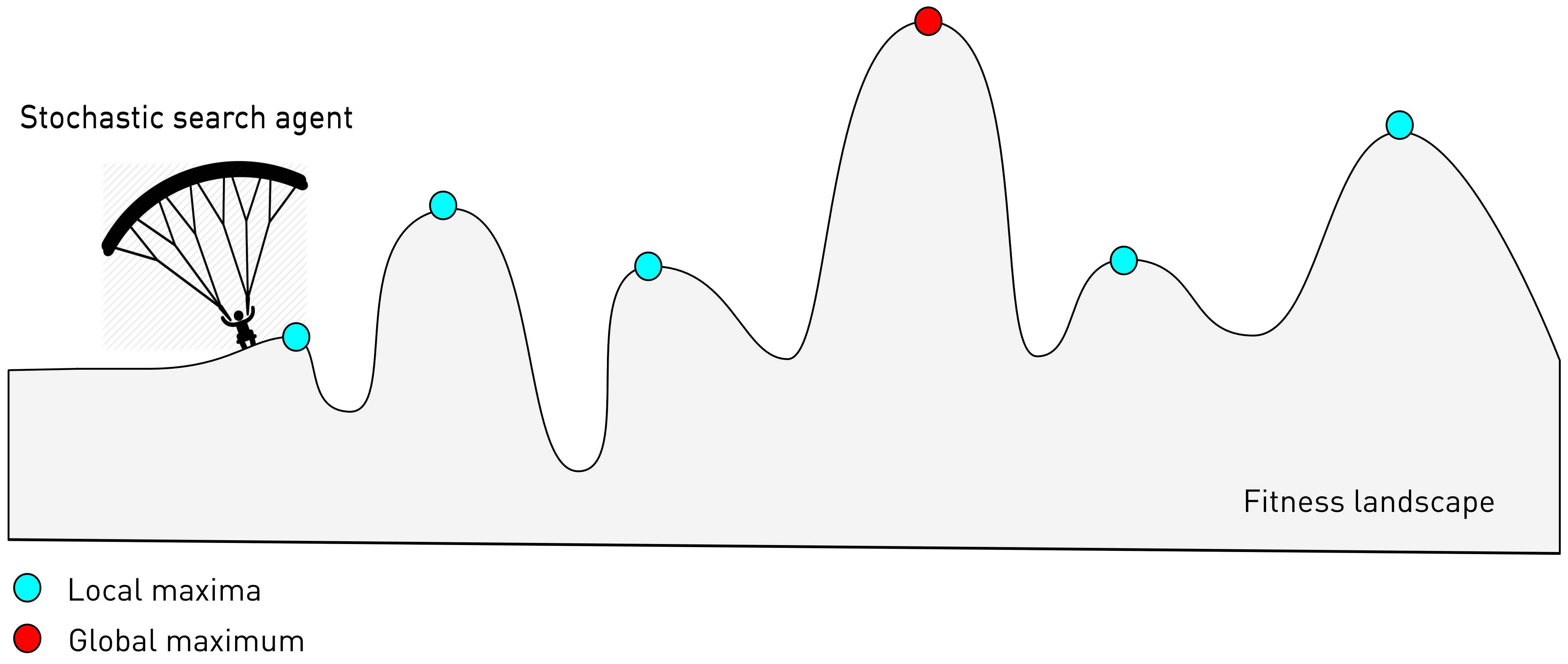
Wildtype Mutation

I will try to convince you that natural evolution is similar to a search algorithm

