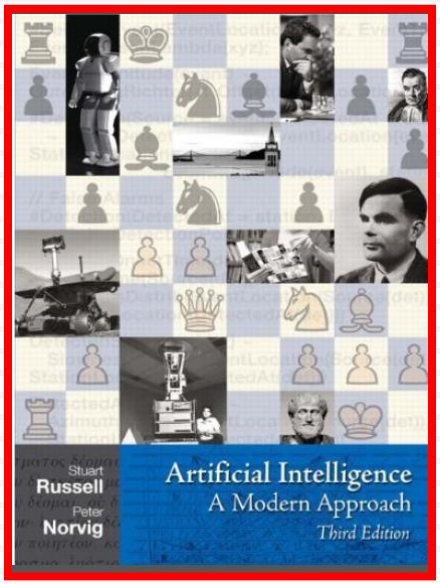
Princess Nora University
Faculty of Computer & Information Systems

ARTIFICIAL INTELLIGENCE

(CS 370D)

جامعة الأميرة نورة بنت عبد الرحمن
Princess Nora Bint Abdul Rahman University



College of Computer and Information Sciences

(CHAPTER-4)
BEYOND CLASSICAL SEARCH

LOCAL SEARCH STRATEGY

- Hill-Climbing Search.
- Simulated Annealing Search.
- Local Beam Search.
- Genetic Algorithms.

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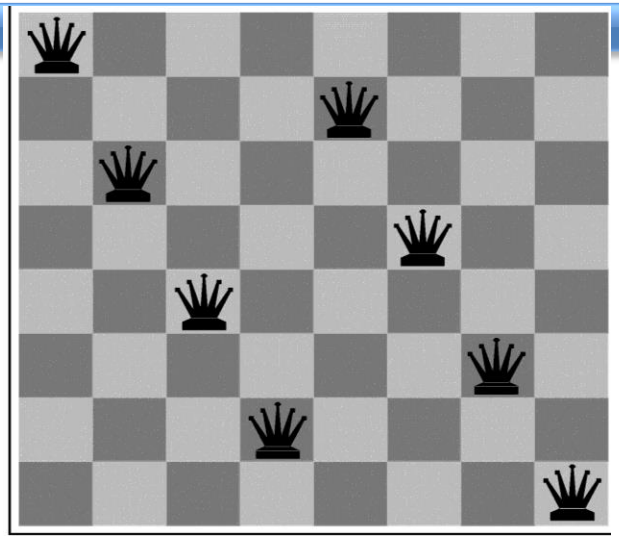
(course coordinator)

Classical search **versus** Local Search

Classical search	Local Search
1. Find solution in a systematic exploration of search space.	1. Find best state according to some objective function h(s). e.g., **n-queens**, h(s)= # of attacking queens.
2. The **path** to the goal is a **solution** to the problem.	2. the path to the goal is **irrelevant ; the goal state itself is the solution**.
3. Keeps one or more paths in memory.	3. Solution path needs not be maintained.
4. Records which alternatives have been explored at each point along the path.	4. record a **single "current"** state, and move to neighboring states in order to try **improve** it.

Example: n-queens

- Put n queens on an n × n board with no two queens on the same row, column, or diagonal.



- In the 8-queens problem, what matters is the final configuration of queens, not the order in which they are added.

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Local Search: Key Idea

Key idea:

1. Select (**random**) initial state (generate an initial guess).
2. Make local modification to improve current state (evaluate current state and move to other states).
3. Repeat Step 2 until goal state found (or out of time).

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Local Search: Key Idea

Advantages	Drawback:
➢ Use very little memory – usually a constant amount. ➢ Can often find reasonable solutions in large or infinite state spaces (e.g., continuous). For which systematic search is unsuitable.	➢ Local Search can get stuck in local maxima and not find the optimal solution.

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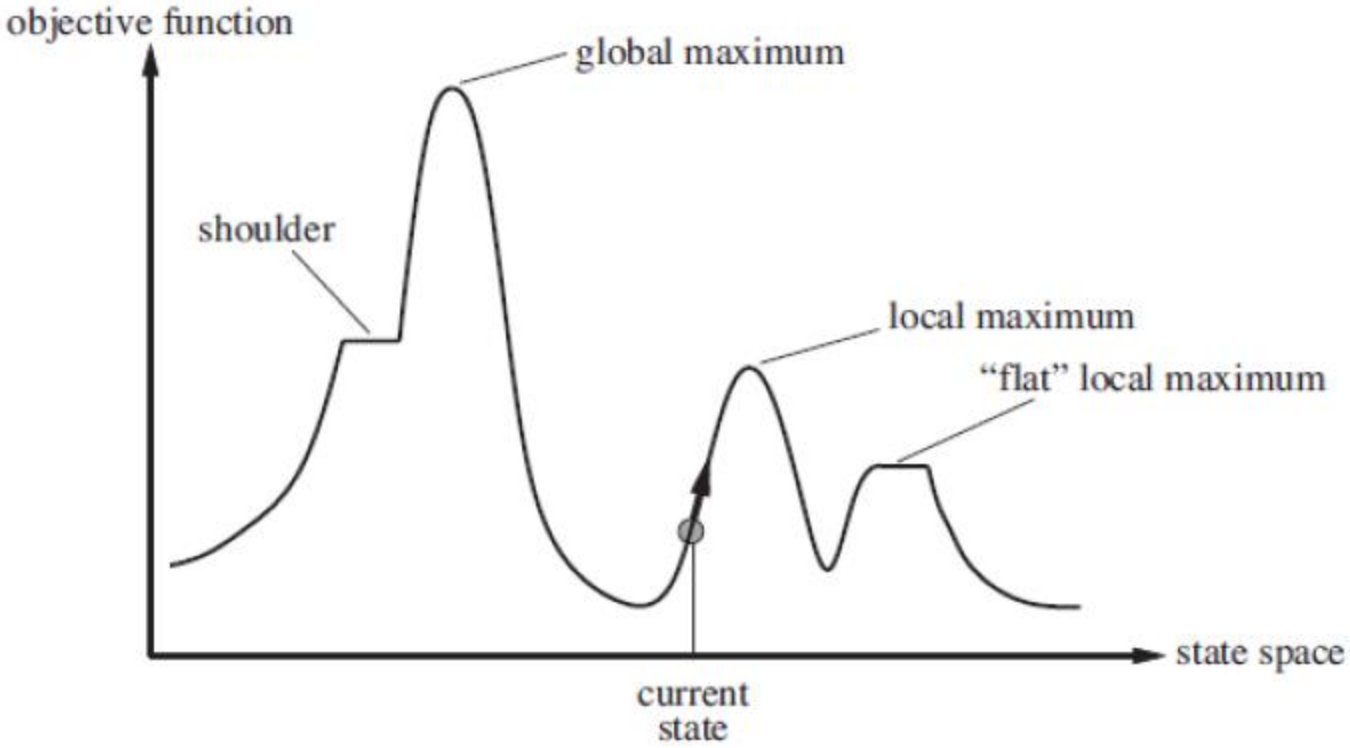
State Space Landscape

- A state space landscape: is a graph of states associated with their costs.



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Hill-Climbing Search

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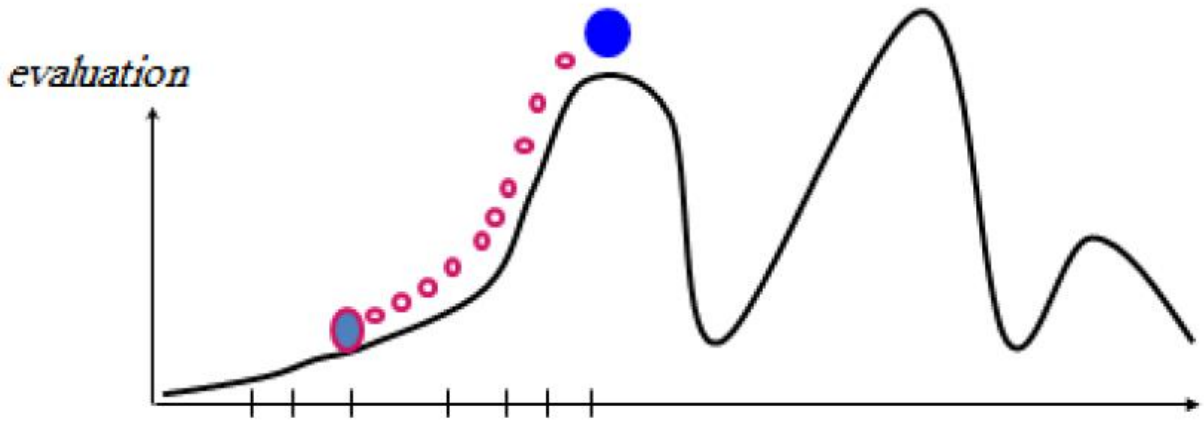
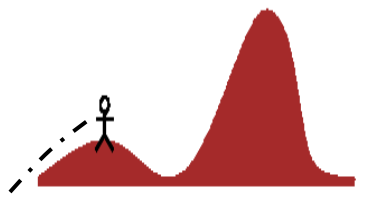
Hill-Climbing Search

- **Main Idea**: Keep a single current node and move to a neighboring state to improve it.
- Uses a loop that continuously moves in the direction of increasing value (**uphill**):
- Choose the best successor, choose randomly if there is more than one.
- Terminate when a peak reached where no neighbor has a higher value.
- It also called **greedy local search**, steepest ascent/descent.





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Hill-Climbing Search

```
function HILL-CLIMBING(problem) returns a state that is a local maximum
    inputs: problem, a problem
    local variables: current, a node
                     neighbor, a node

    current ← MAKE-NODE(INITIAL-STATE[problem])
    loop do
        neighbor ← a highest-valued successor of current
        if VALUE[neighbor] ≤ VALUE[current] then return STATE[current]
        current ← neighbor
```

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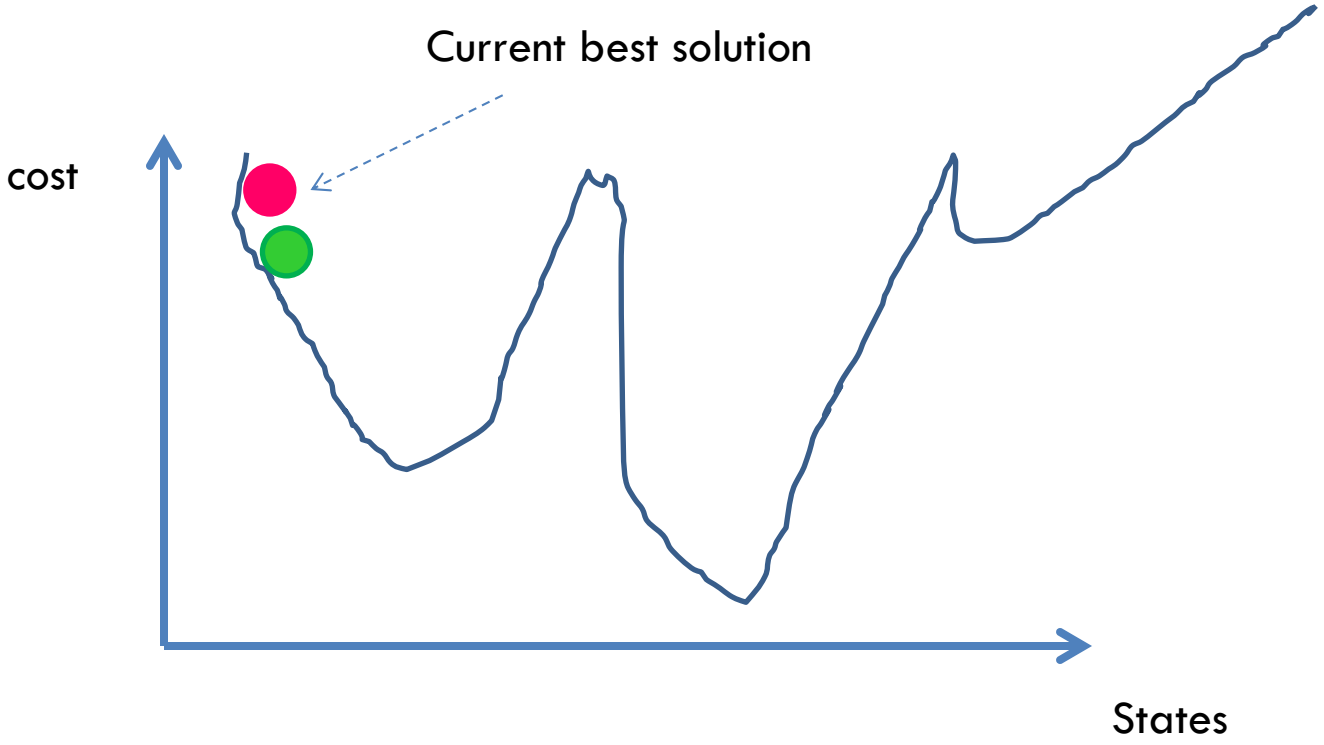
Hill-Climbing in Action …



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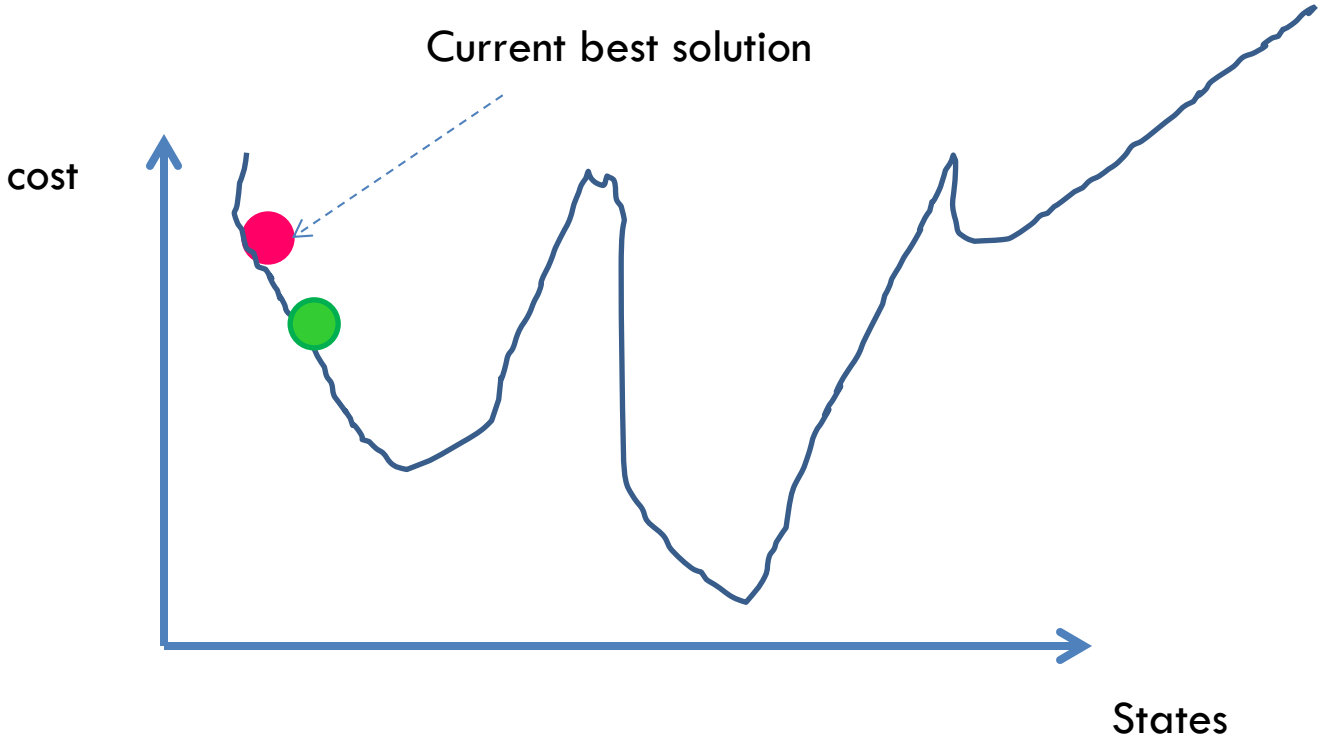
Hill-Climbing in Action …



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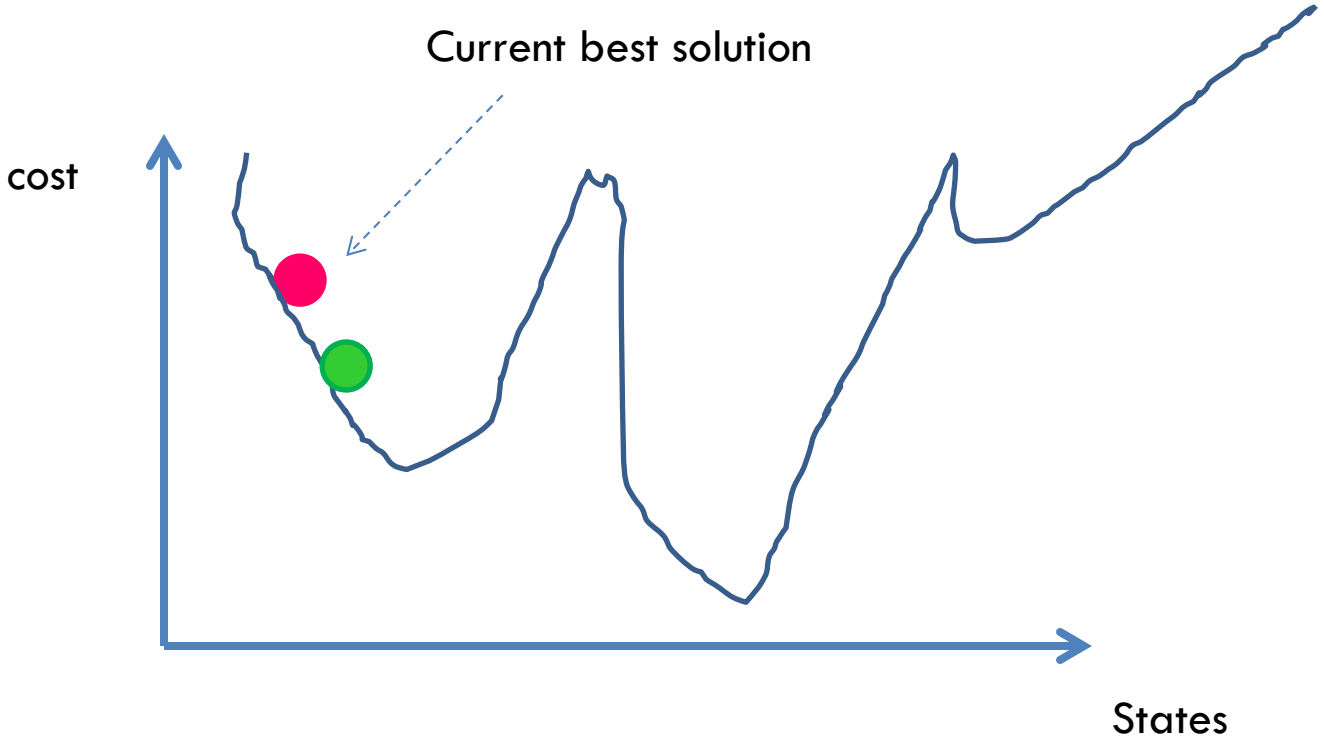

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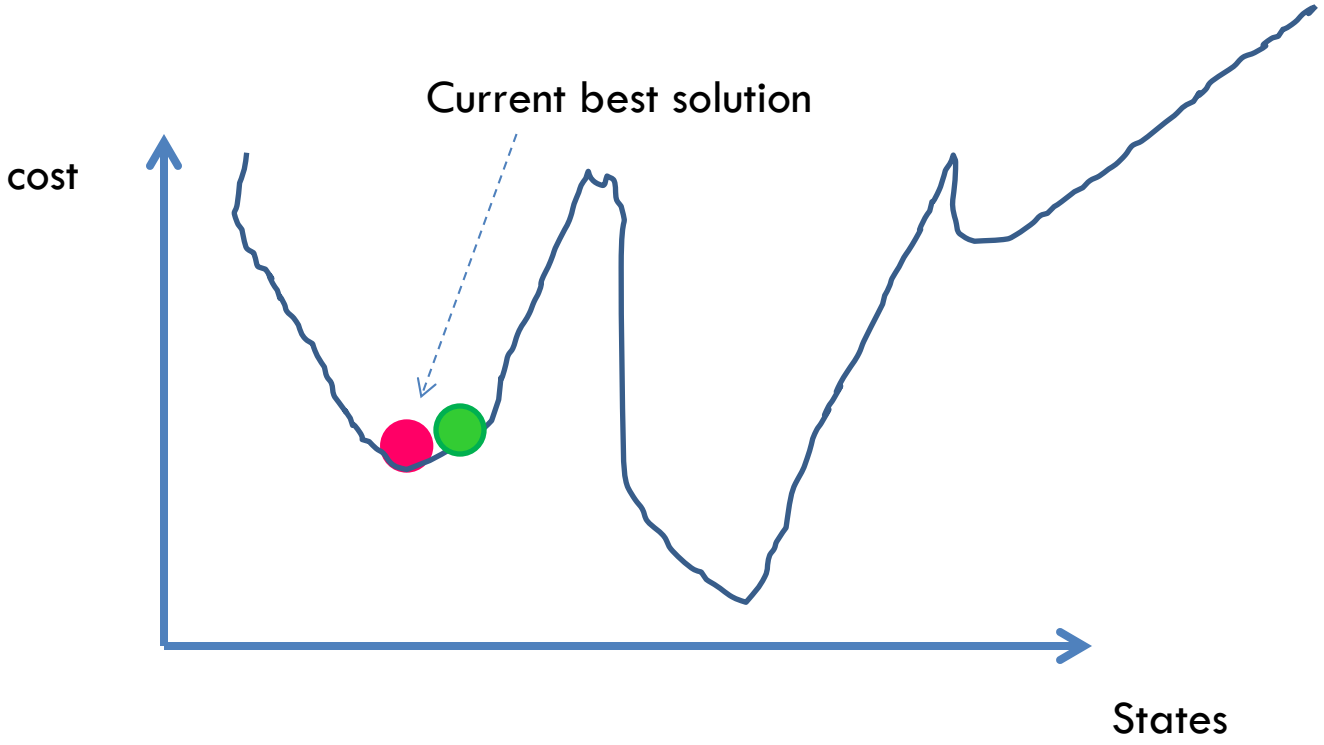
Hill-Climbing in Action …



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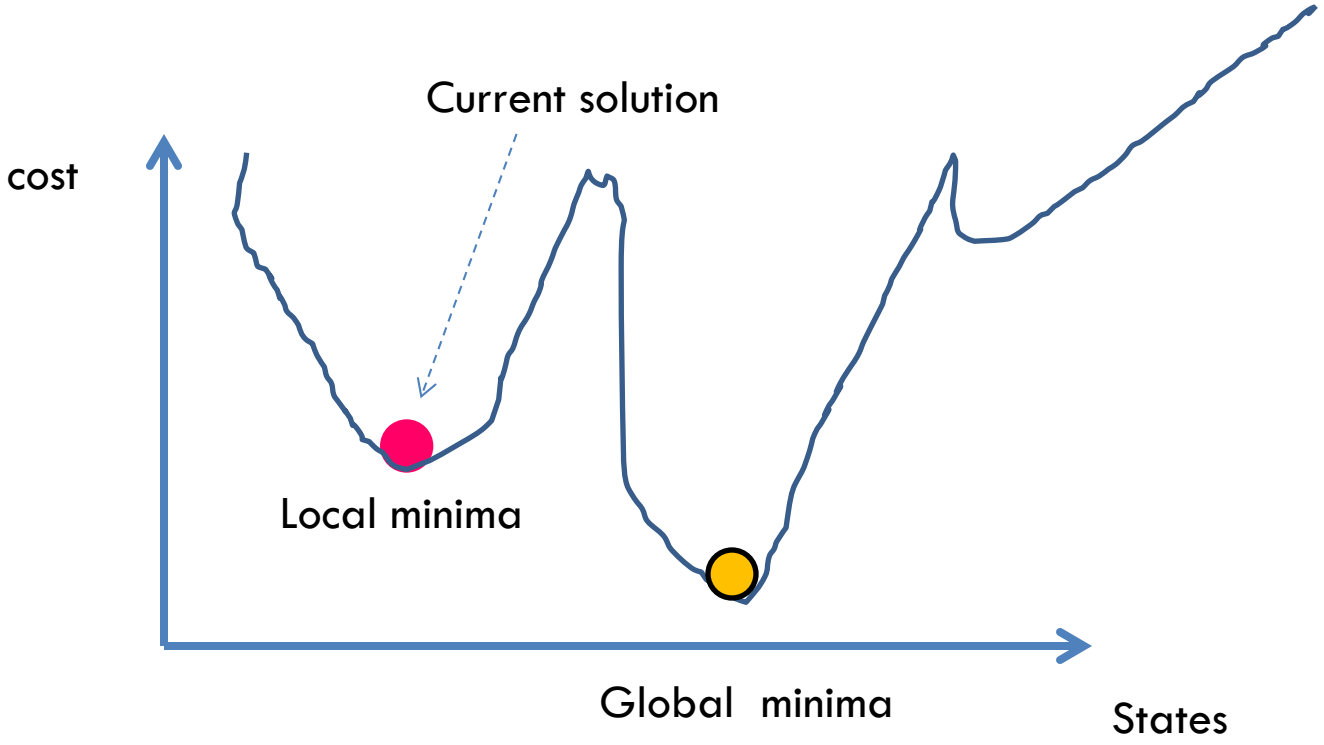
Hill-Climbing in Action …



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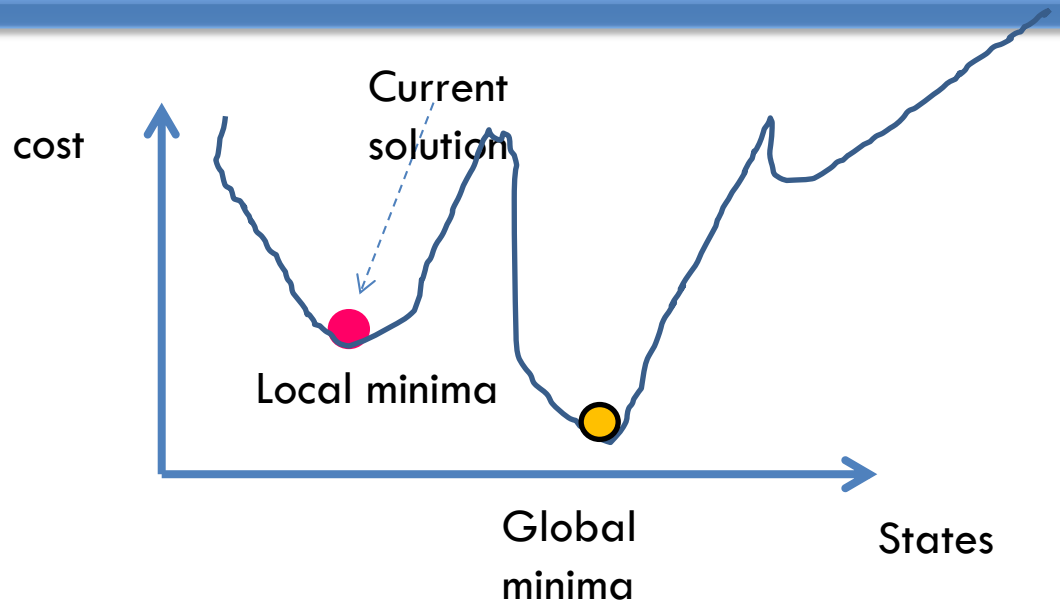
Hill-Climbing in Action …



Drawback: Depending on initial state, it can get stuck in local maxima/minimum or flat local maximum and not find the solution.