Stochastic Search

Simulated Annealing

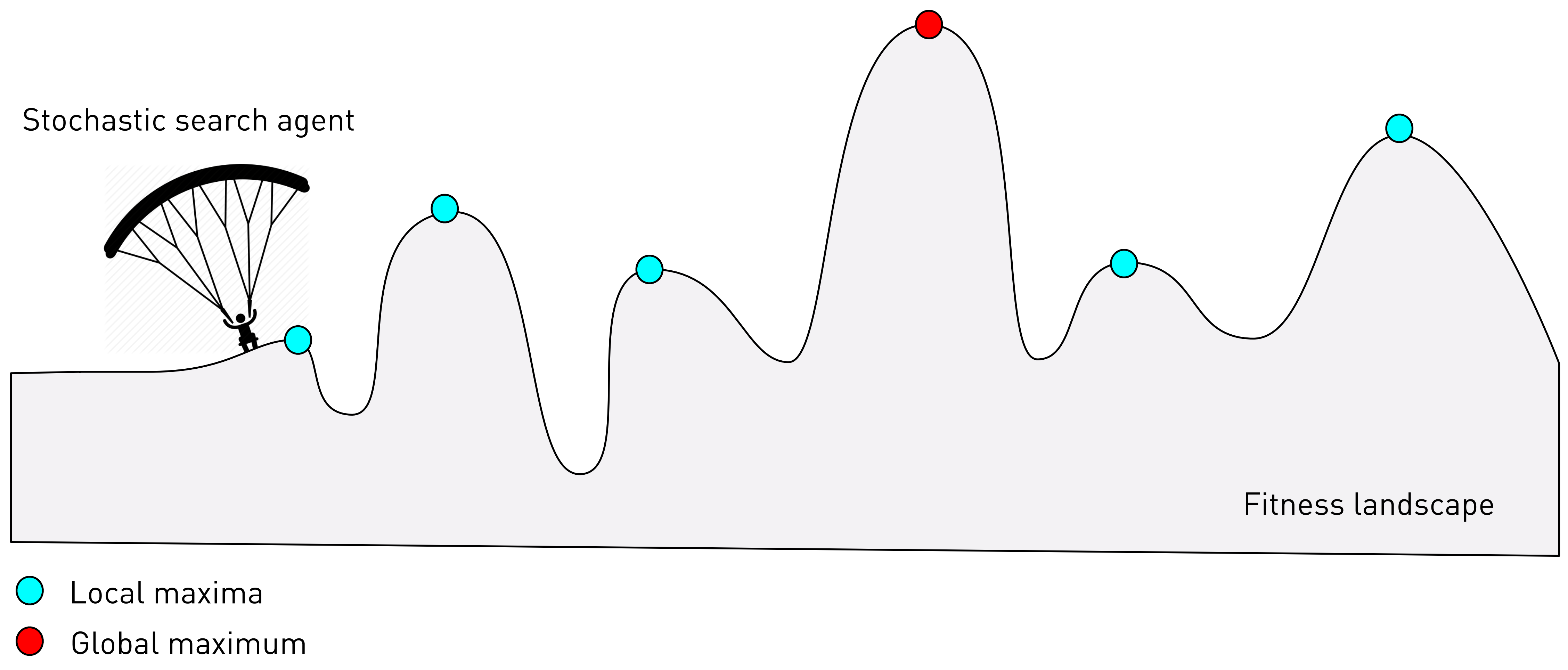
- We don’t have a search space anymore, imagine the parachuter in Mars situation
- The parachuter needs to get to the highest peak (how is this different from canalisation?)
- What to do?
  - Move around one step in every direction
  - Determine direction of highest neighbouring step
  - Move in that direction, repeat.