Cure: Random restart.

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Simulated Annealing Search

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The Problem

- Most minimization strategies find the *nearest* local minimum

- Standard strategy

  - ✓ Generate trial point based on current estimates
  - ✓ Evaluate function at proposed location
  - ✓ Accept new value if it improves solution

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The Solution

- We need a strategy to find other minima
- This means, we must sometimes select new points that do not improve solution
- How?

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Annealing

- One manner in which crystals are formed
- Gradual cooling of liquid …
  - ✓ At high temperatures, molecules move freely
  - ✓ At low temperatures, molecules are "stuck"
  - ✓ If cooling is slow

  Low energy, organized crystal lattice formed

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Simulated annealing Search

- **Main Idea**: escape local maxima by allowing some "bad" moves but gradually **decrease their frequency**.

- Instead of picking the **best** move, it picks a **random** move..

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Simulated annealing Search

function SIMULATED-ANNEALING(*problem, schedule*) **returns** a solution state
  inputs: *problem*, a problem
    schedule, a mapping from time to "temperature"
  local variables: *current*, a node
    next, a node
    T, a "temperature" controlling prob. of downward steps

current ← MAKE-NODE(INITIAL-STATE[*problem*])
for $t \leftarrow 1$ **to** ∞ **do**
  $T \leftarrow schedule[t]$
  if $T = 0$ **then return** *current*
  next ← a randomly selected successor of *current*
  $\Delta E \leftarrow$ VALUE[*next*] – VALUE[*current*]
  if $\Delta E > 0$ **then** *current* ← *next*
  else *current* ← *next* only with probability $e^{\Delta E/T}$

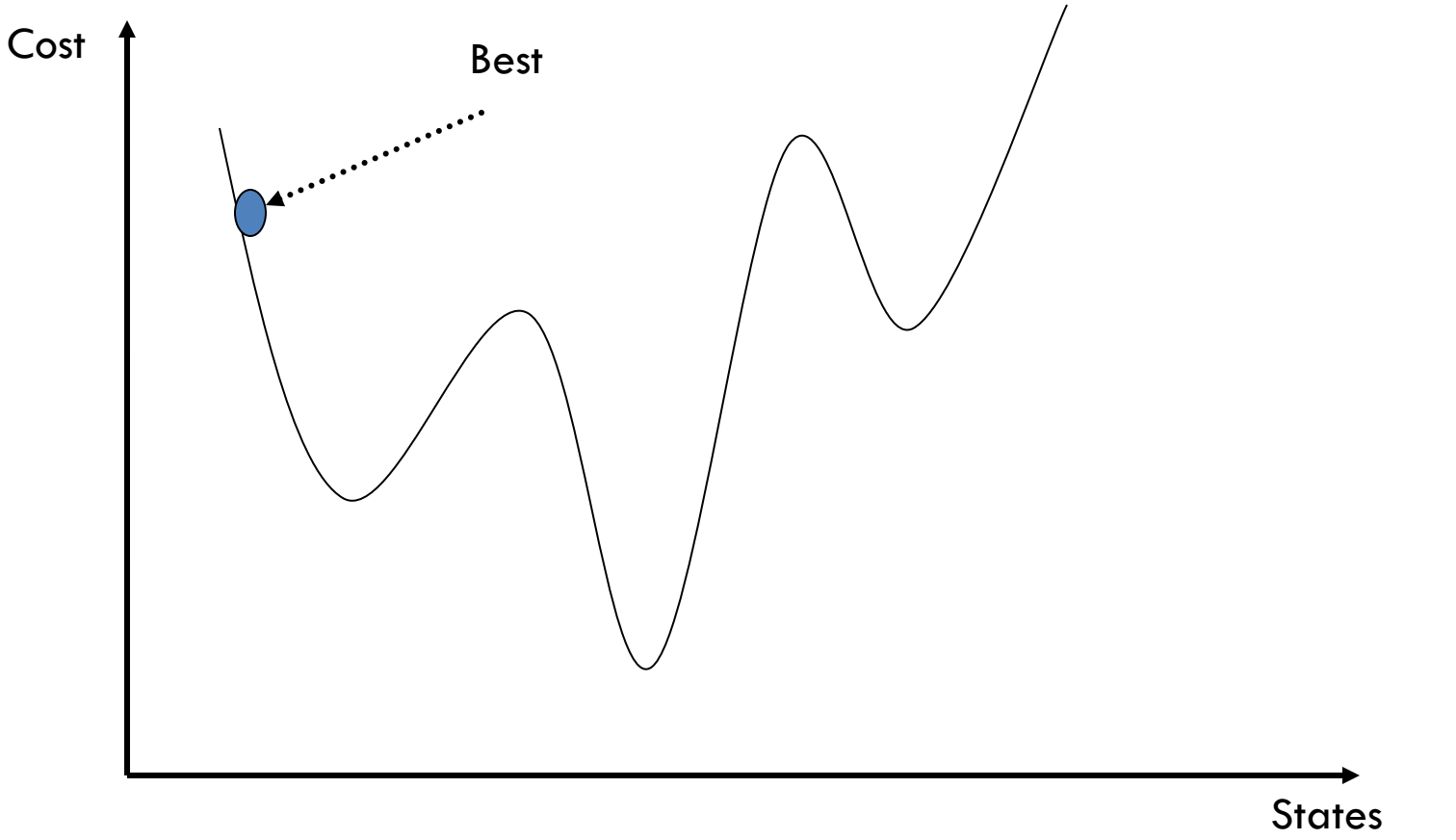
Similar to hill climbing, but a random move instead of best move.

Case of improvement, make the move.

Otherwise, choose the move with probability that decreases exponentially with the "badness" of the move.

- say the change in objective function is δ
- **if** δ is positive, then move to that state
- **otherwise**:
  - move to this state with probability proportional to δ
  - thus: worse moves (very large negative δ) are executed less often

Simulated Annealing



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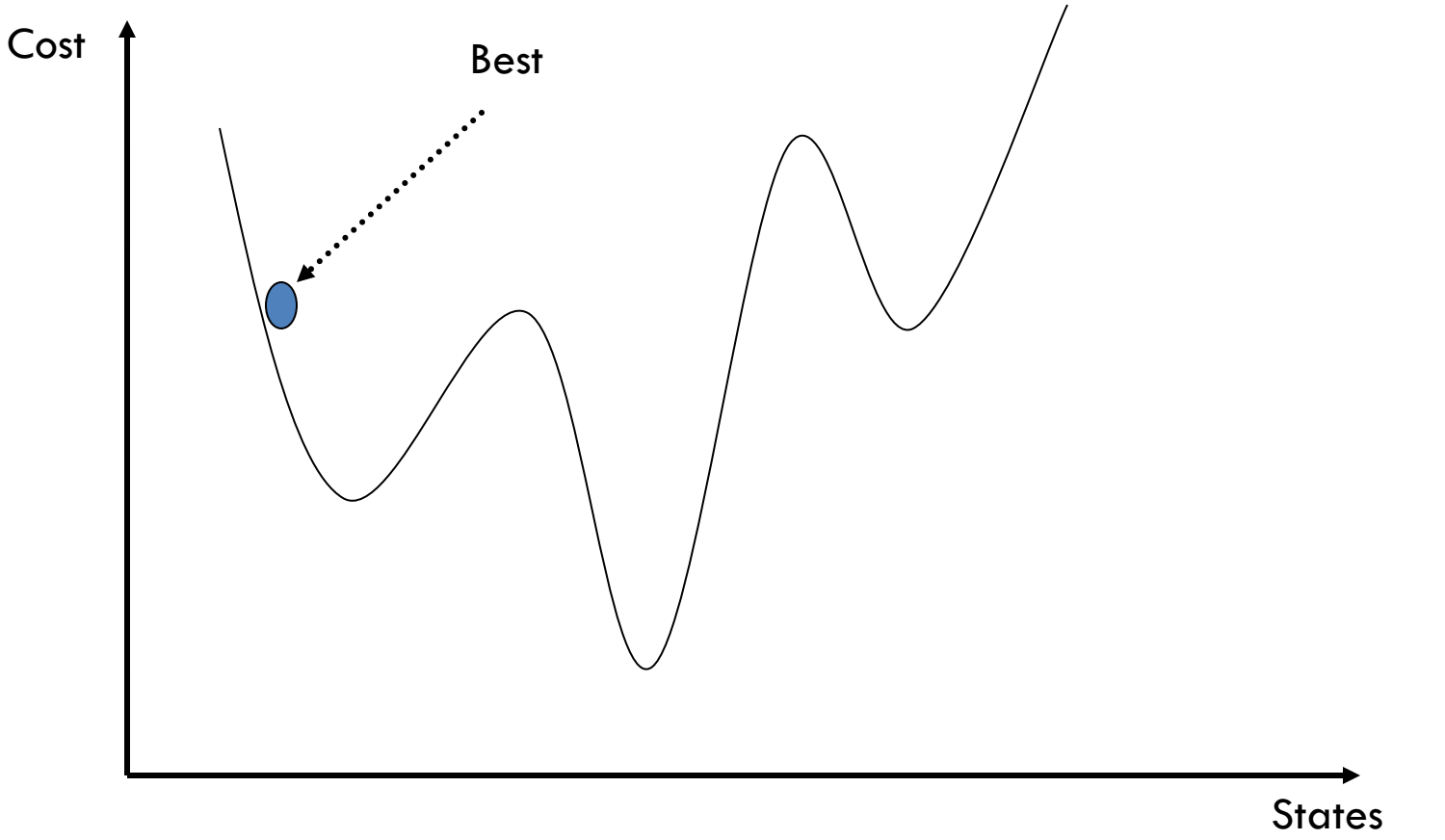

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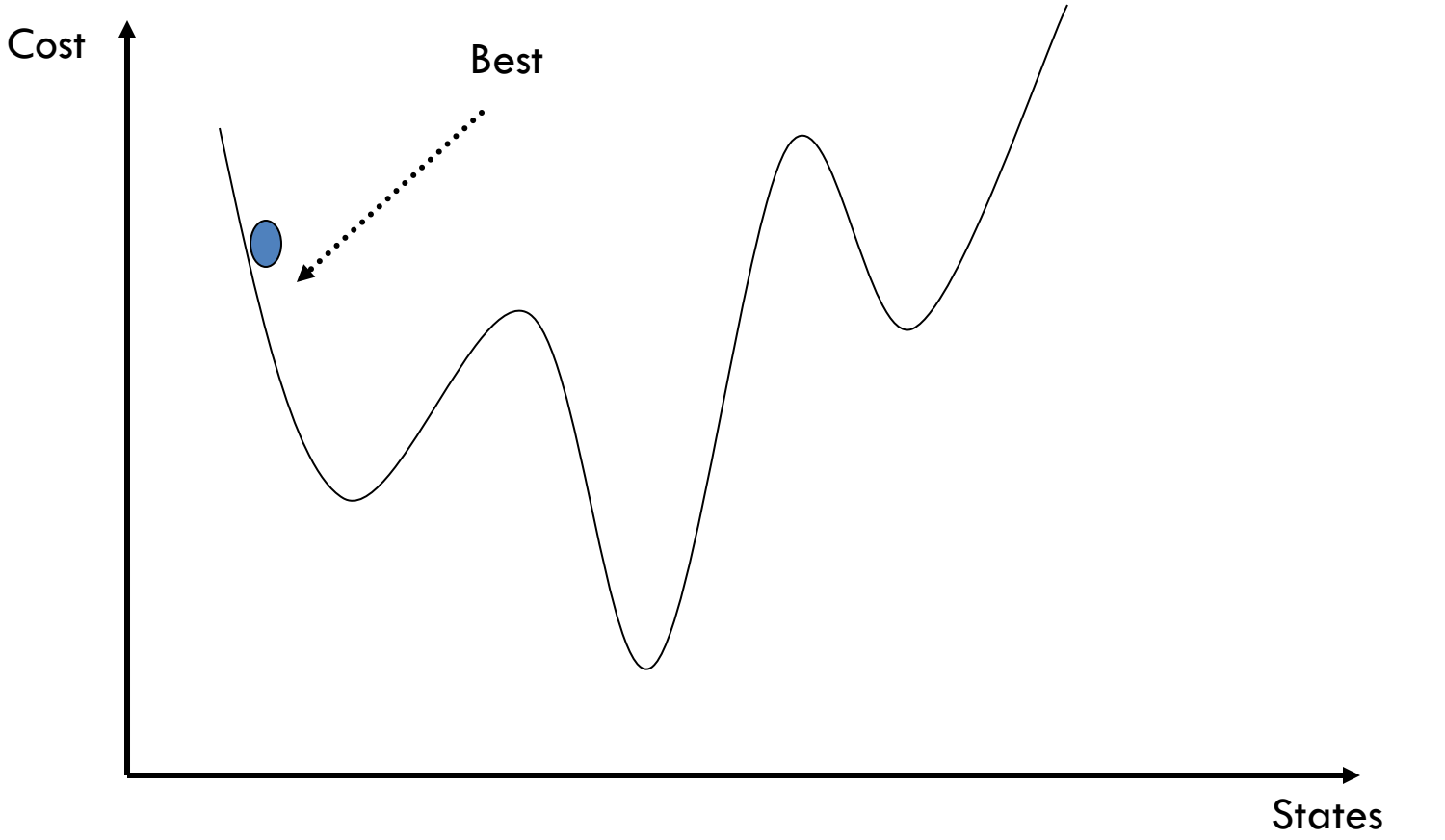

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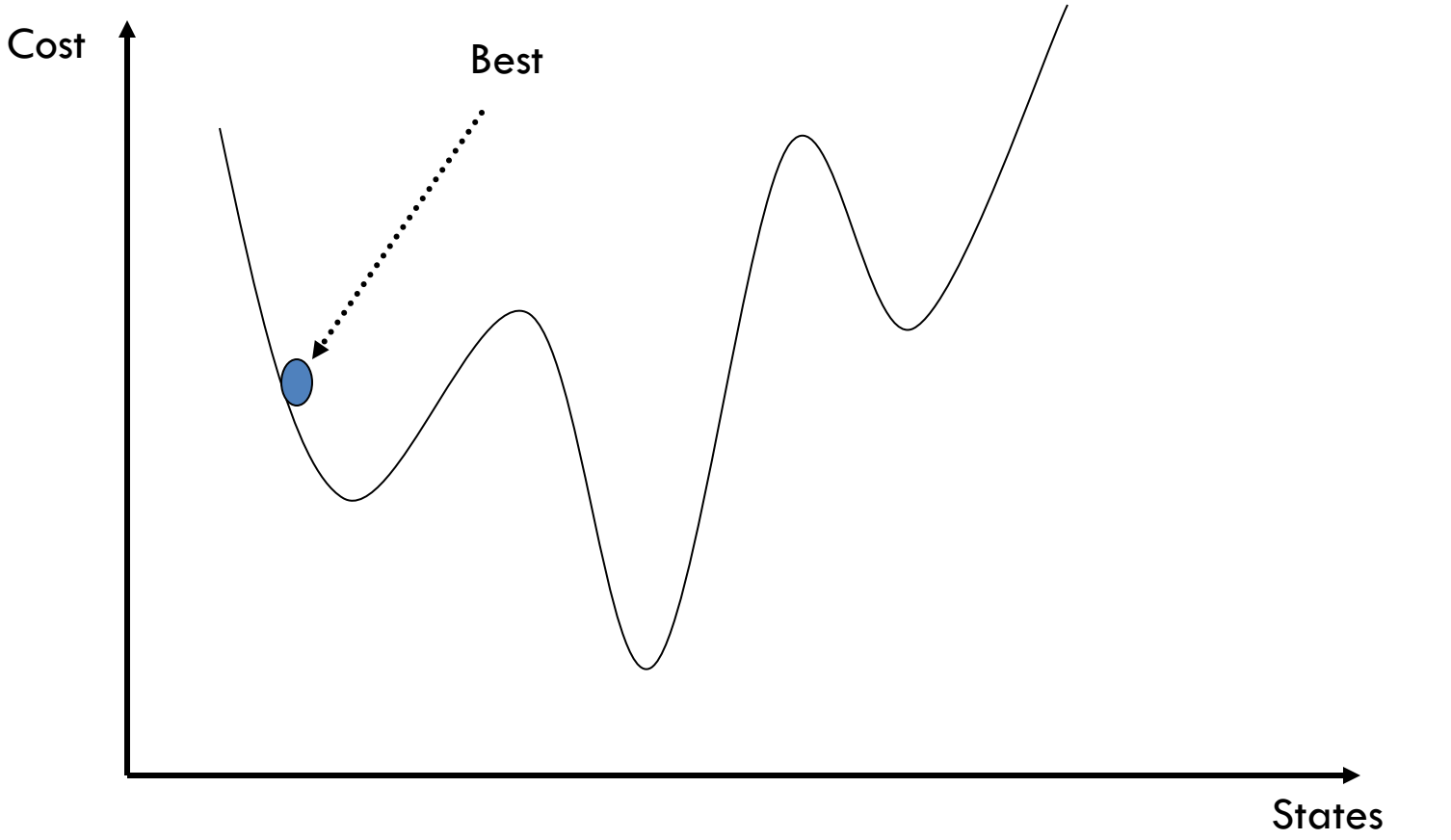

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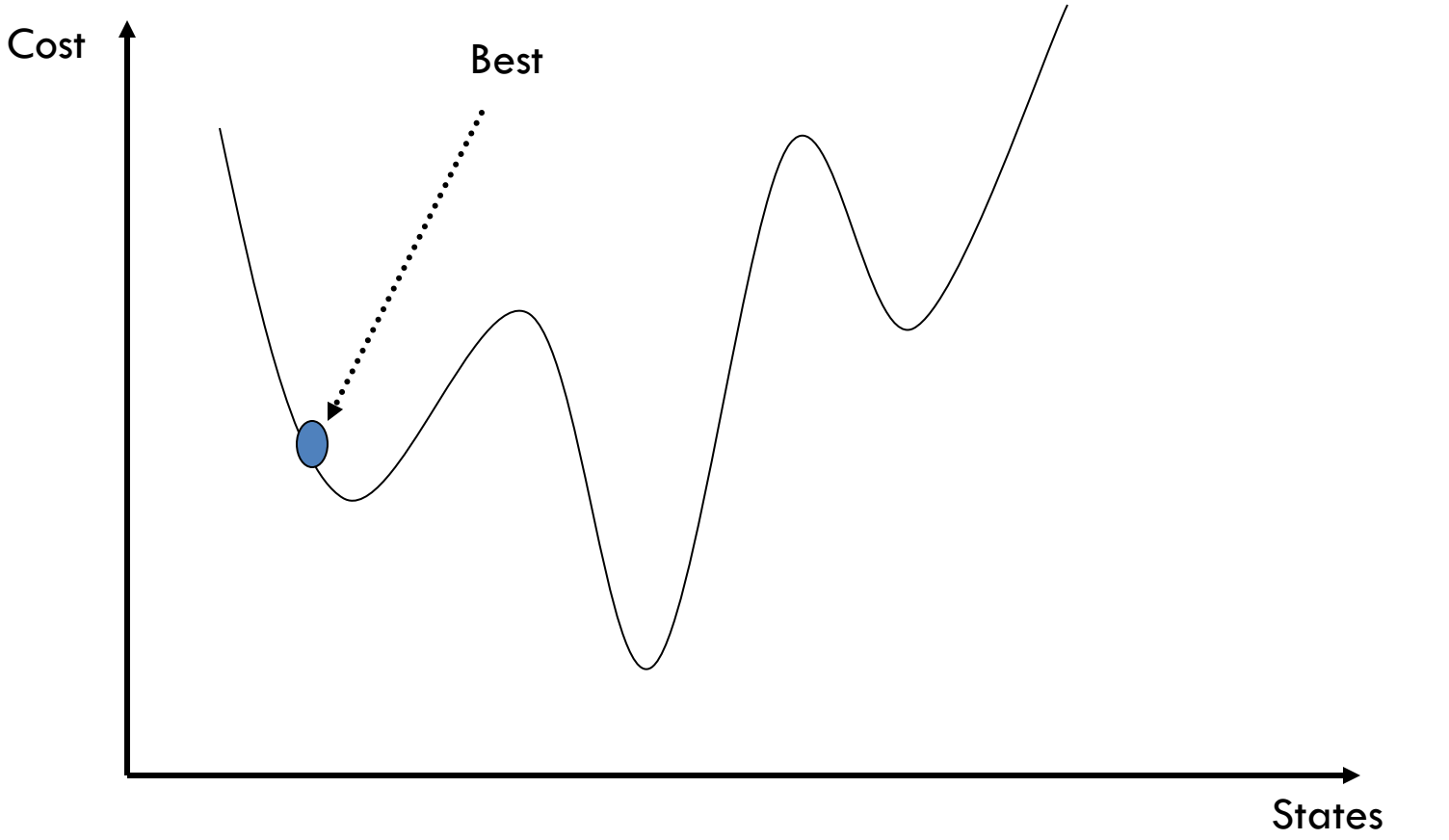

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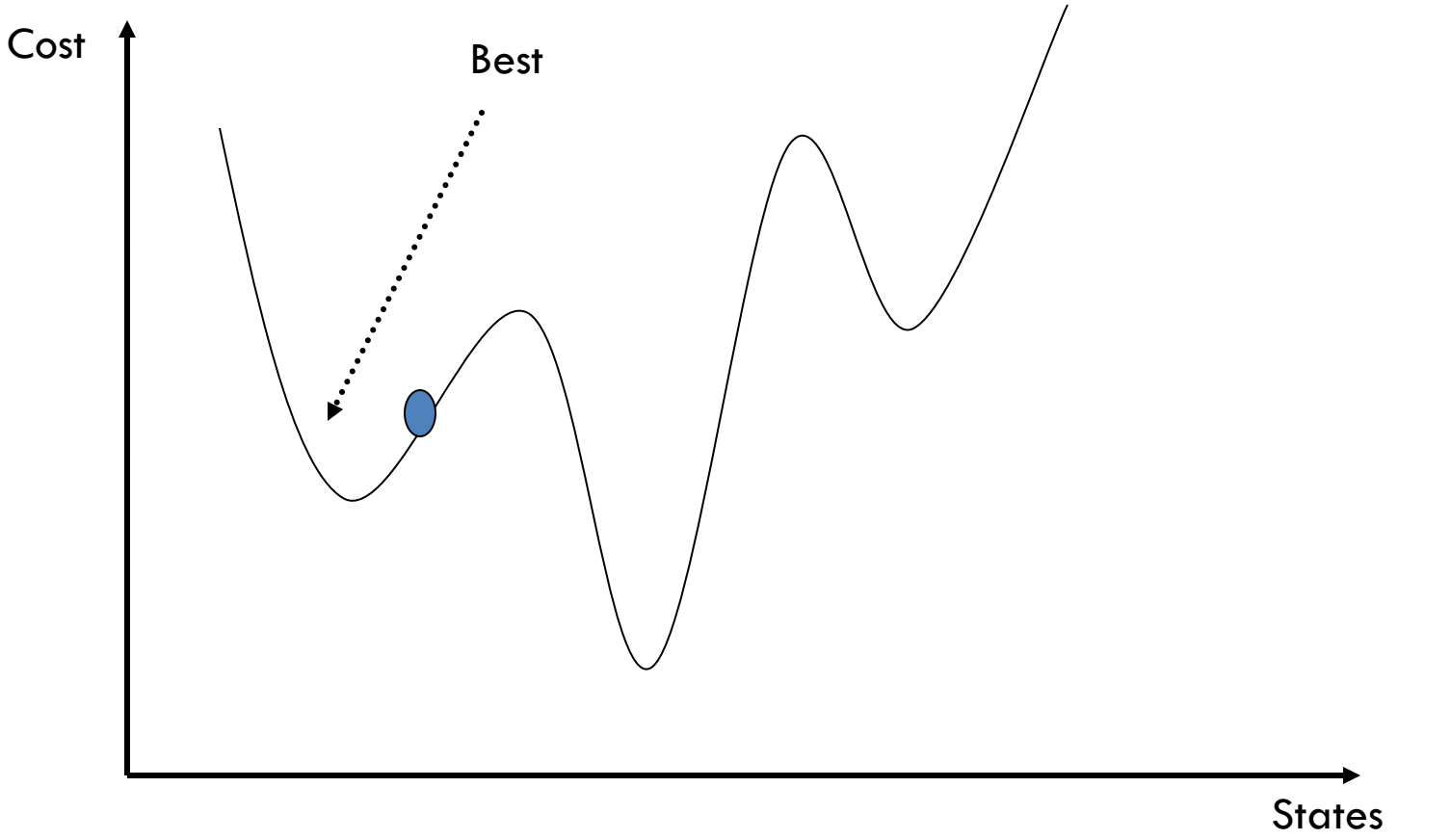

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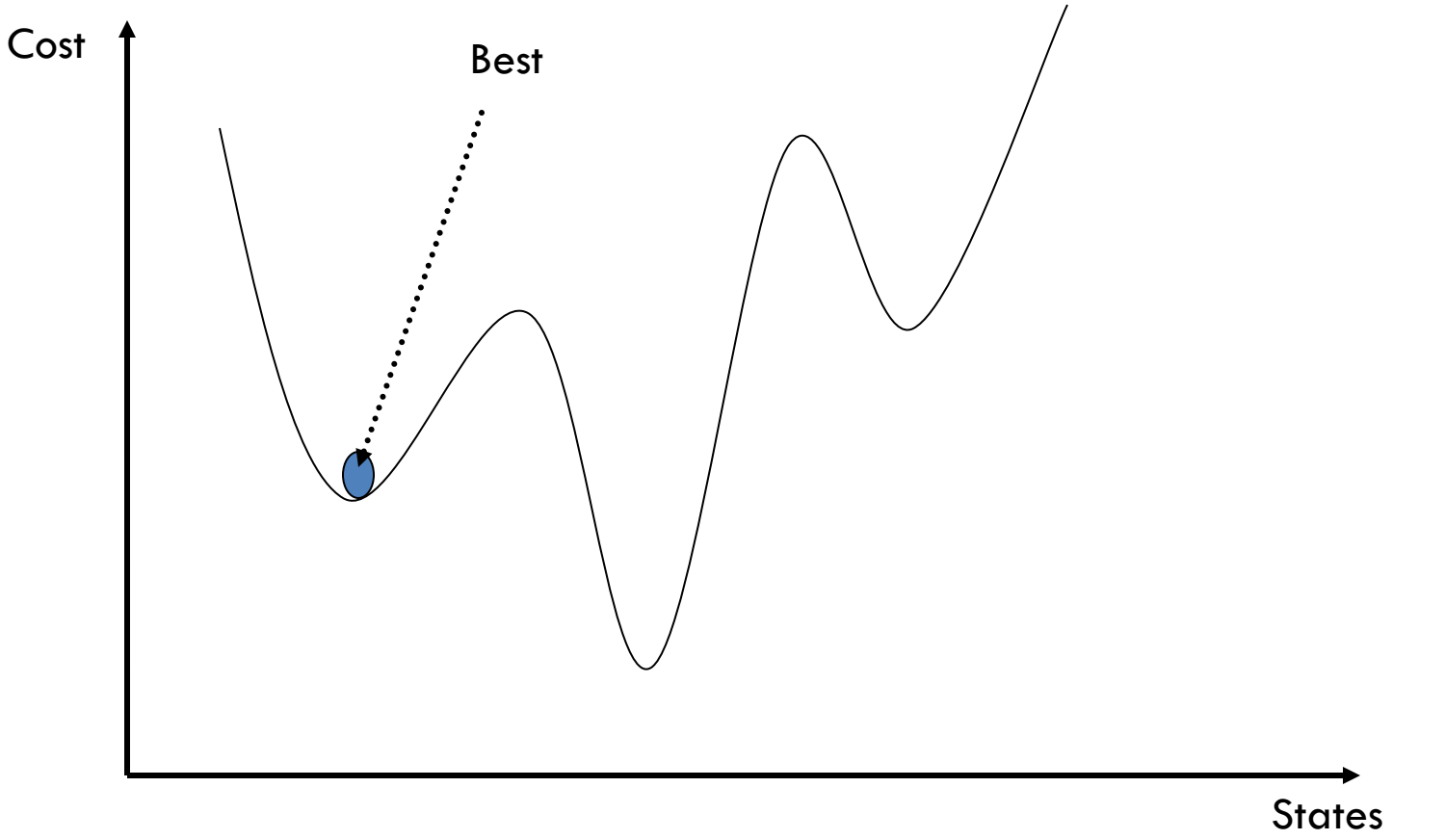

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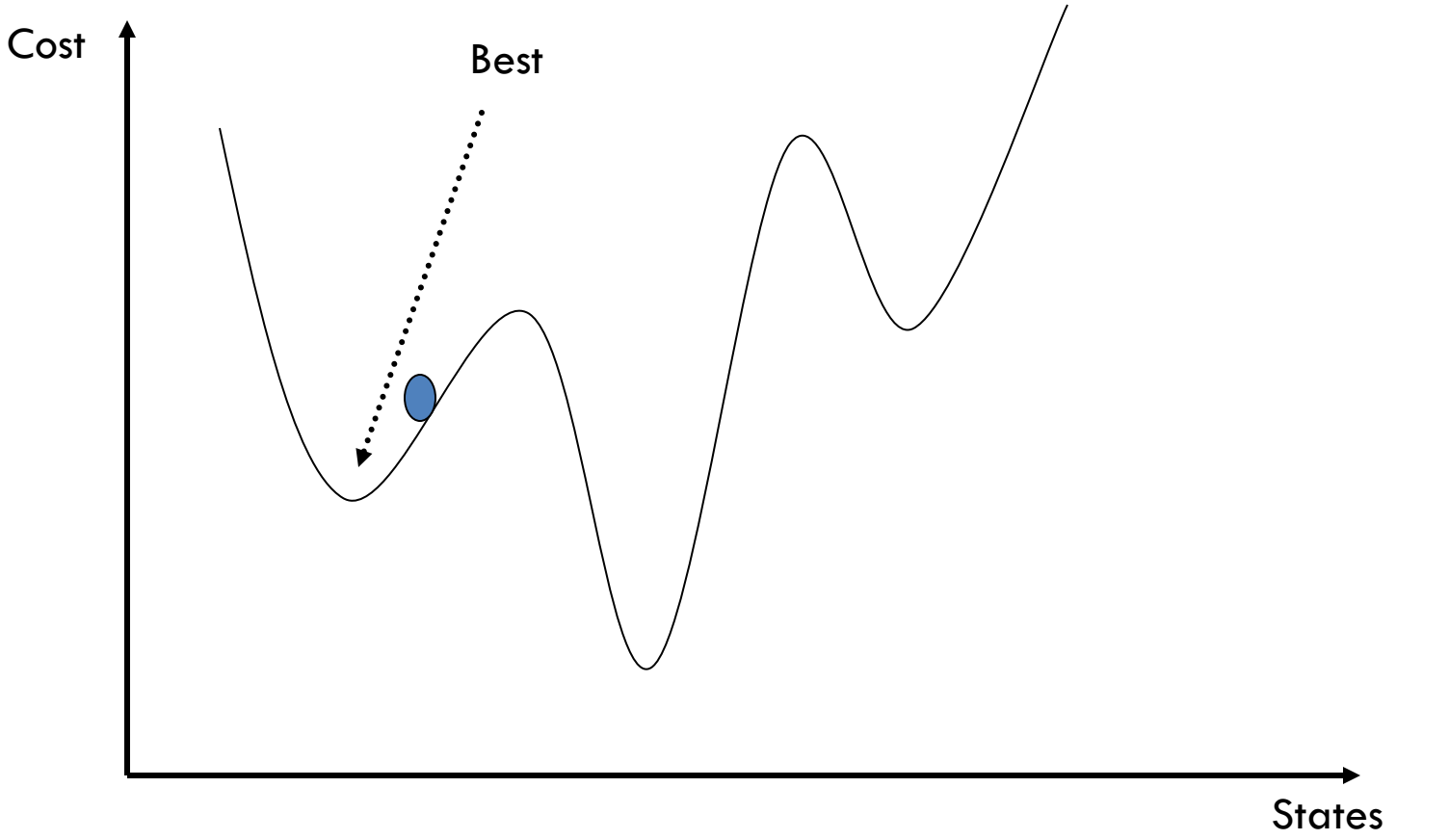

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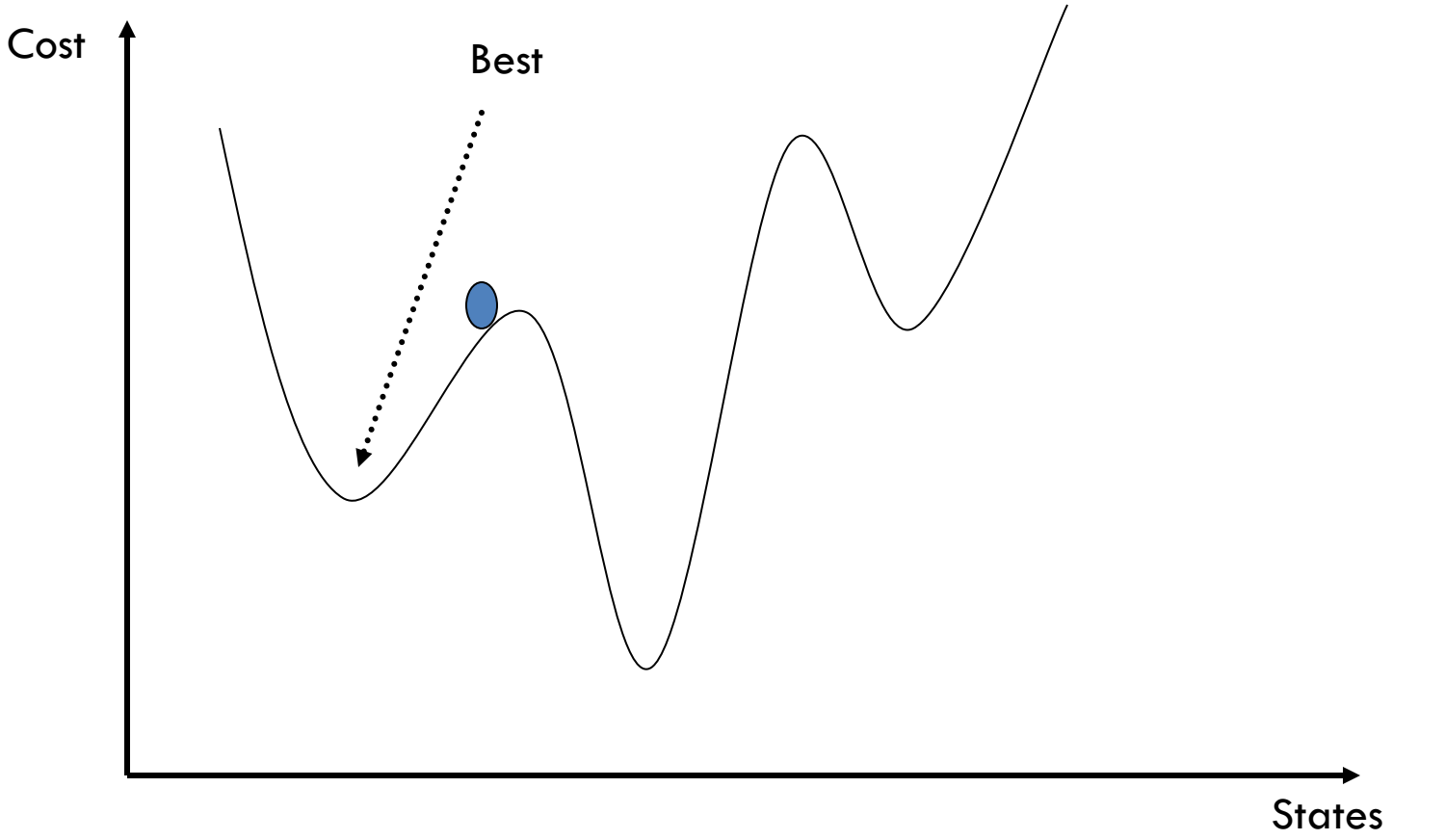

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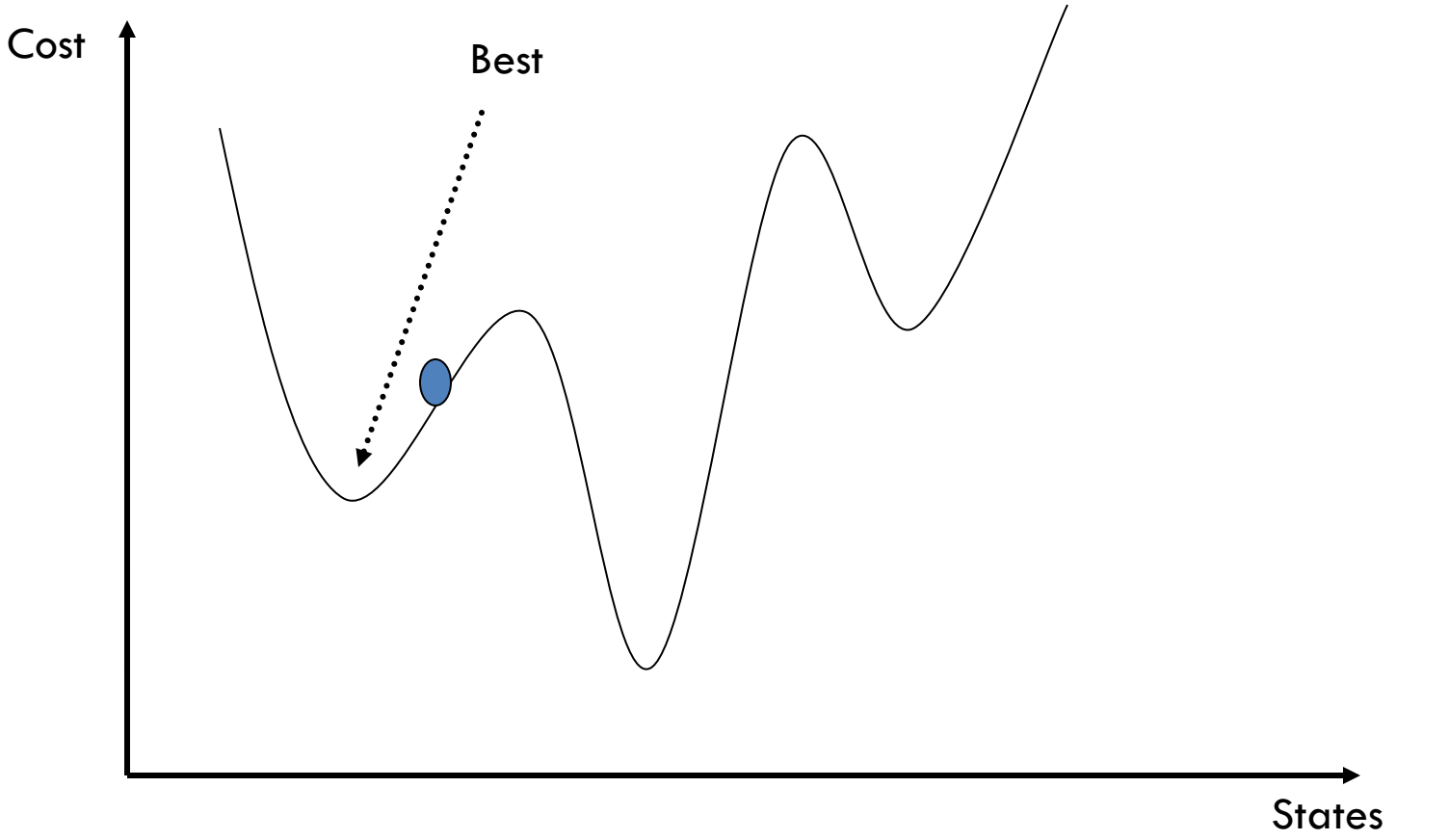

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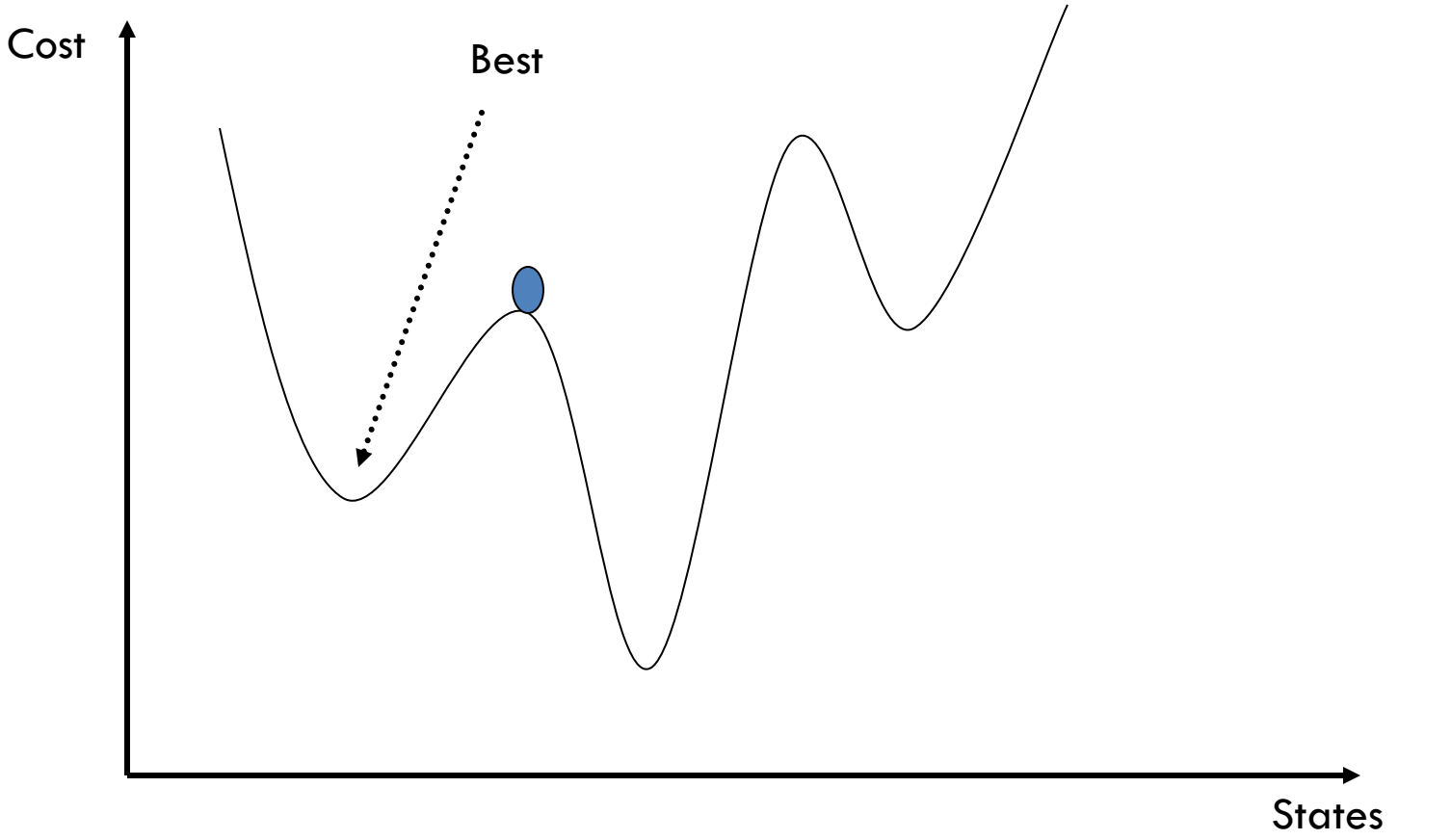