Stochastic Search

Simulated Annealing

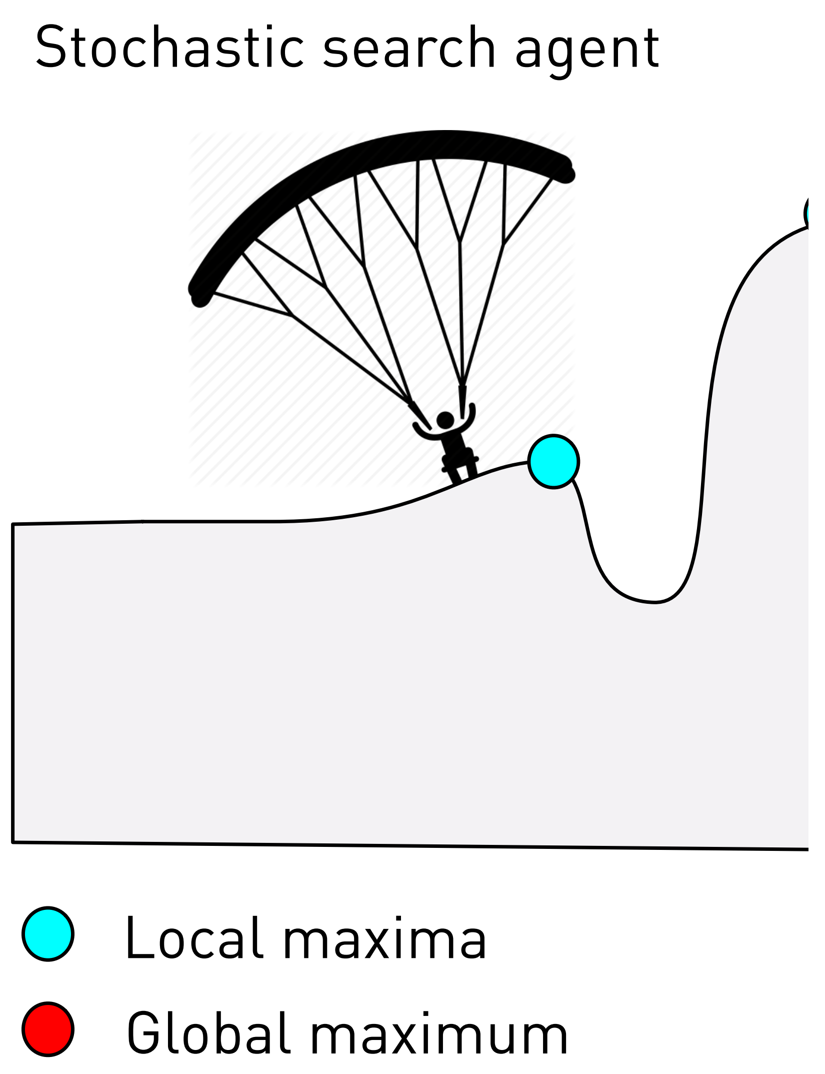
- What happens when agent gets to the first local maximum?
- All steps lead to lower ground, agent can’t choose where to go and stays stuck
- How can we get our agent moving again?
  - Introduce a new parameter T, which is a probability of taking a step to lower ground
  - Set T to a higher value first, and decrease it by a factor *alpha* as the search space is explored
  - How does T work?