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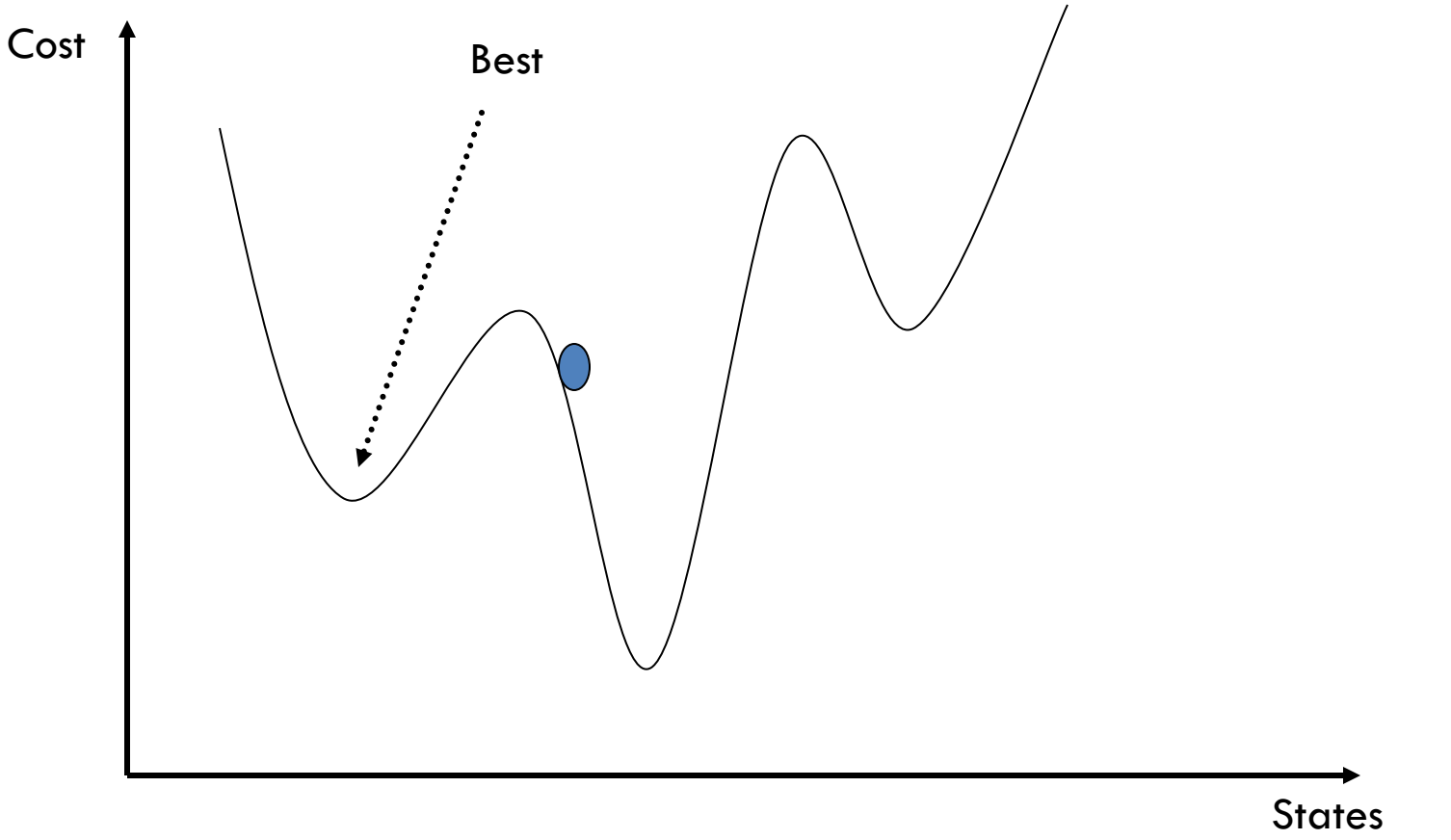

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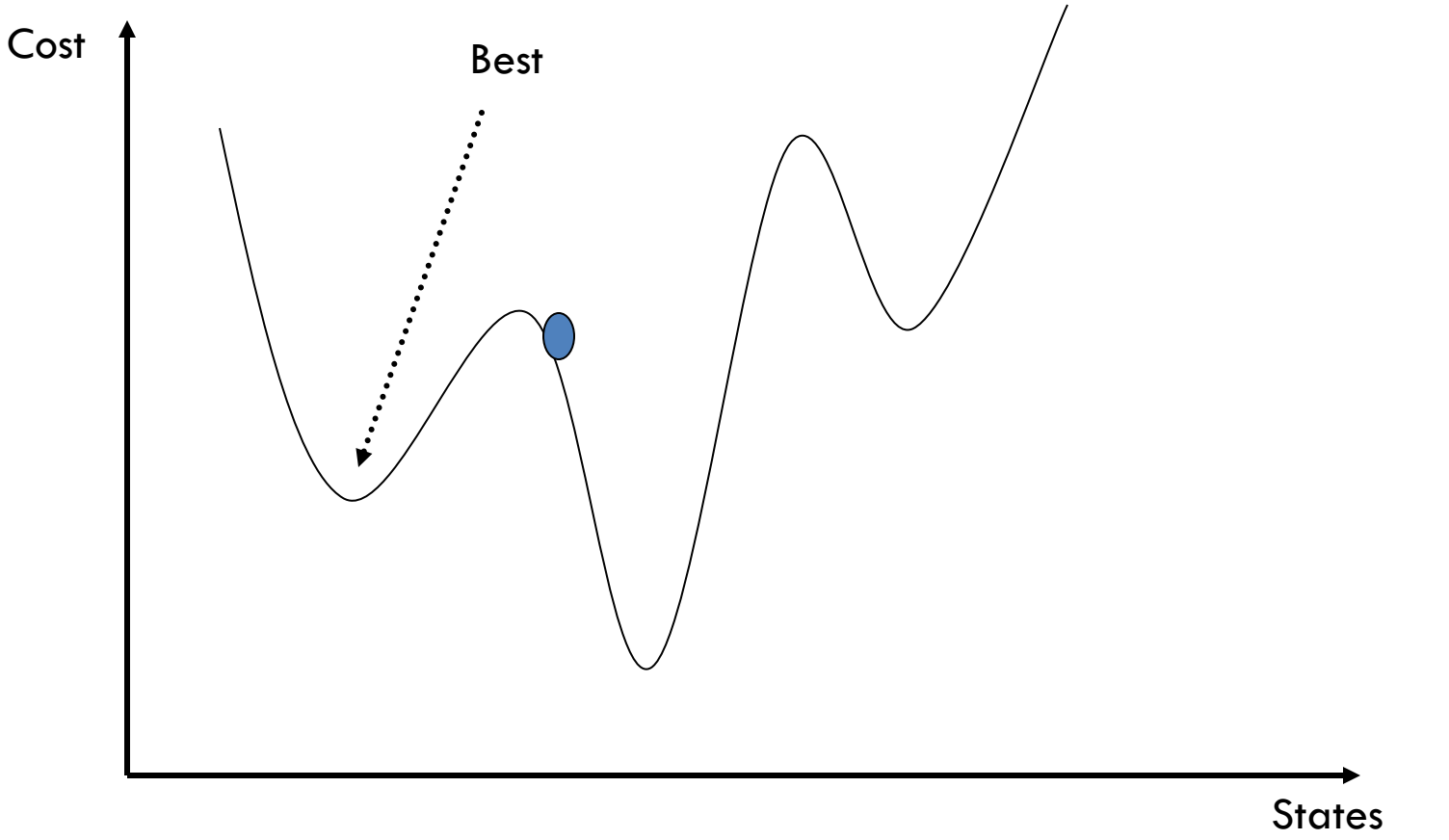

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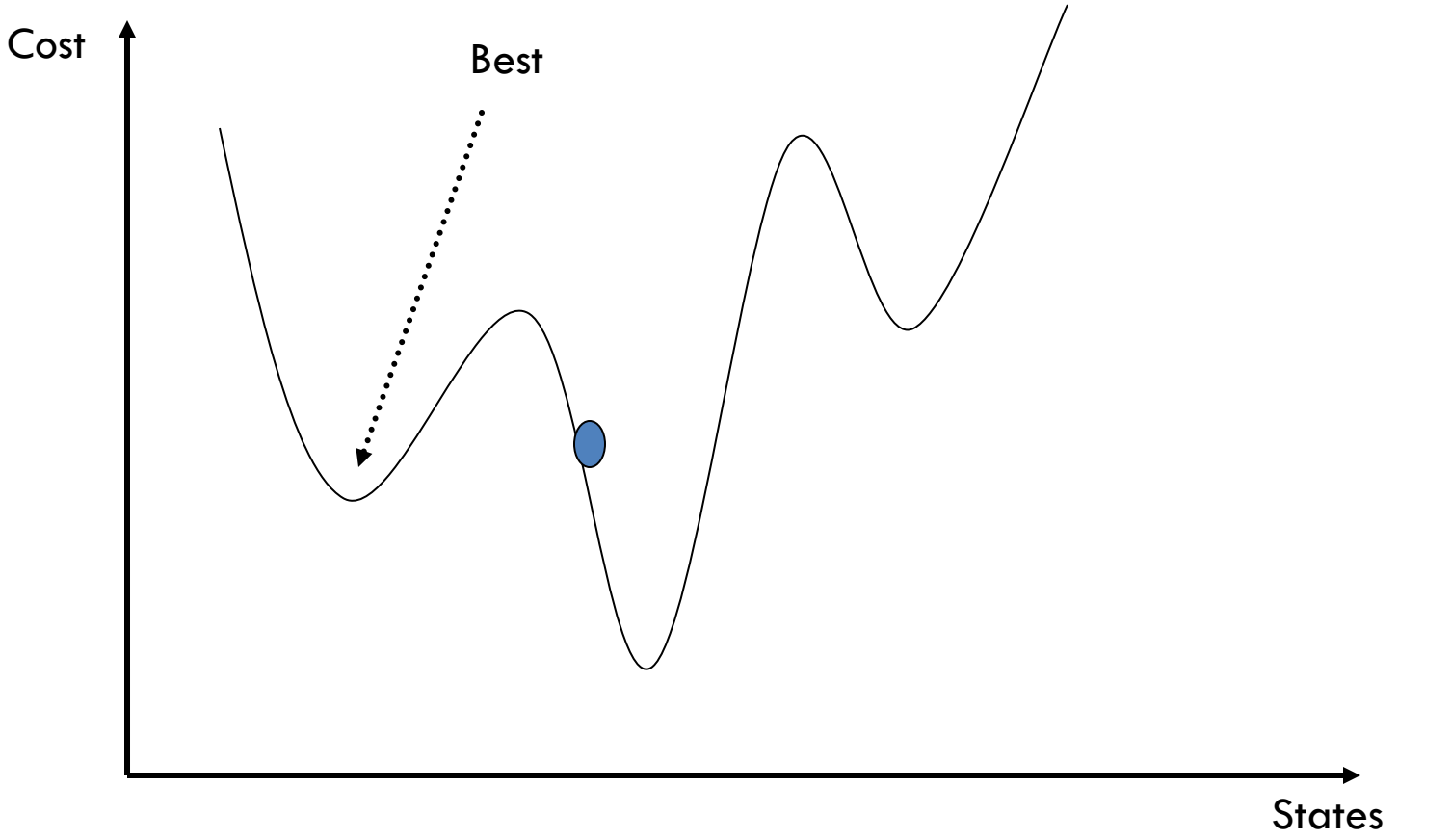

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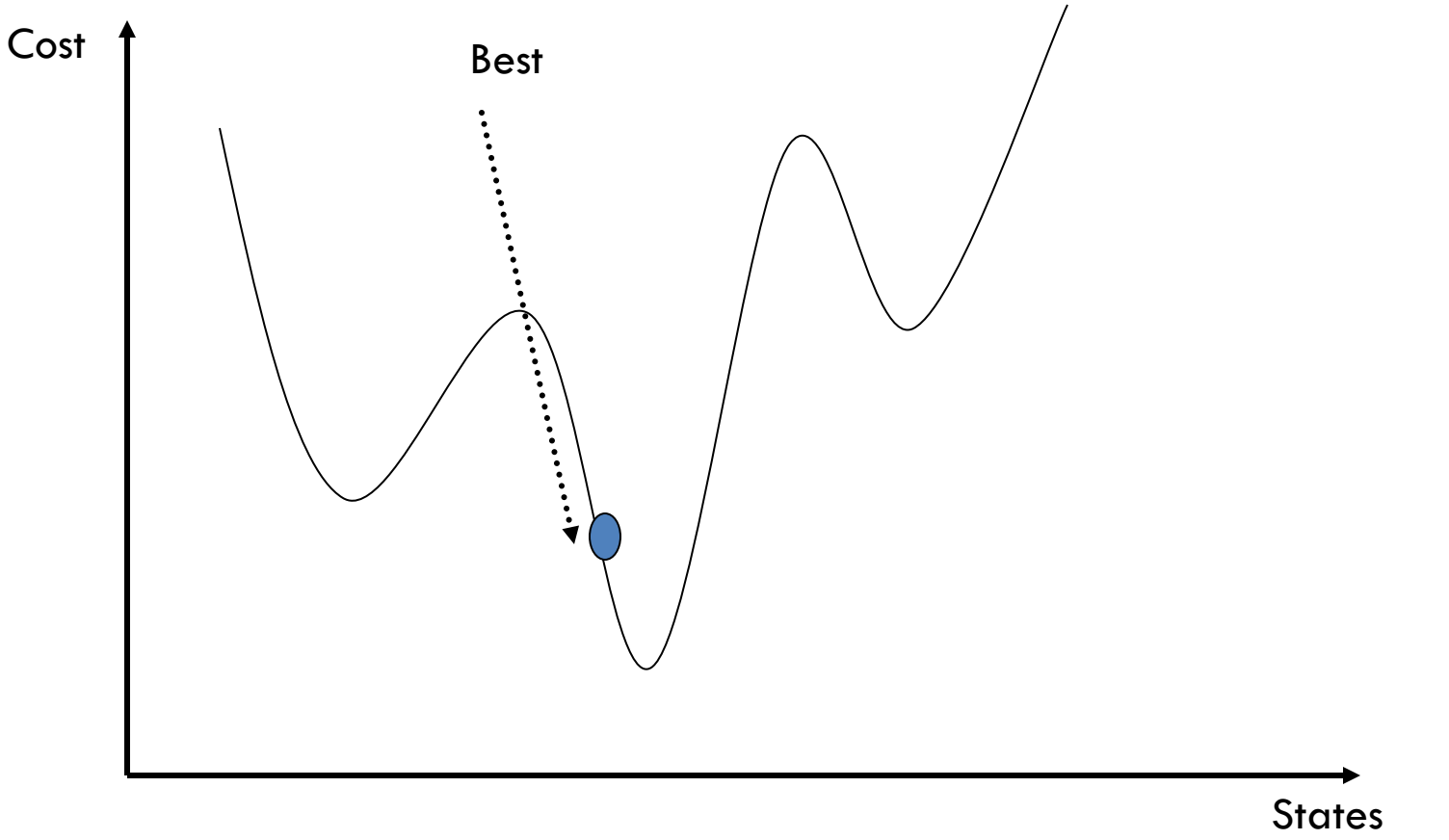

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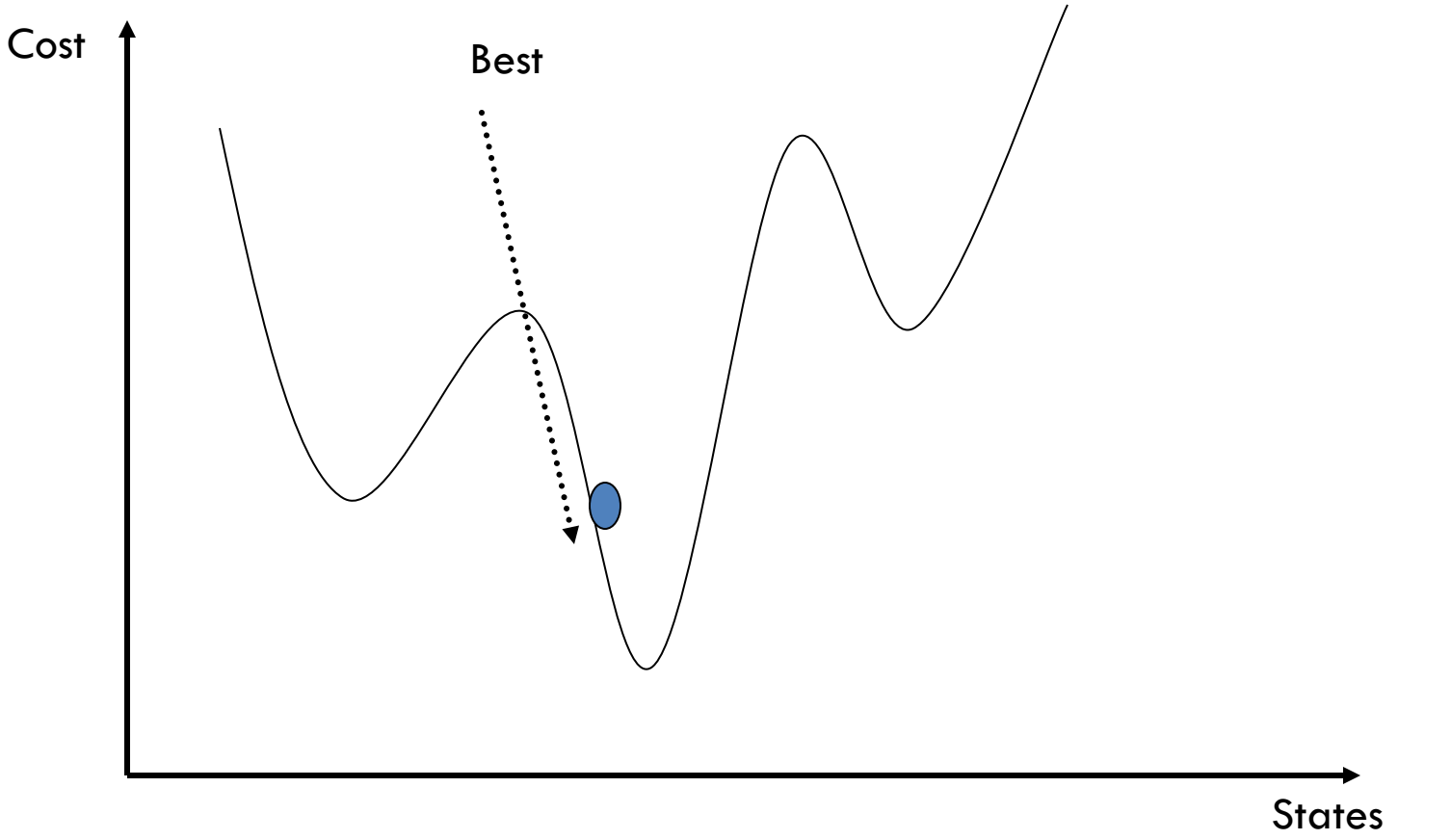

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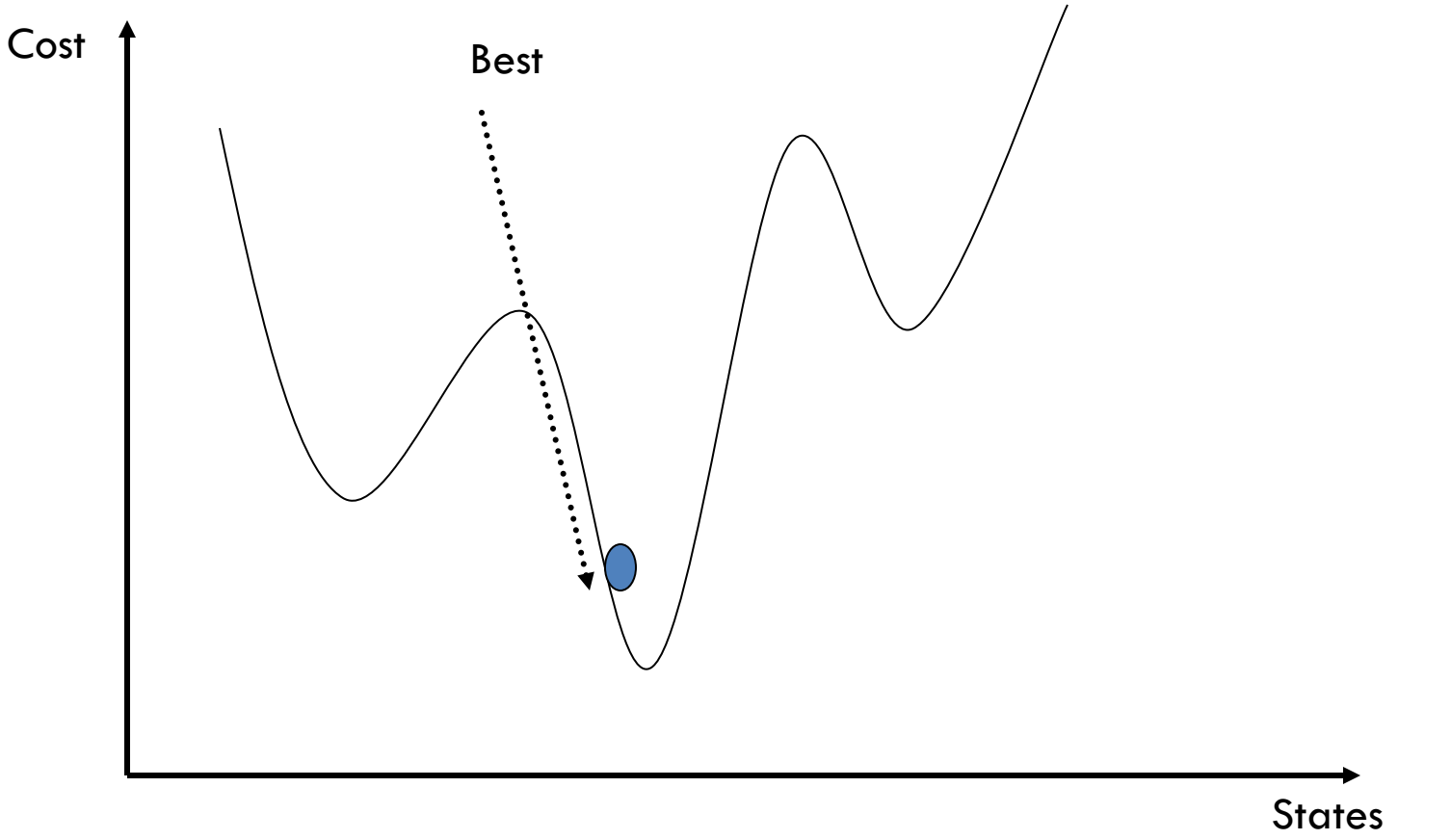

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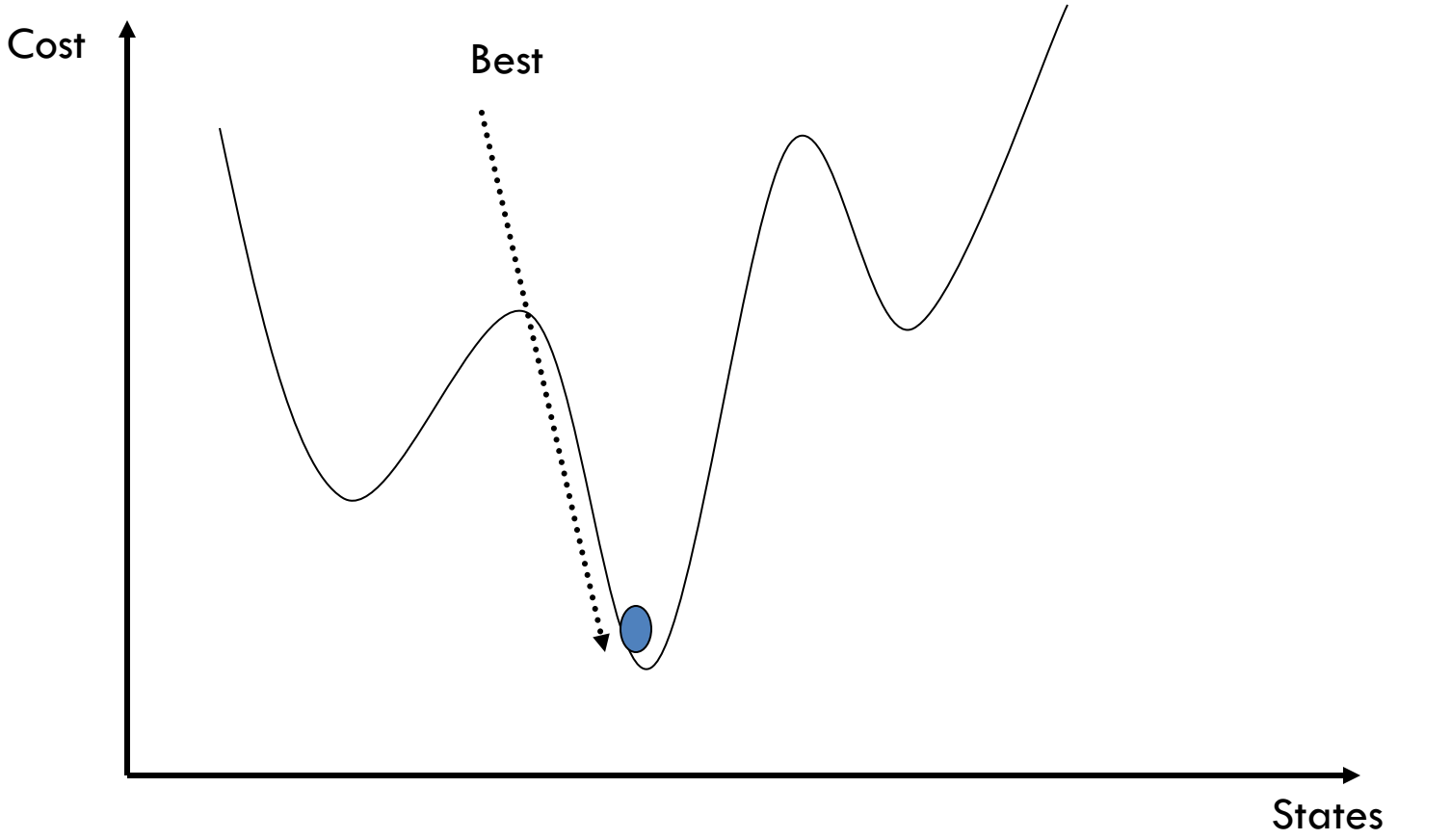

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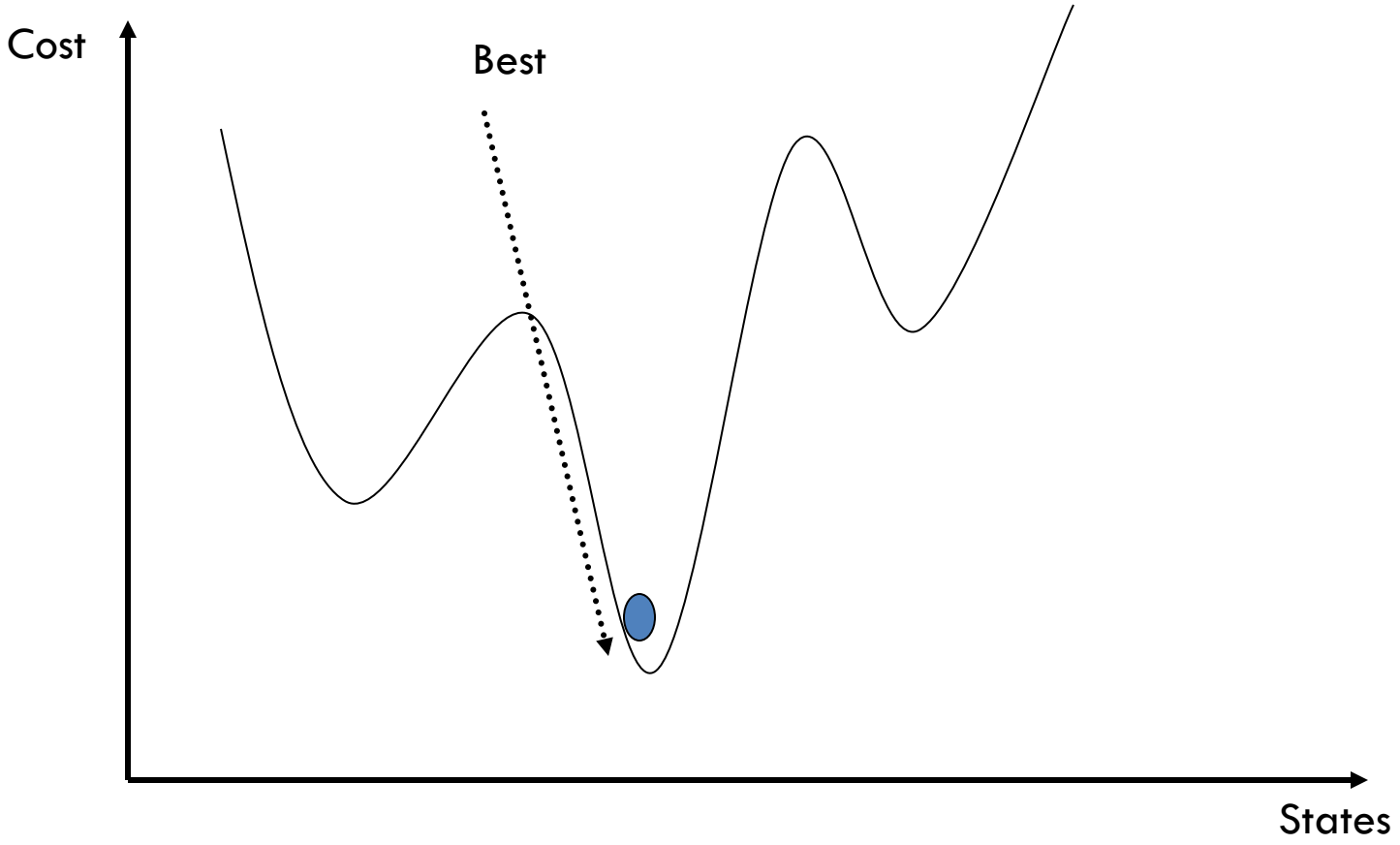

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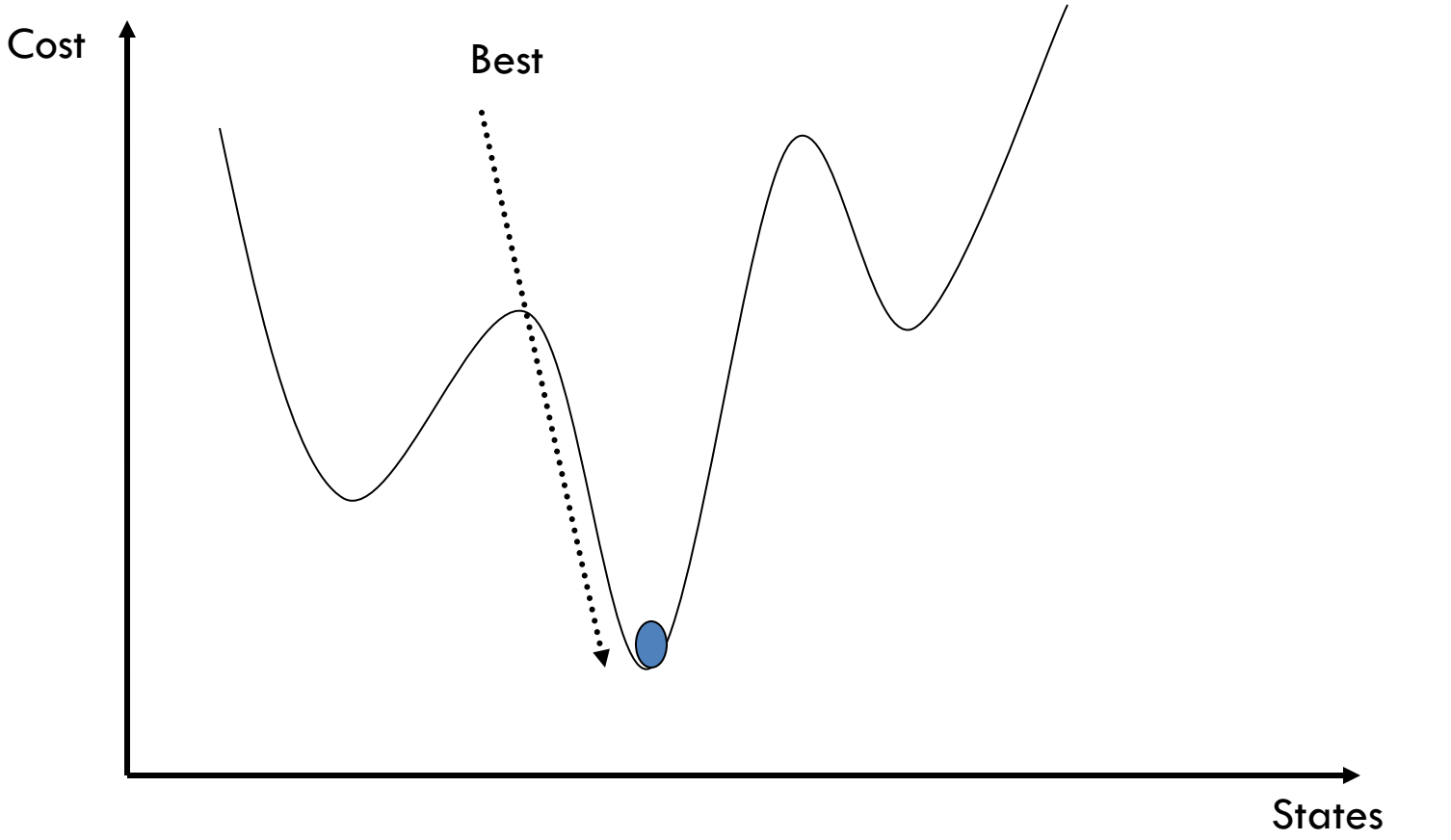

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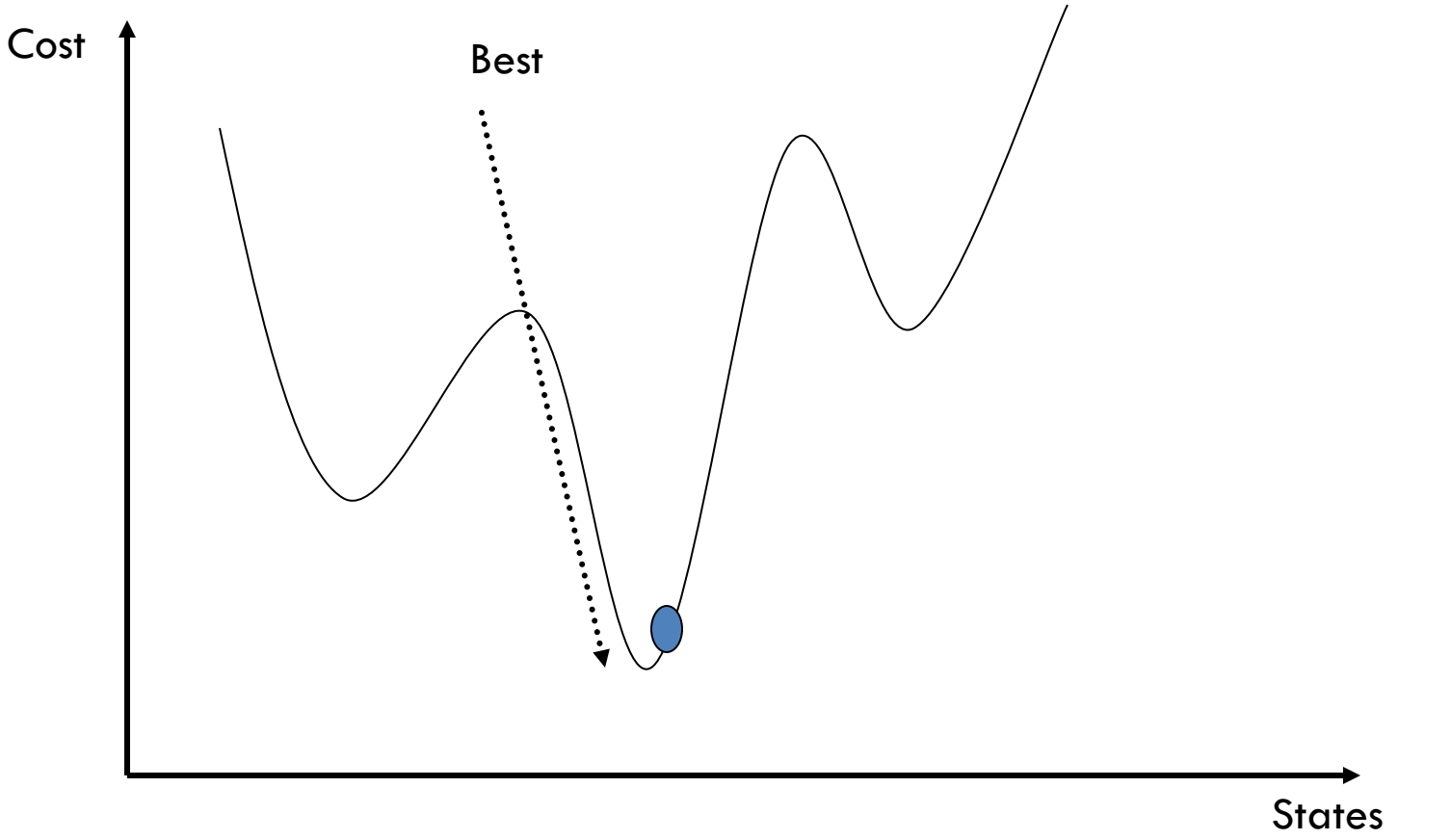

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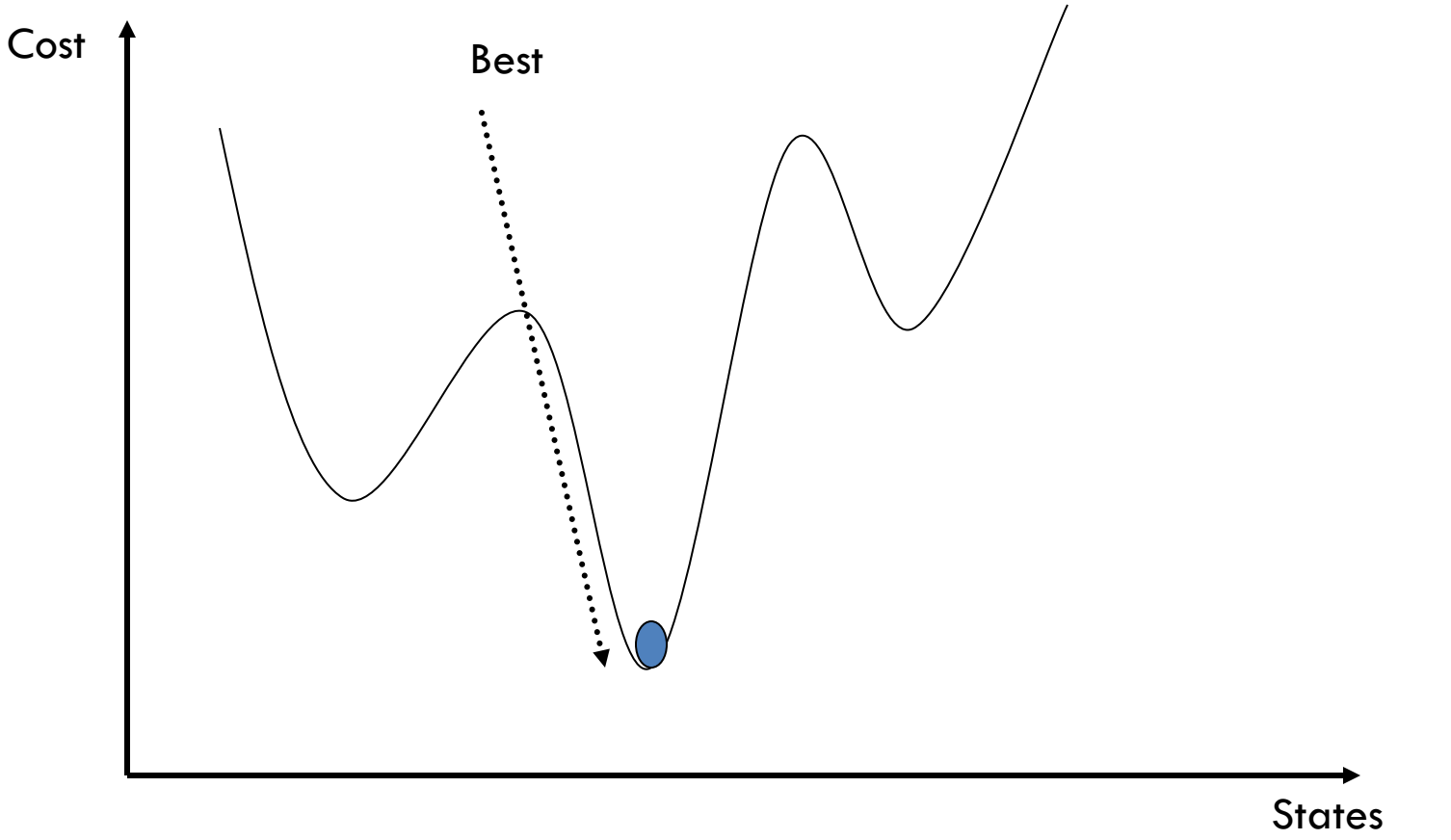

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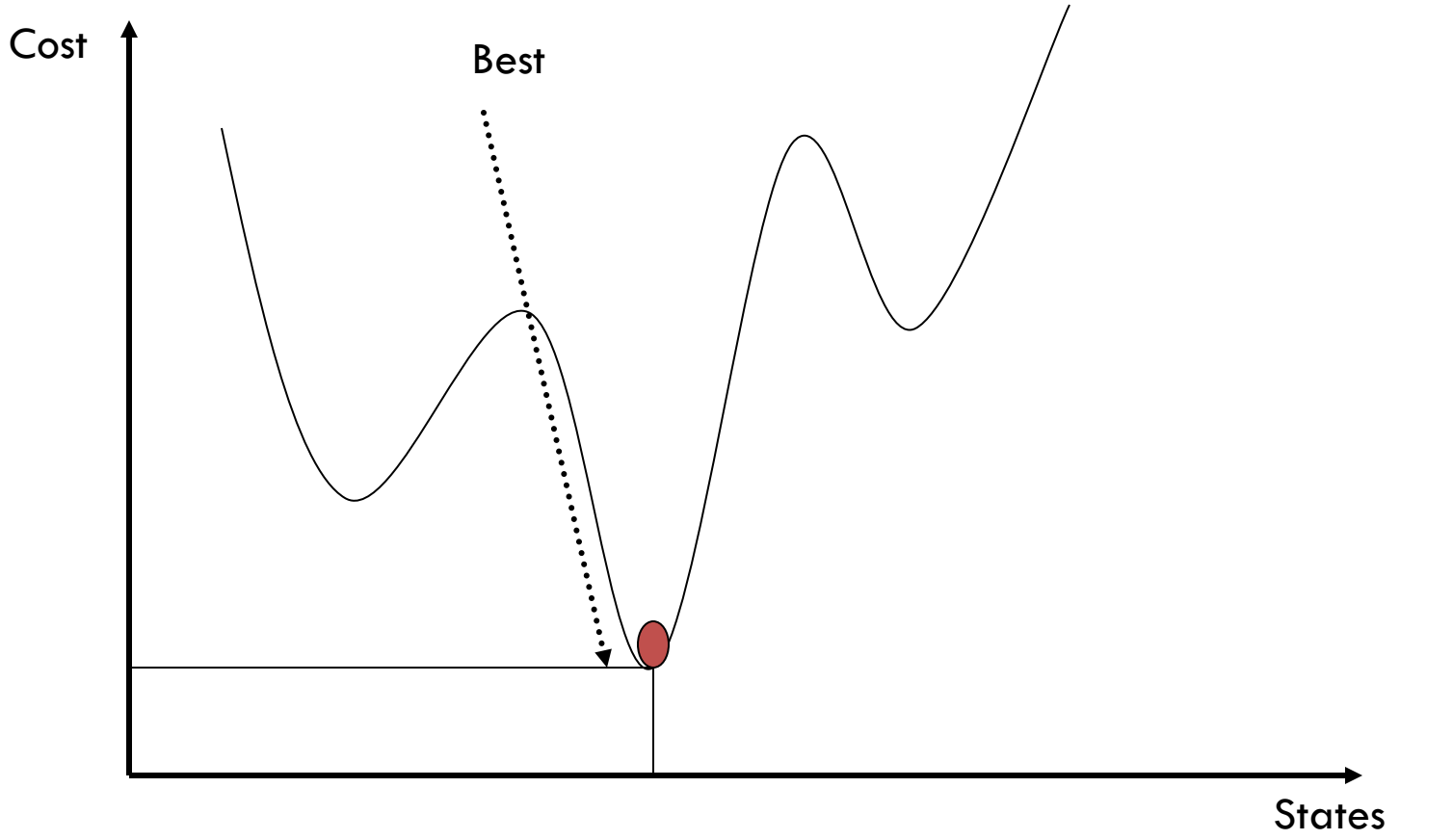

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Simulated annealing Search

- Lets say there are 3 moves available, with changes in the objective function of d1 = -0.1, d2 = 0.5, d3 = -5. (Let T = 1).
- pick a move randomly:
  - if d2 is picked, move there.
  - if d1 or d3 are picked, probability of move = exp(d/T)
  - move 1: prob1 = exp(-0.1) = 0.9,
    - i.e., 90% of the time we will accept this move
  - move 3: prob3 = exp(-5) = 0.05
    - i.e., 5% of the time we will accept this move

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Properties of Simulated Annealing

- Cooling Schedule: determines rate at which the temperature T is lowered.

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Local Beam Search

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(course coordinator)

Local Beam Search

- **Main Idea**: Keep track of **k** states rather than just one.
- Start with **k** randomly generated states.
- At each iteration, all the successors of all **k** states are generated.
- If any one is a goal state, stop; else select the k best successors from the complete list and repeat.
- Drawback: the k states tend to regroup very quickly in the same region → lack of diversity.