Stochastic Search

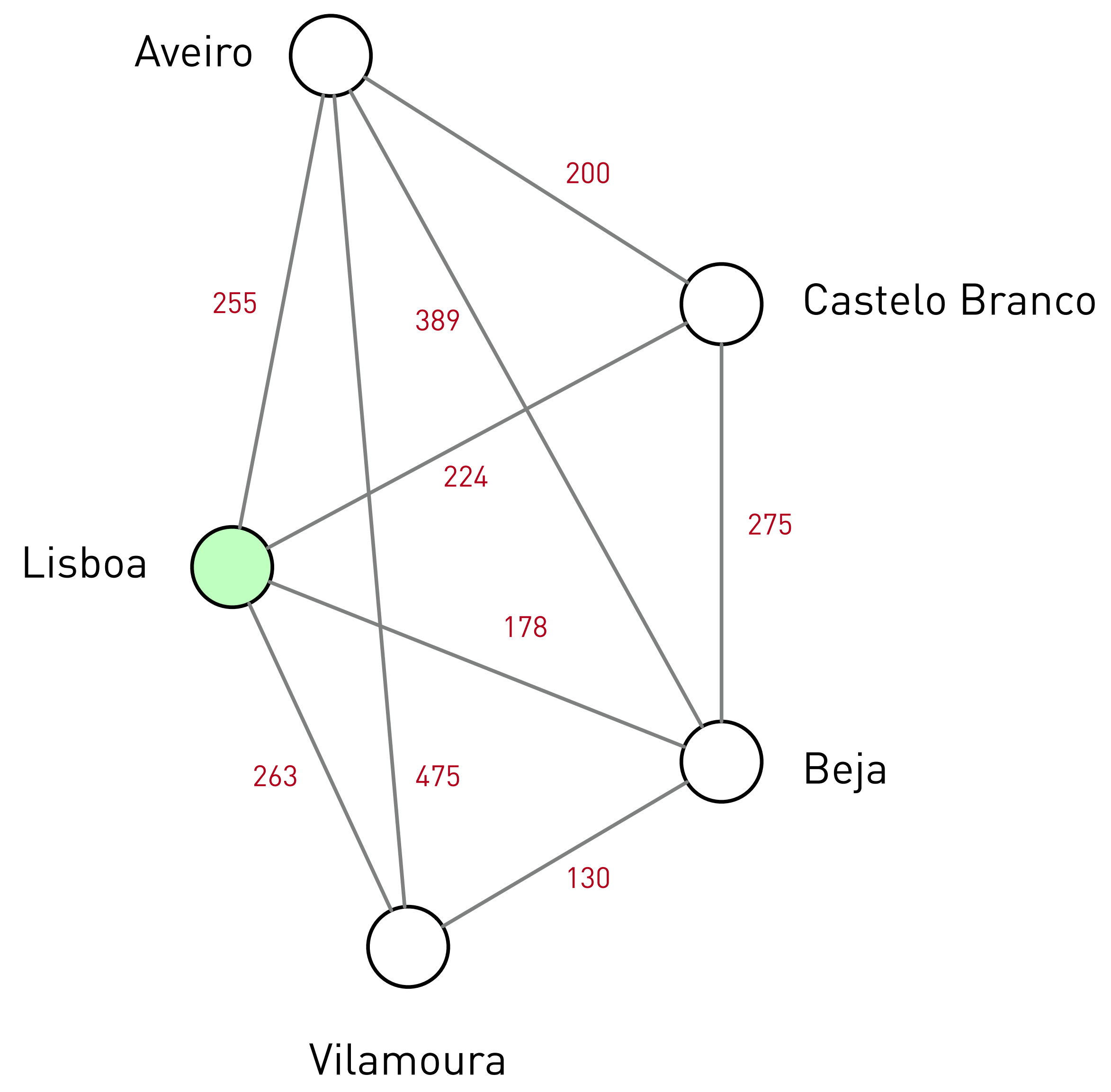
Basic explanation of how T works

- Imagine that agent is at a local maximum, stuck. And $T = 0.15$
- I draw a random real between 0 and 1, and get 0.2 since $0.2 > 0.15$ agent stays stuck
- I draw a random real again. This time I get 0.035 (smaller than T): agent picks a worse move
- We will look at this in more detail in our next lecture



The Travelling Salesman Problem (TSP)

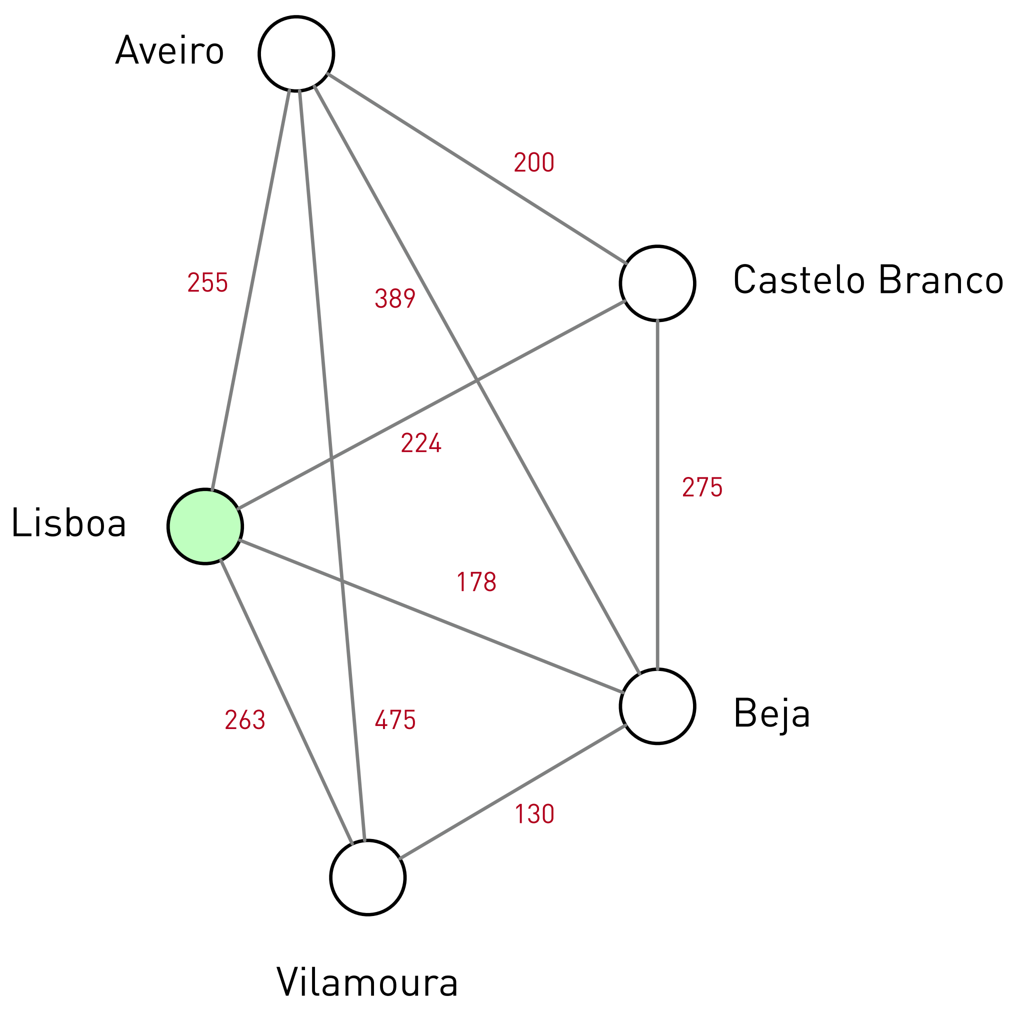
- One of the most studied problems in Computer Science
- We start with a search graph of cities interconnected with distances between them
- We want to find the shortest possible route that visits every city only **once**
- Search must return to the starting point.
- How is this different from our past problems?
  - Init state = Goal State
  - Open paths cannot repeat nodes (we already studied this)
  - Problem is, as number of nodes and links grow it gets really hard
- Can we use DFS? BFS? Dijkstra? A*? Yes, but. Try it!