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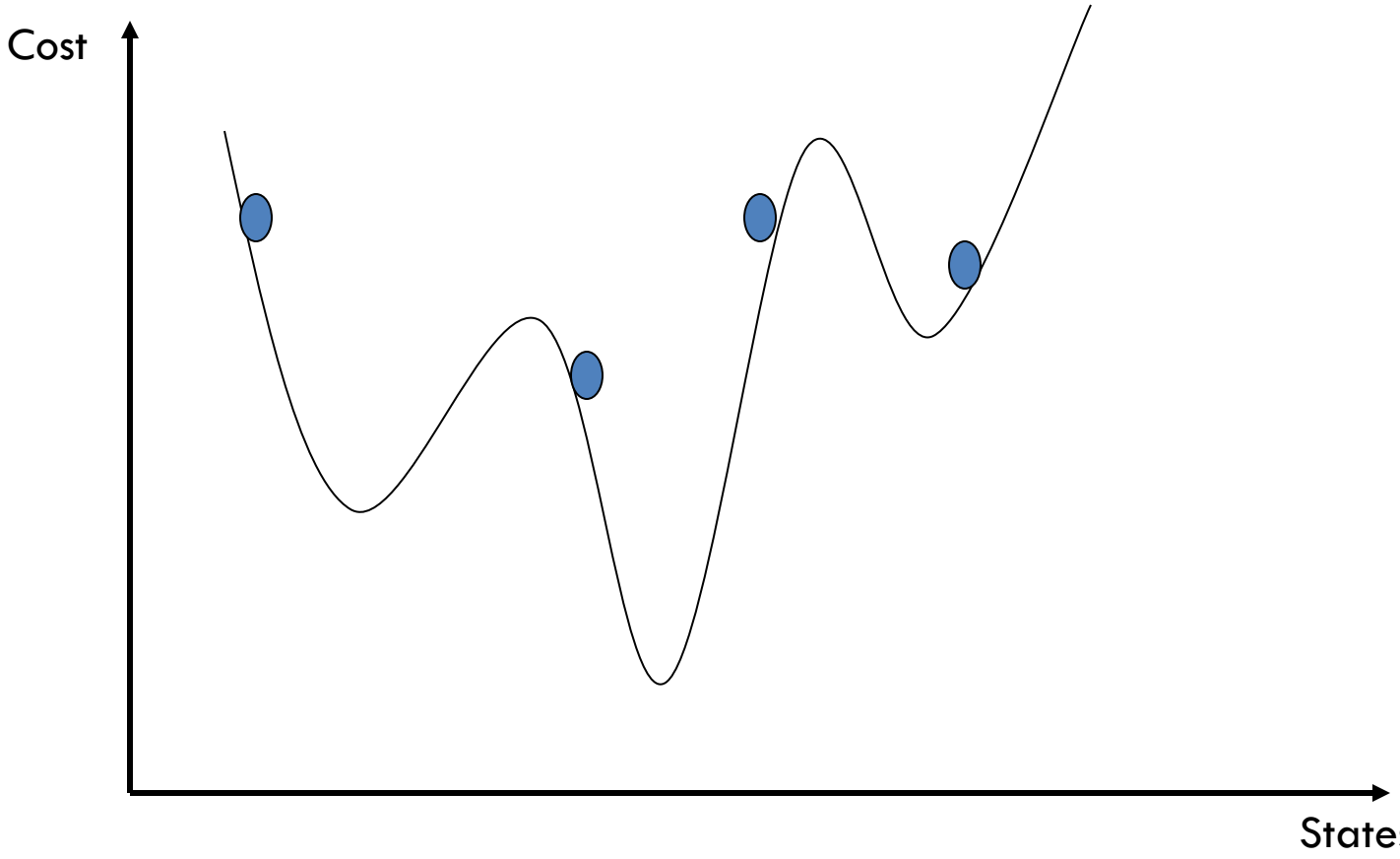
Local Beam Search



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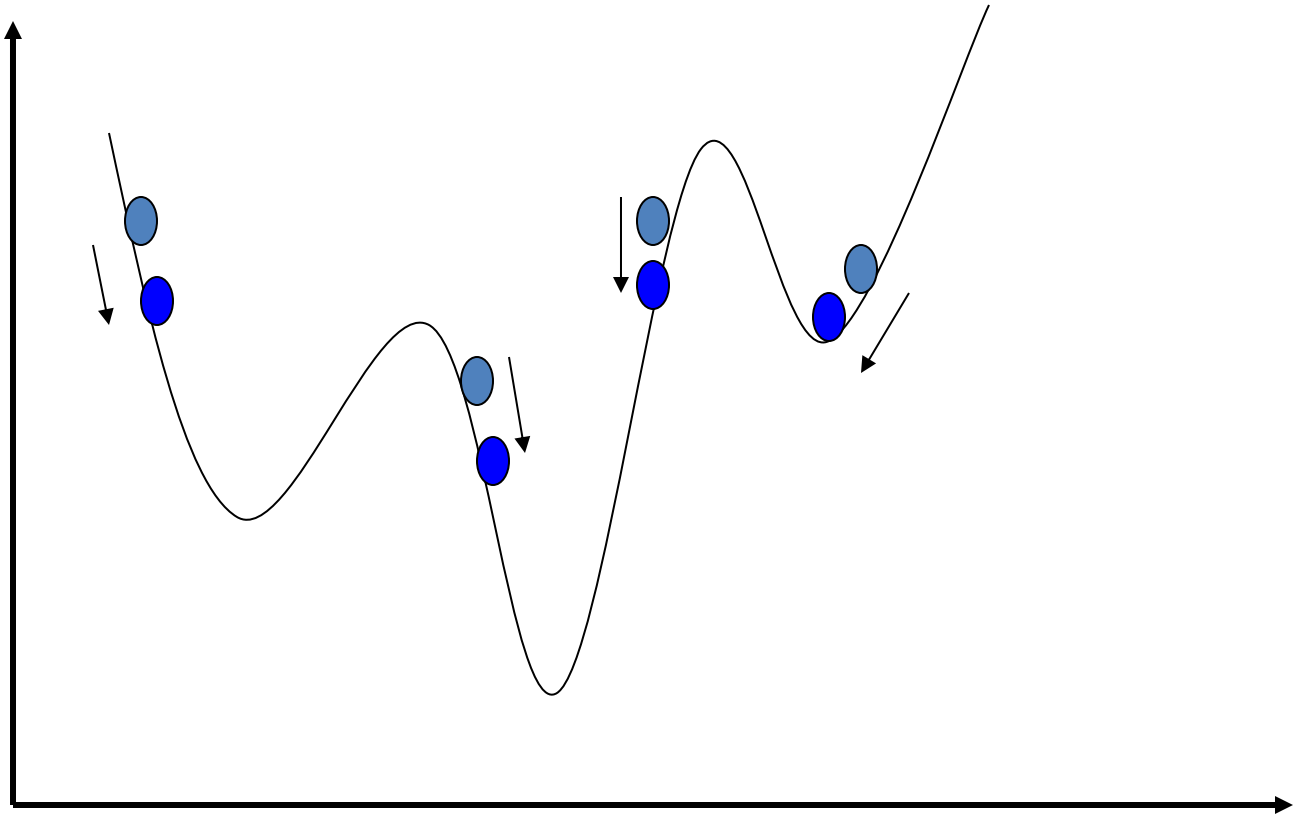
Local Beam Search



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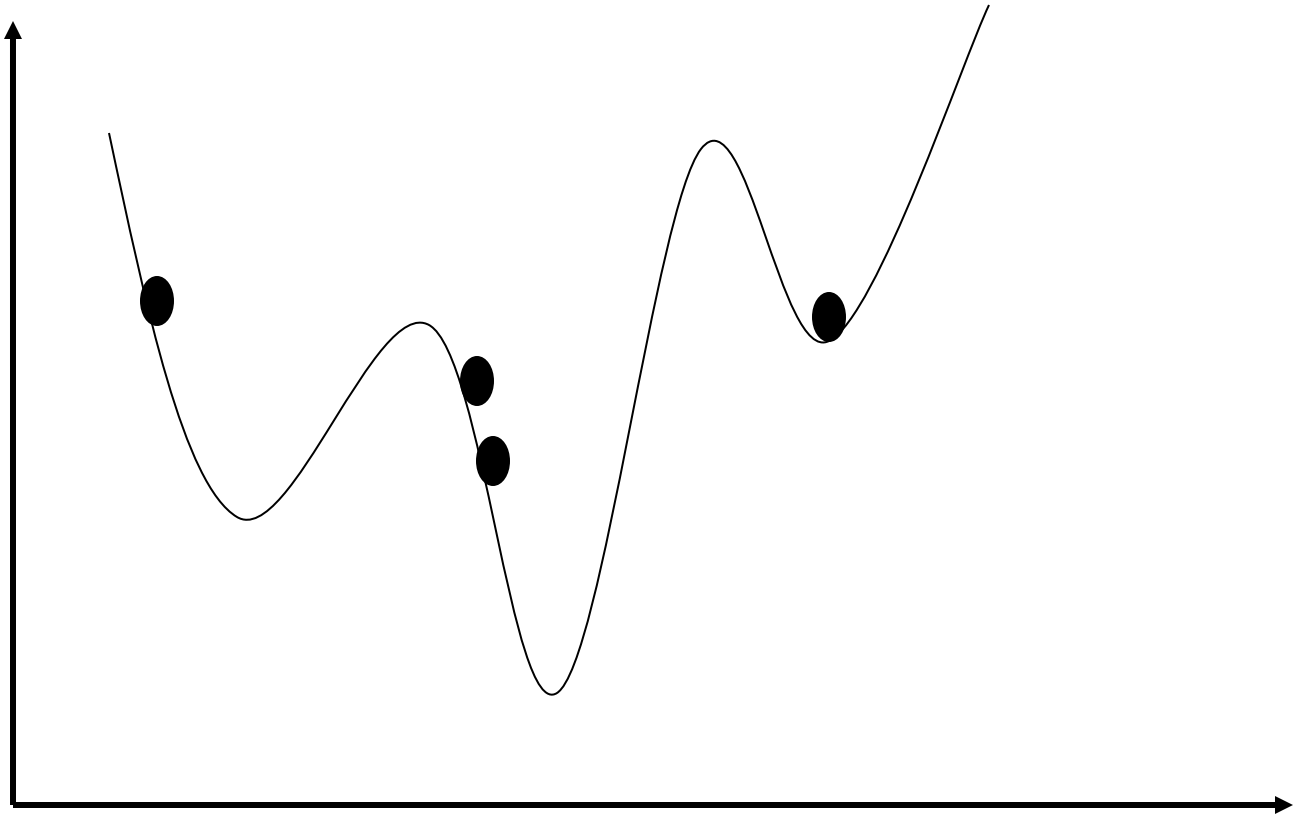
Local Beam Search



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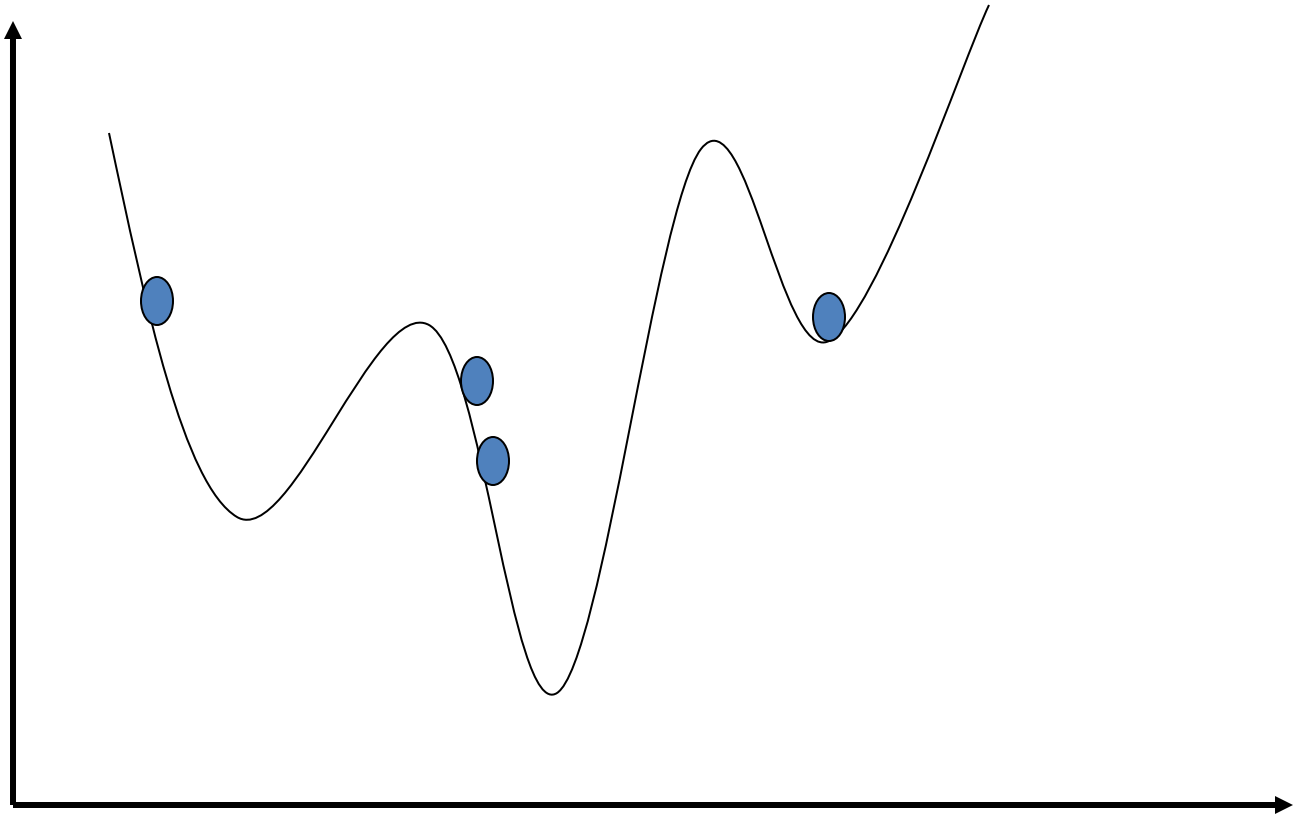
Local Beam Search



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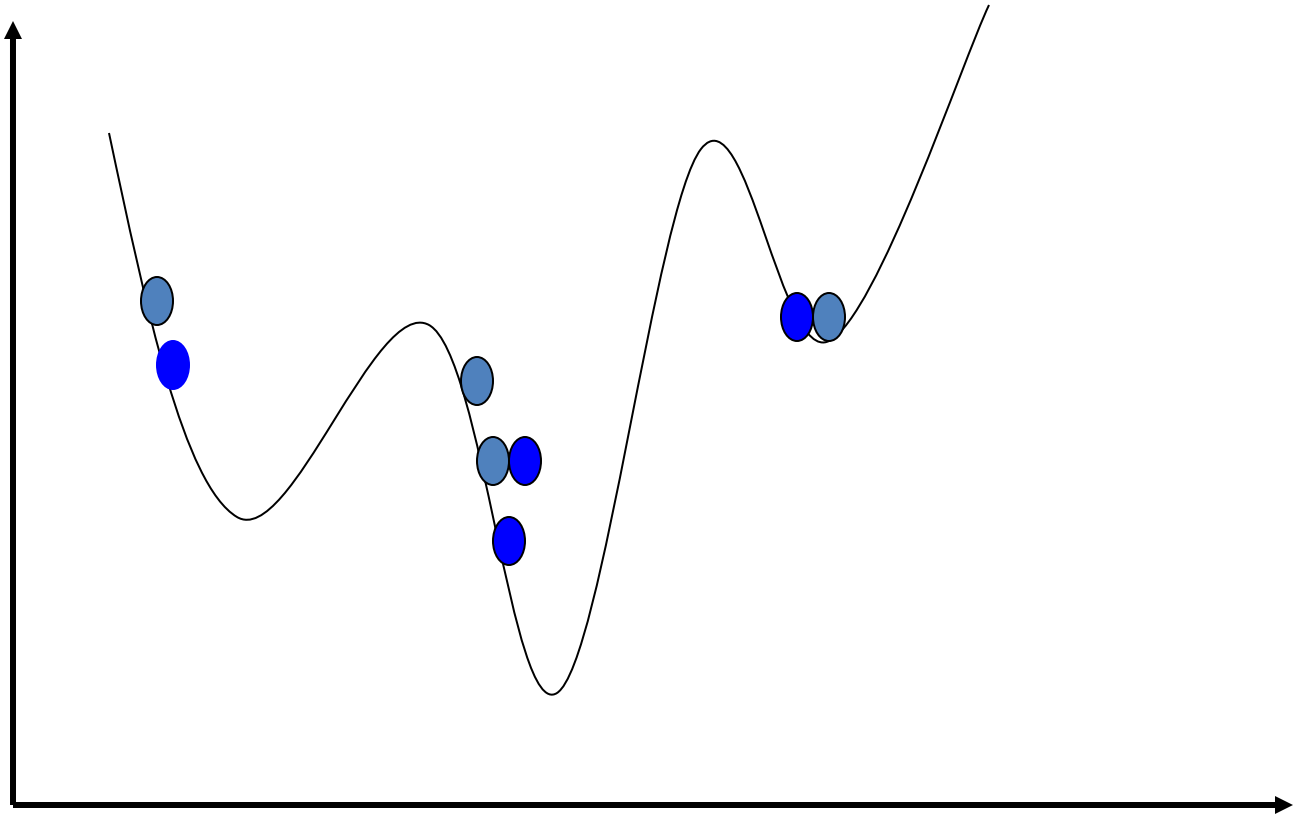
Local Beam Search



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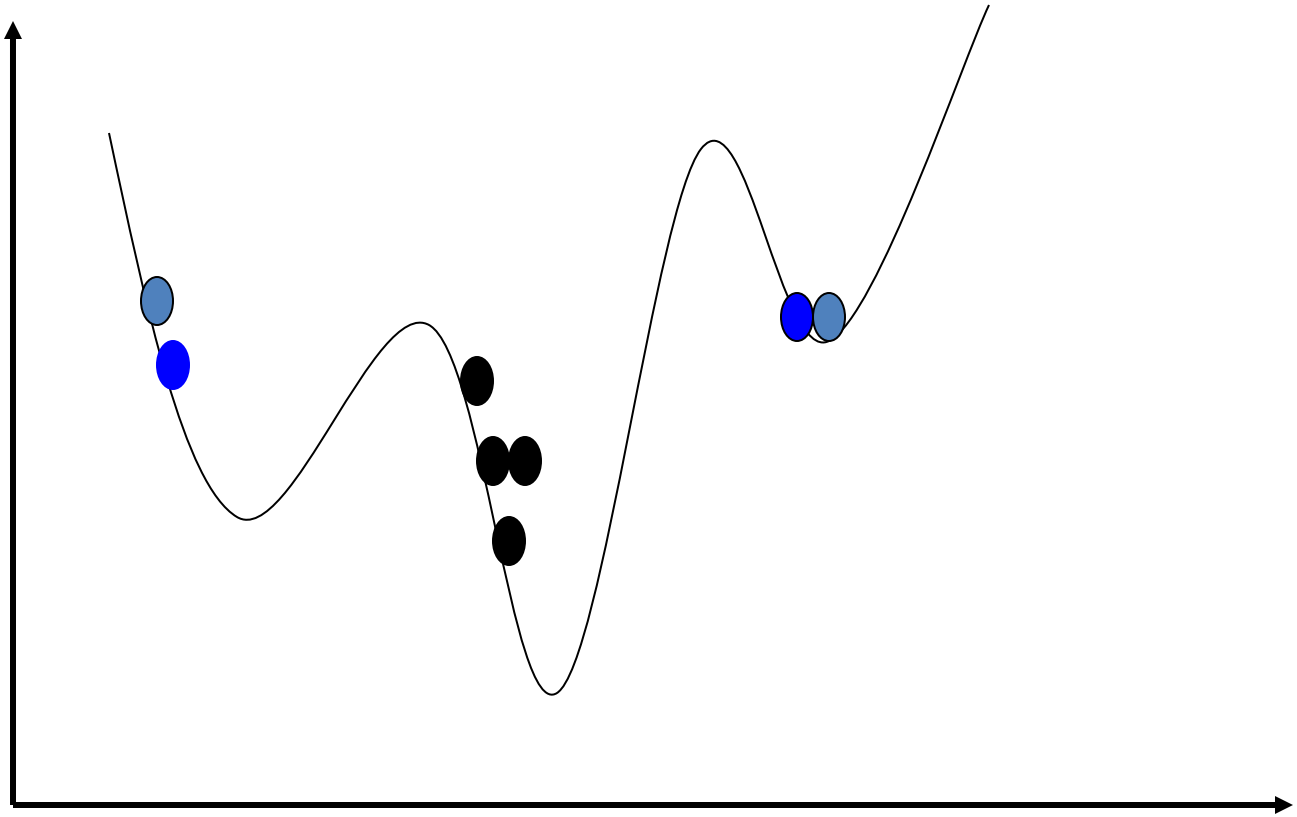
Local Beam Search



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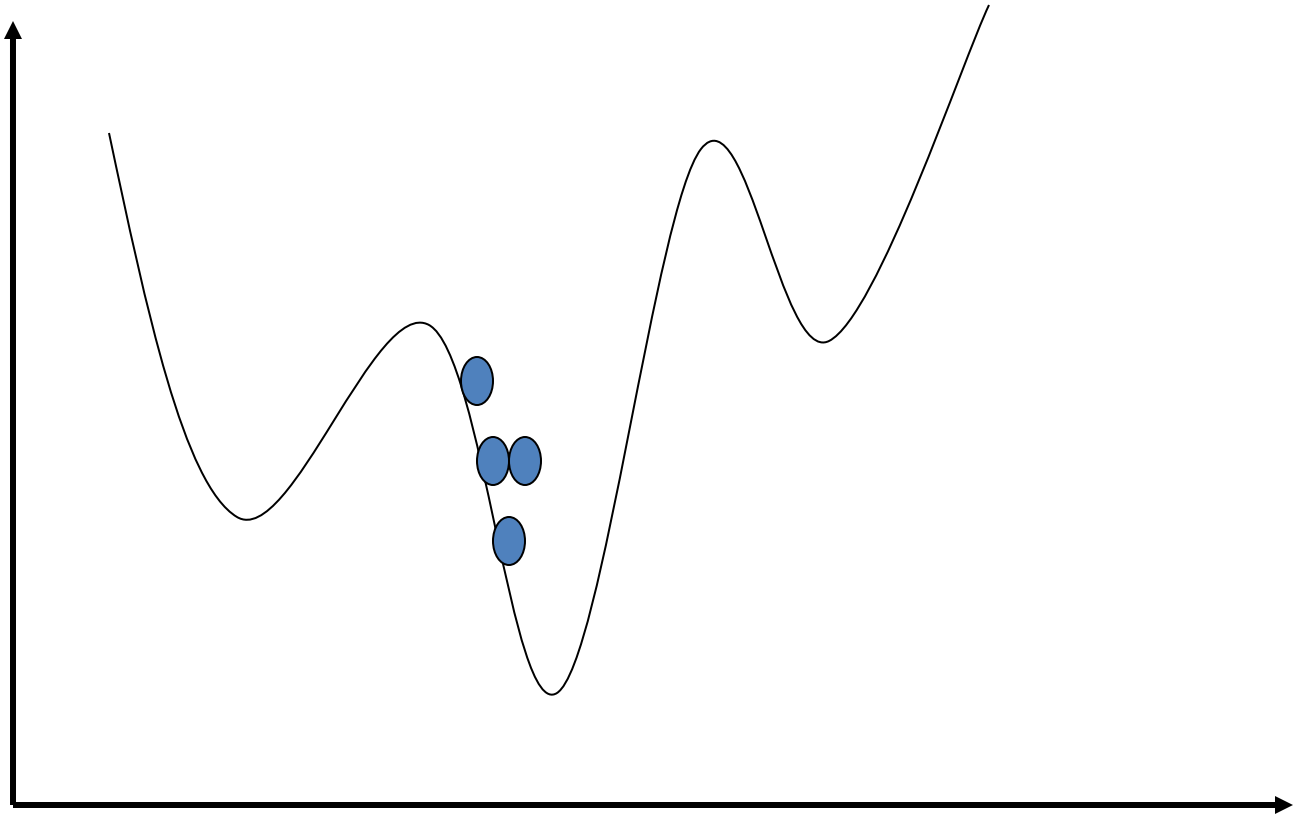
Local Beam Search



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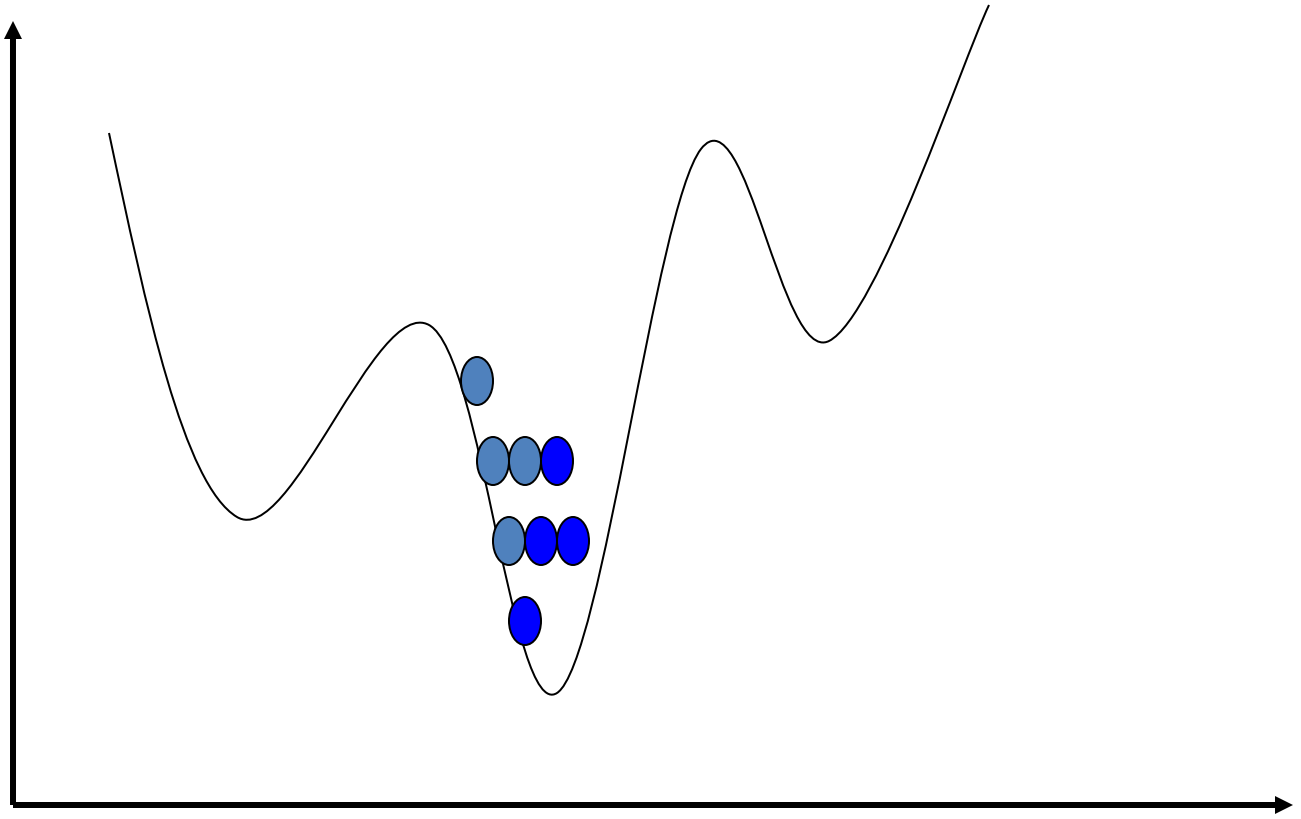
Local Beam Search