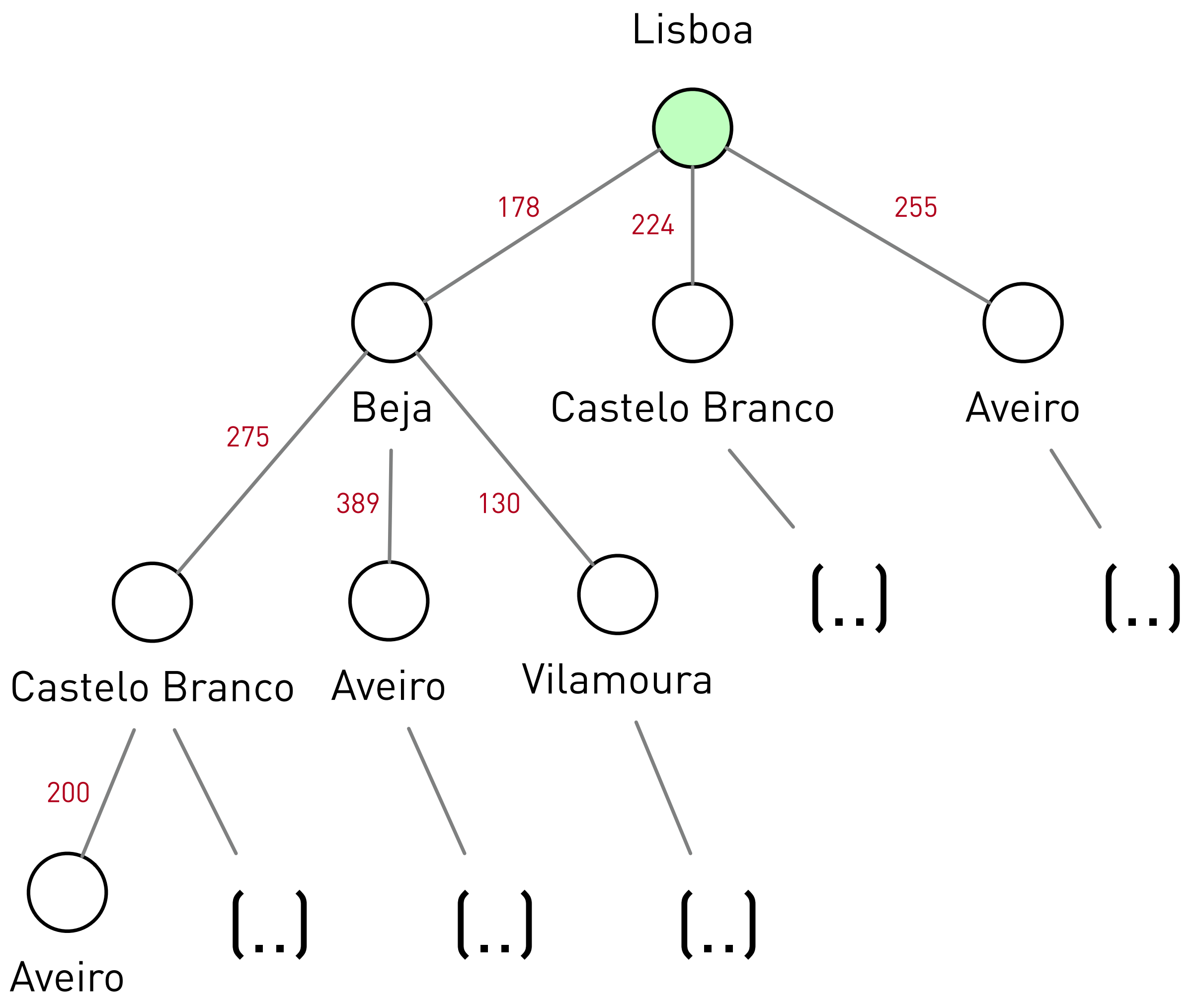


The Travelling Salesman Problem

Combinatorial explosion on the number of trajectories

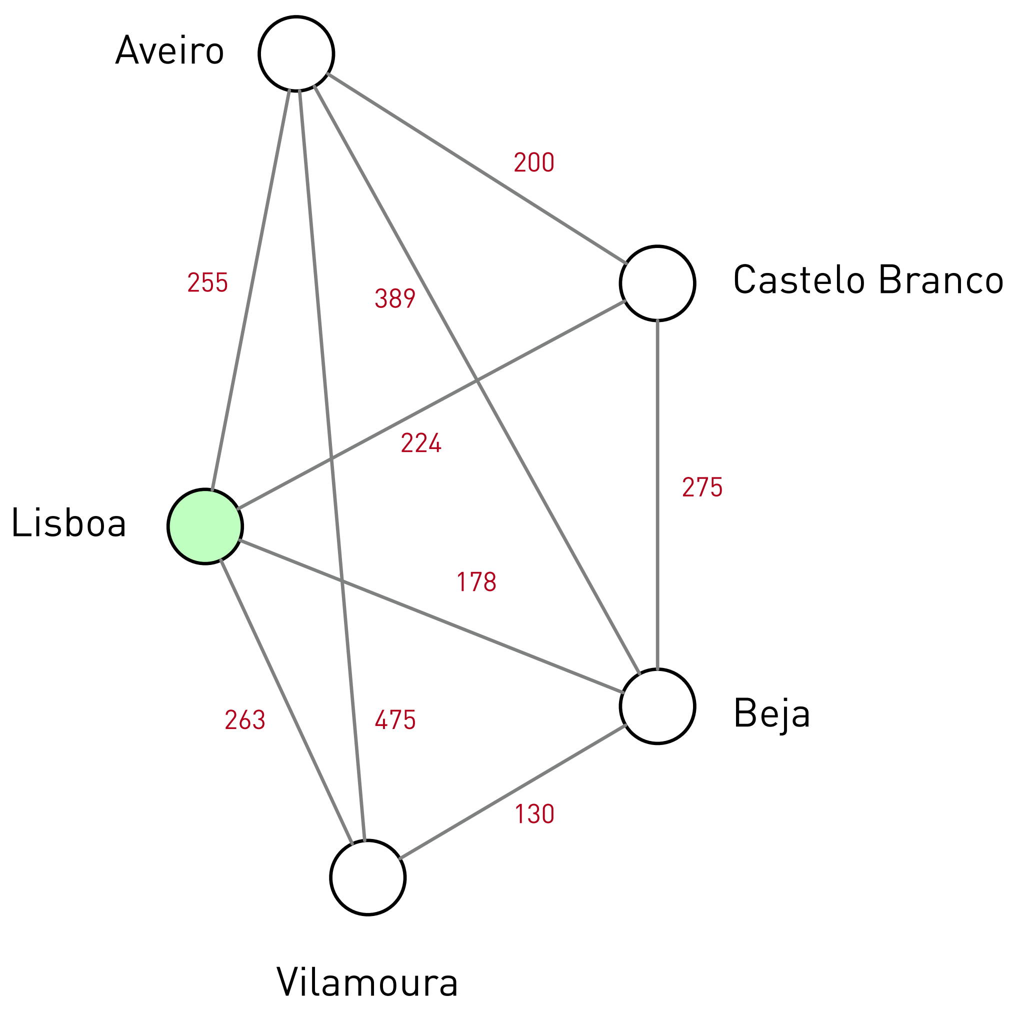
- Possible itineraries with n cities grow as n!
- If we have n = 30 cities
- 30! = 265,252,859,812,191,058,636,308,480,000,000





The Travelling Salesman Problem

Final notes, for now



- Think about search spaces and about the space of solutions to a given problem, like the TSP
- If the space of solutions becomes our search space, what do the links between these represent?