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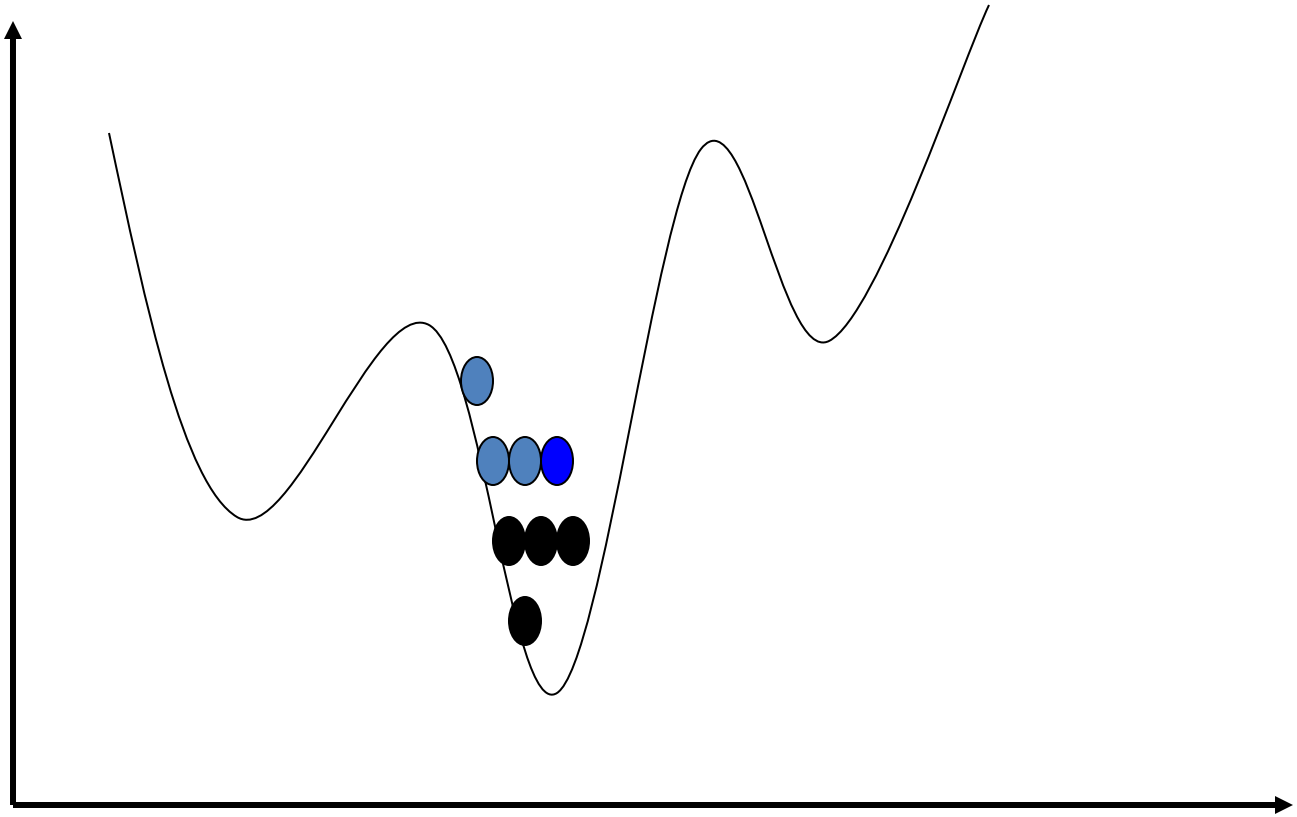
Local Beam Search



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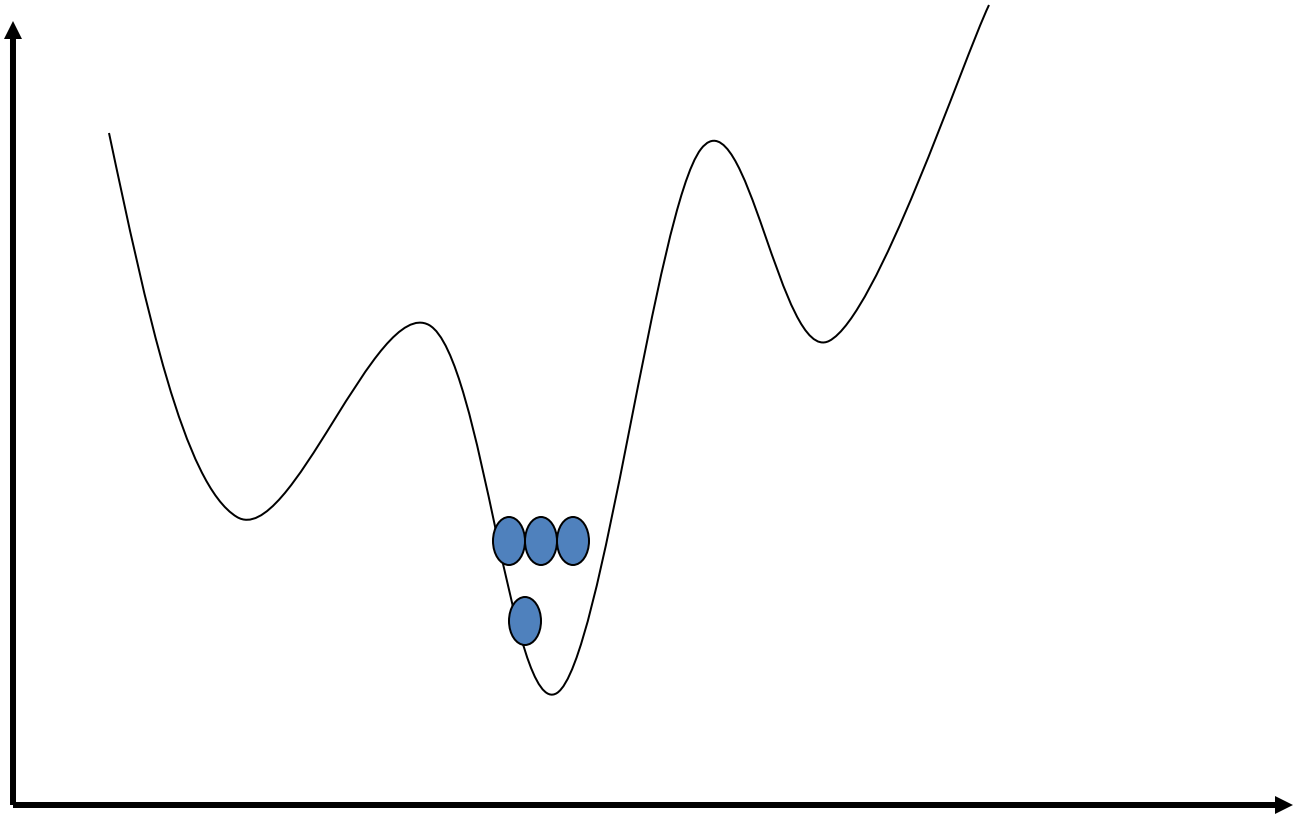
Local Beam Search



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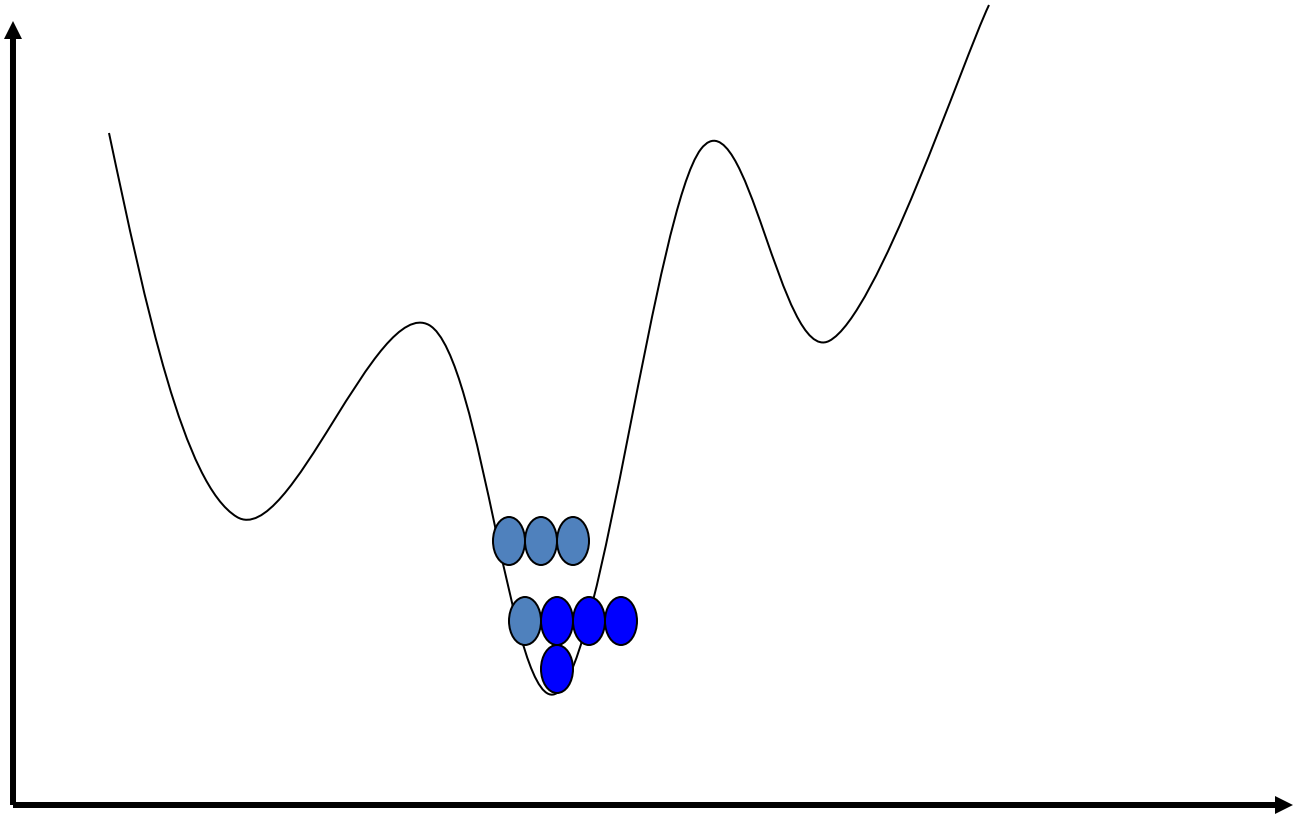
Local Beam Search



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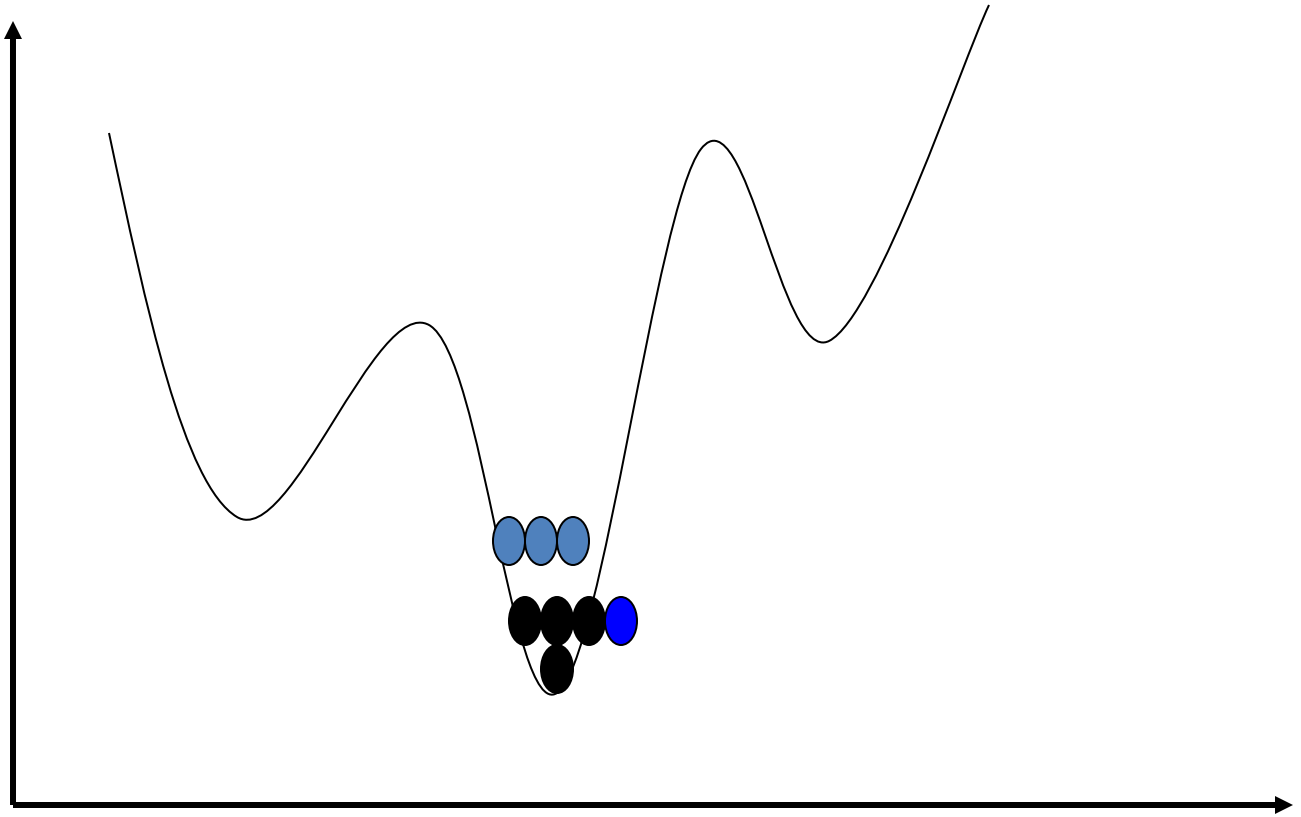

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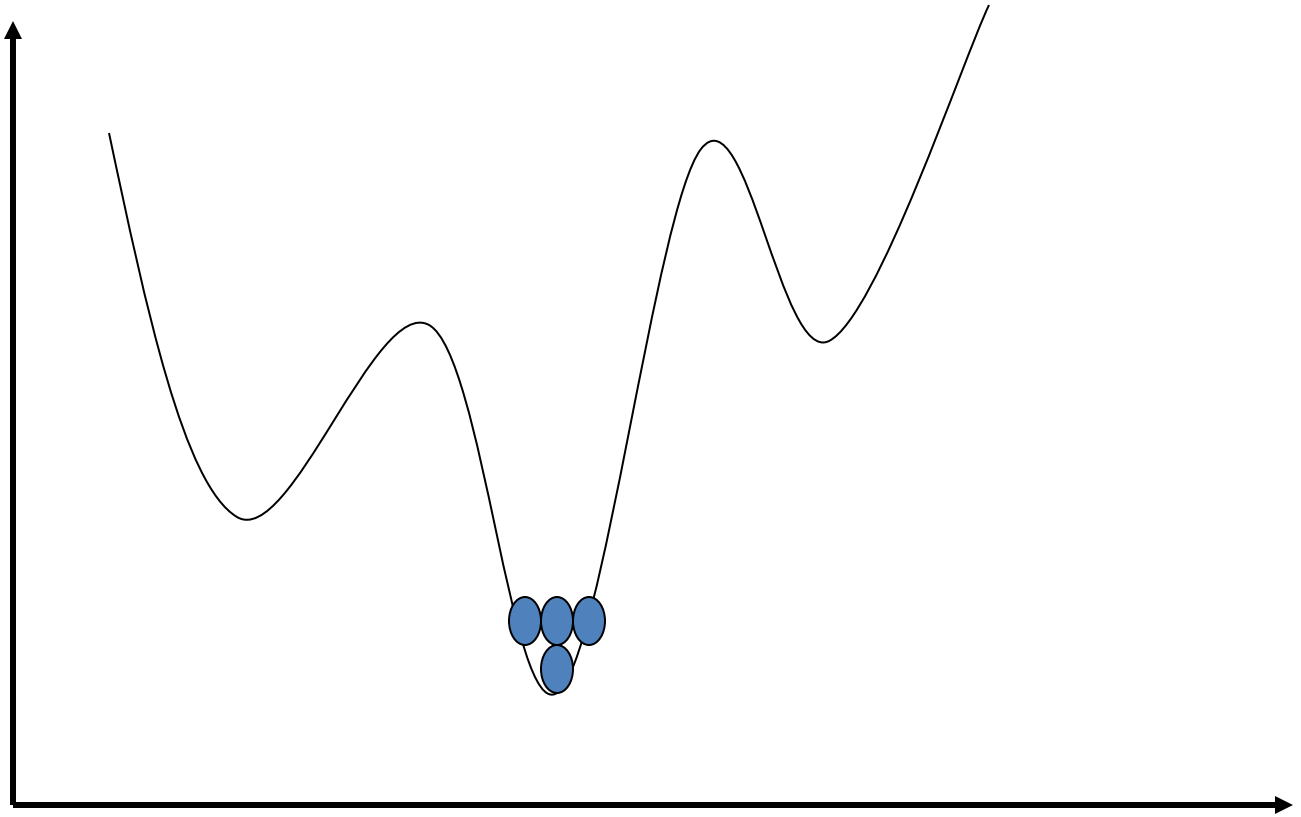
Local Beam Search



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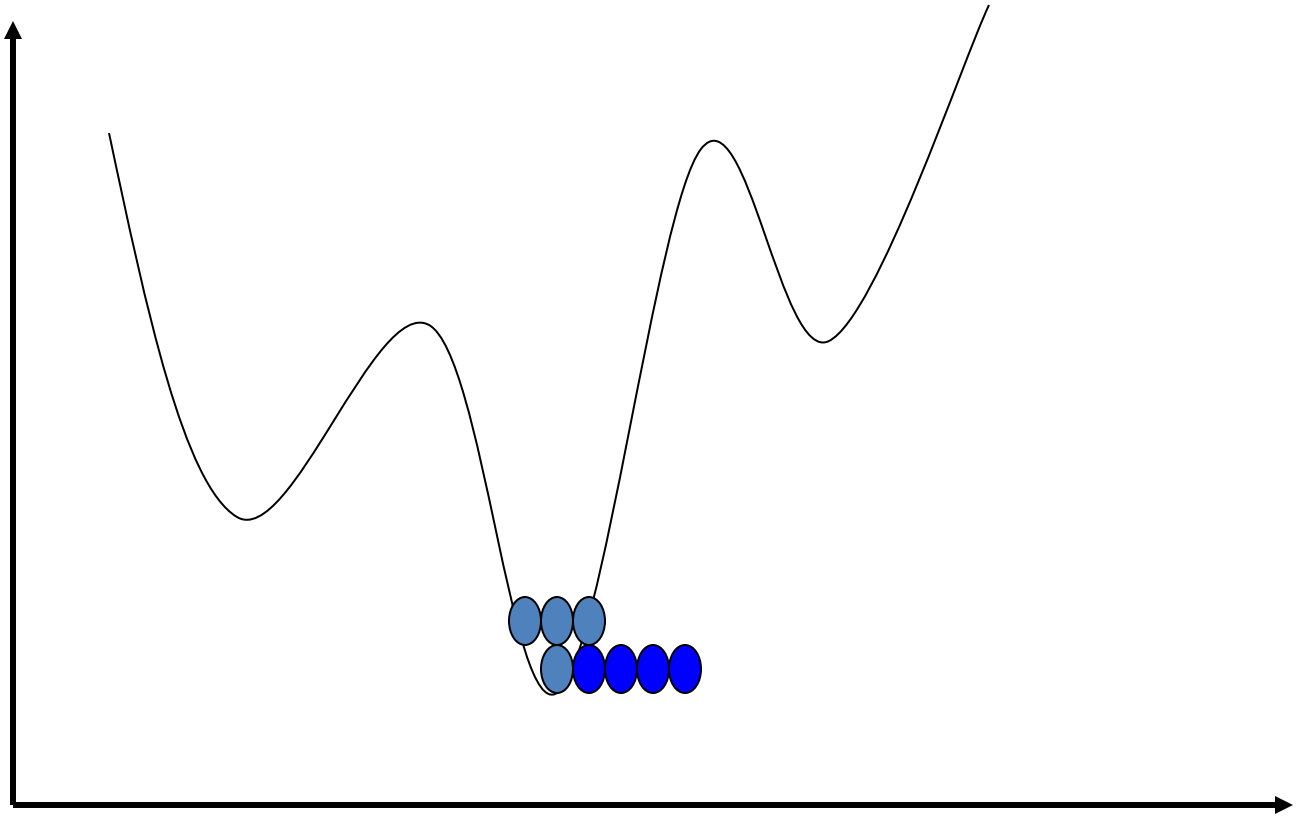
Local Beam Search



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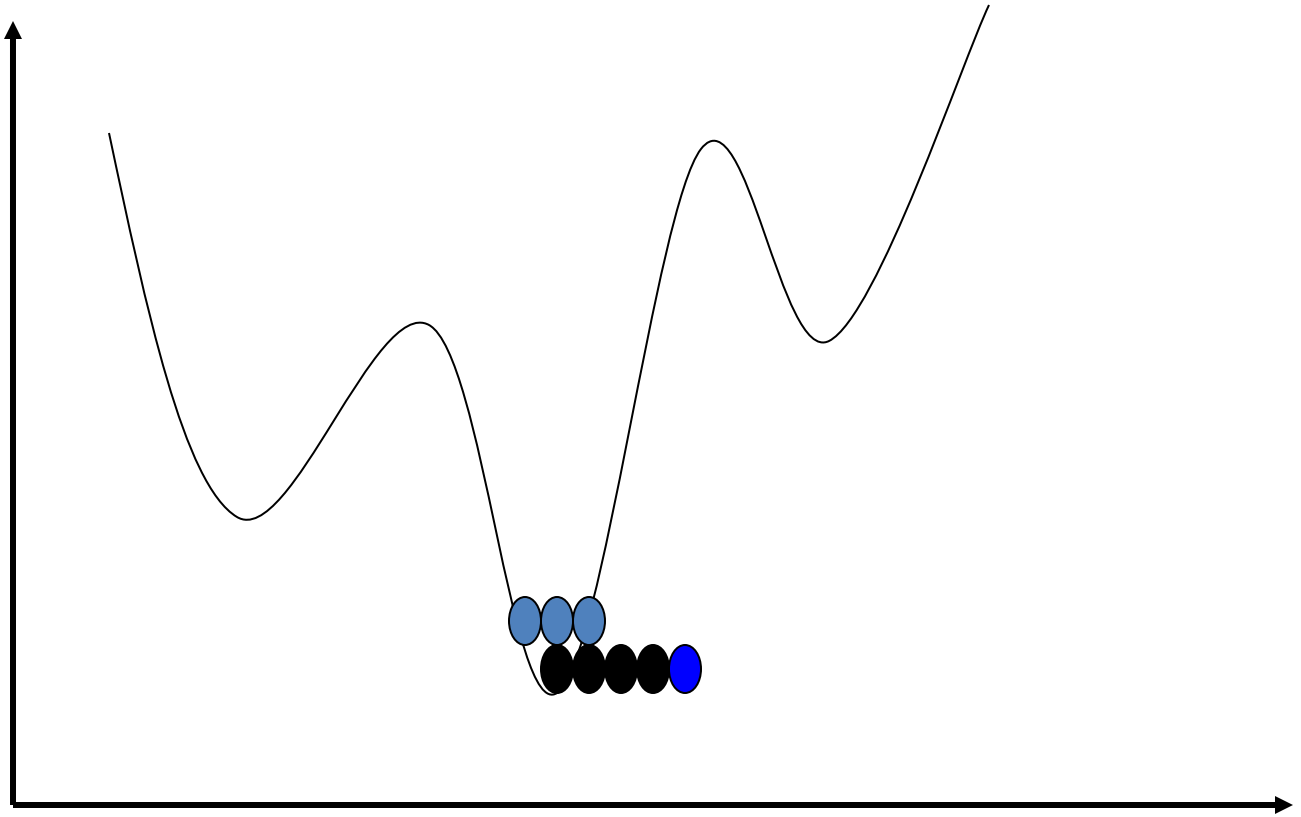
Local Beam Search



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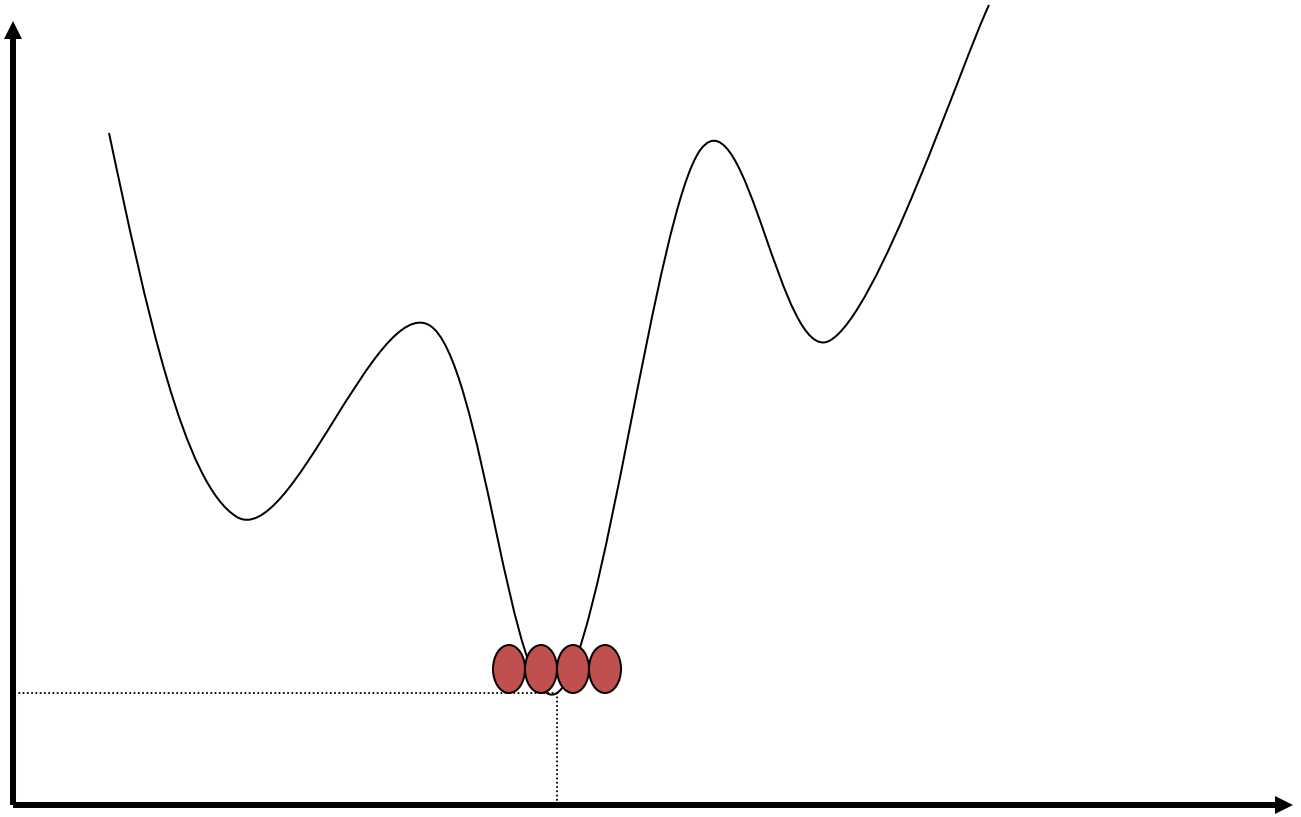
Local Beam Search



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Genetic Algorithm Search

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(course coordinator)

Genetic Algorithms

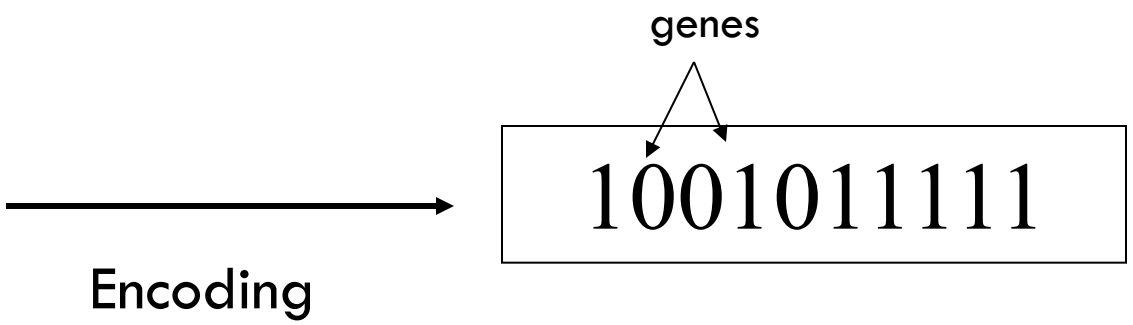
- Formally introduced in the US in the 70s by John Holland.
- GAs emulate ideas from genetics and natural selection and can search potentially large spaces.
- Before we can apply Genetic Algorithm to a problem, we need to answer:

  - How is an individual represented?
  - What is the fitness function?
  - How are individuals selected?
  - How do individuals reproduce?

Genetic Algorithms: Representation of states (solutions)

- Each state or individual is represented as a string over a finite alphabet. It is also called **chromosome** which Contains **genes**.

Solution: 607



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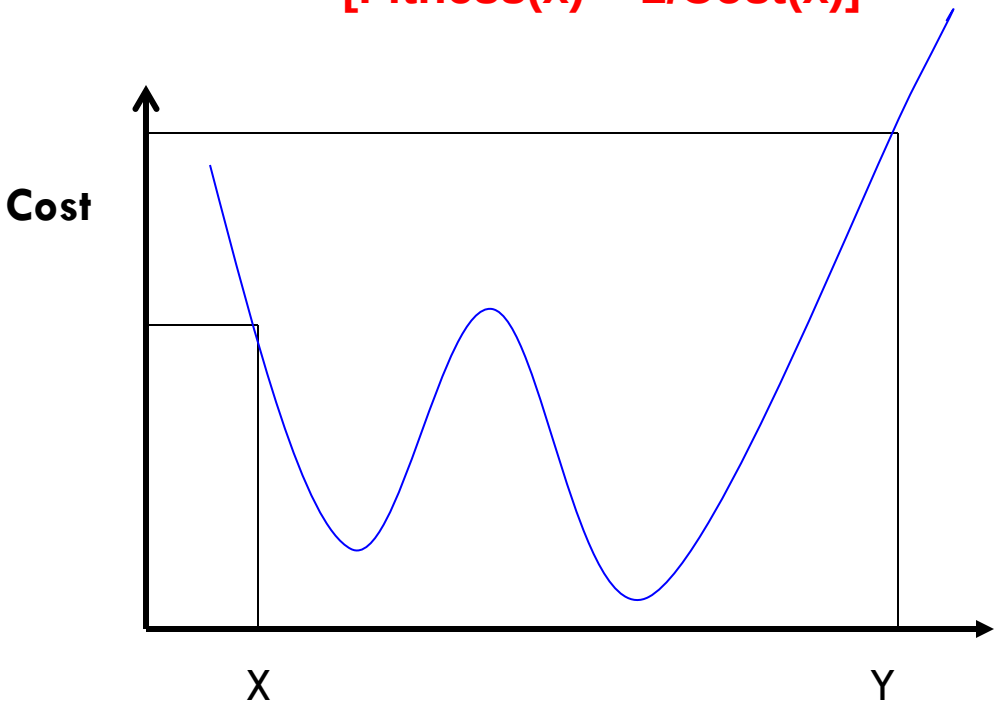
Genetic Algorithms: Fitness Function

- Each state is rated by the evaluation function called **fitness function**. Fitness function should return higher values for better states:

Fitness(X) should be greater than Fitness(Y) !!

[Fitness(x) = 1/Cost(x)]



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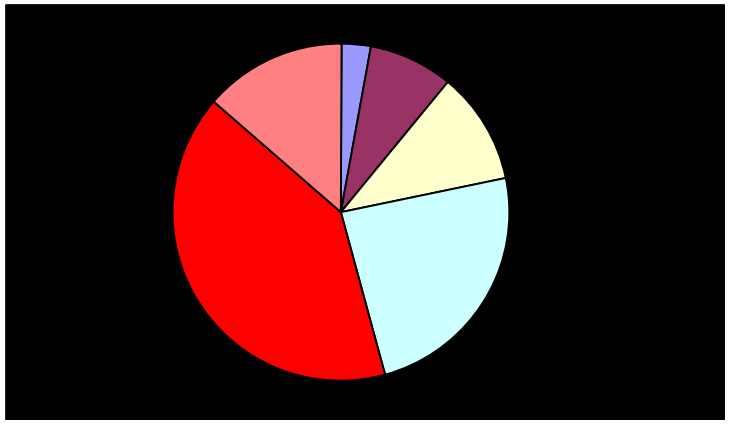
GA Parent Selection - Roulette Wheel



- **Sum the fitnesses of all the population members, *TF***
- **Generate a random number, *m*, between 0 and *TF***
- **Return the first population member whose fitness added to the preceding population members is greater than or equal to *m***

Roulette Wheel Selection

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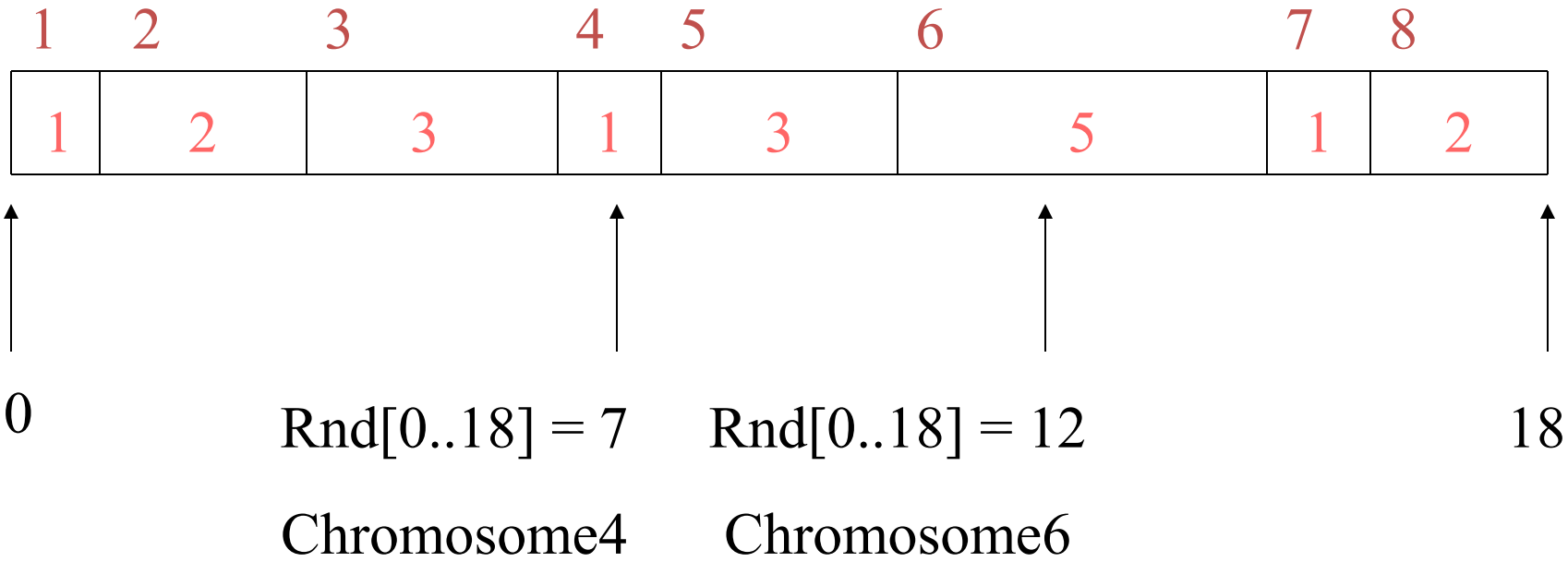
Genetic Algorithms: Selection

How are individuals selected ?

Roulette Wheel Selection



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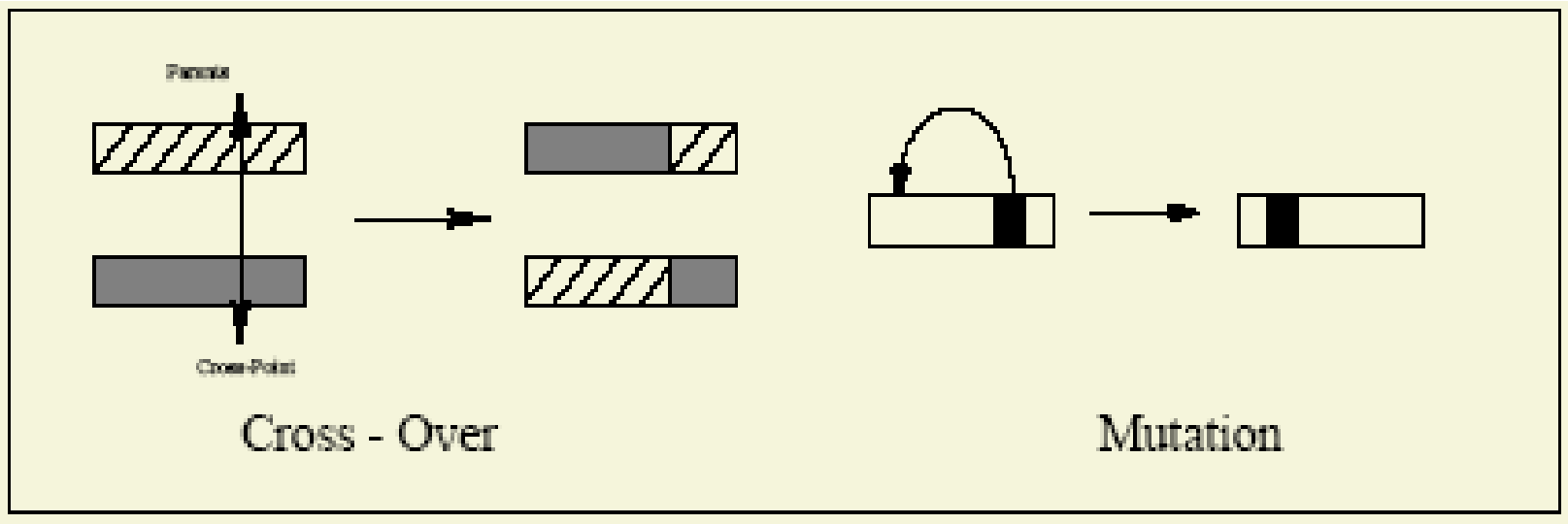
Genetic Algorithms: Cross-Over and Mutation

How do individuals reproduce ?



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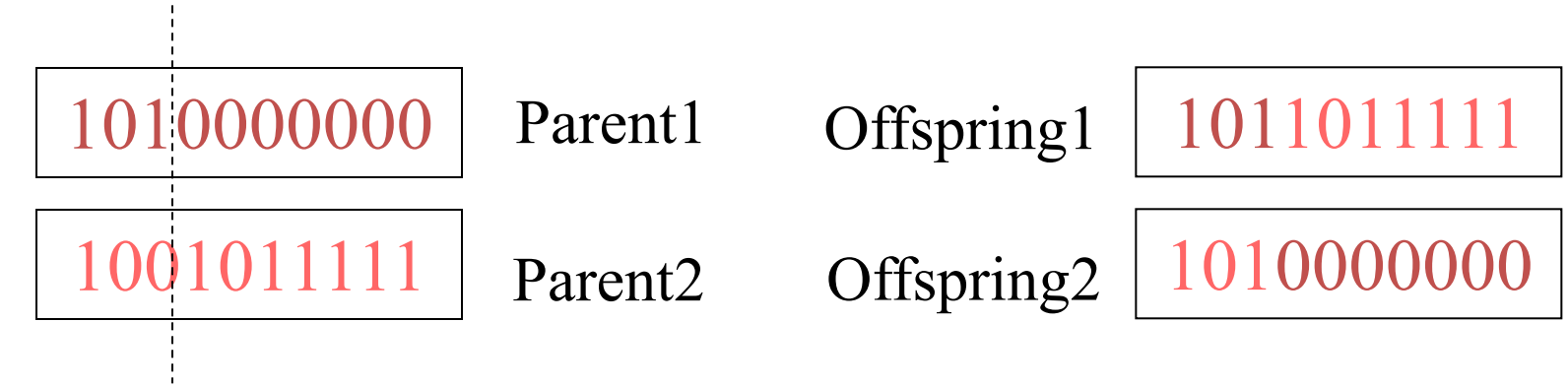
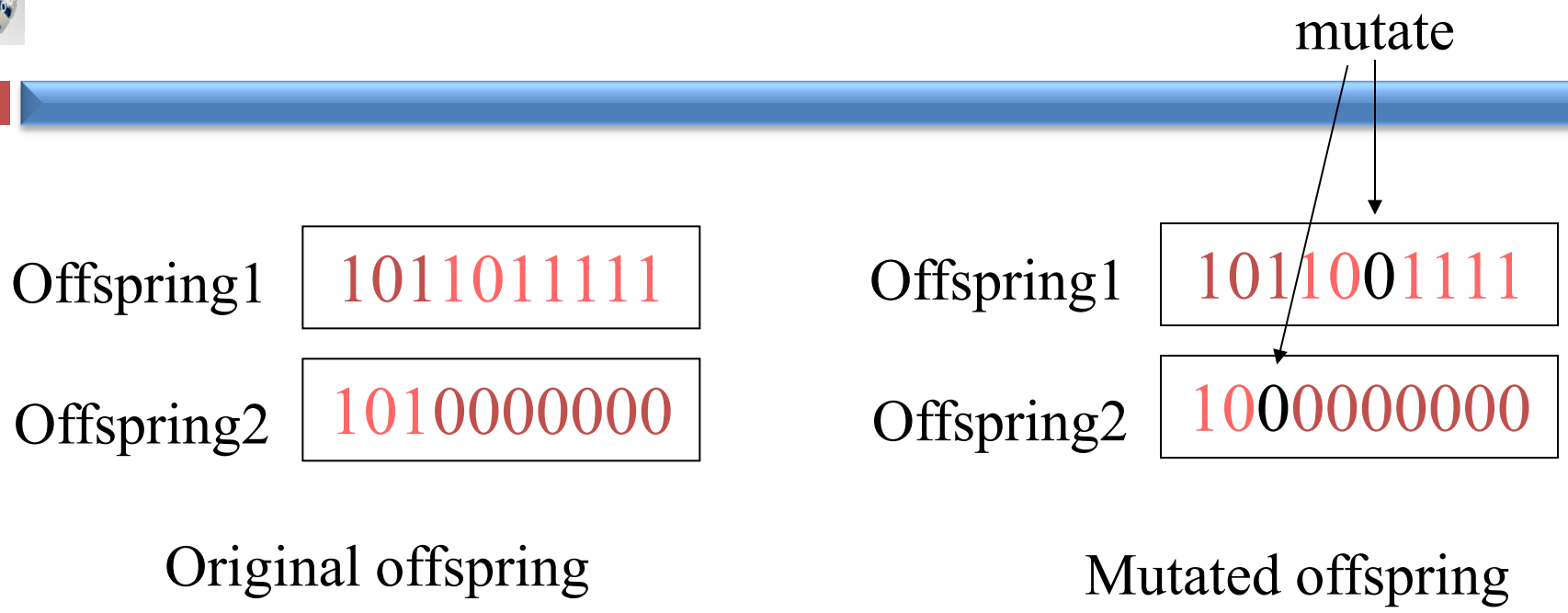
Genetic Algorithms
Crossover - Recombination



Crossover single point - random

With some high probability (*crossover rate*) apply crossover to the parents. (*typical values are 0.8 to 0.95*)

Stochastic Search: Genetic Algorithms Mutation



With some small probability (the *mutation rate*) flip each bit in the offspring (*typical values between 0.1 and 0.001*)

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- Given the following parents, P_1 and P_2, and the template T
- Show how the following crossover operators work uniform crossover

P_1	A	B	C	D	E	F	G	H	I	J
P_2	E	F	J	H	B	C	I	A	D	G
T	1	0	1	1	0	0	0	1	0	1

C_1	A	F	C	D	B	C	I	H	D	J
C_2	E	B	J	H	E	F	G	A	I	G

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- If P_3 and P_2 are chosen as parents and we apply one point crossover show the resulting children, C_1 and C_2. Use a crossover point of 1 (first digit)
- Do the same using P_4 and P_2 with a crossover point of 2(two digit) and create C_3 and C_4
- Do multiple point crossover using parent P1 and P3 to give C5 and C6 on digts 1 and 4

Chromosome	Binary String
P_1	11100
P_2	01111
P_3	10111
P_4	00100

Chromosome	Binary String
C_1	11111
C_2	00111
C_3	00111
C_4	01100

C_5	10110
C_6	11101

Genetic Algorithms

Algorithm:

1. Initialize population with **p** Individuals at random
2. For each Individual **h** compute its fitness
3. While max fitness < threshold do
   Create a new generation Ps
4. Return the Individual with highest fitness

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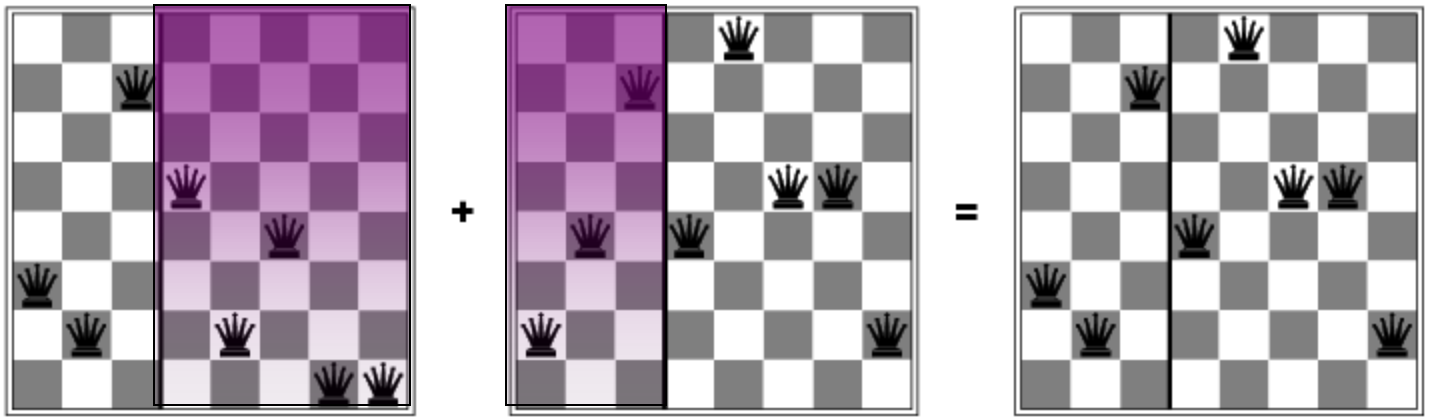
Genetic algorithms



Has the effect of "jumping" to a completely different new part of the search space (quite non-local)

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Thank you

End of Chapter 4

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