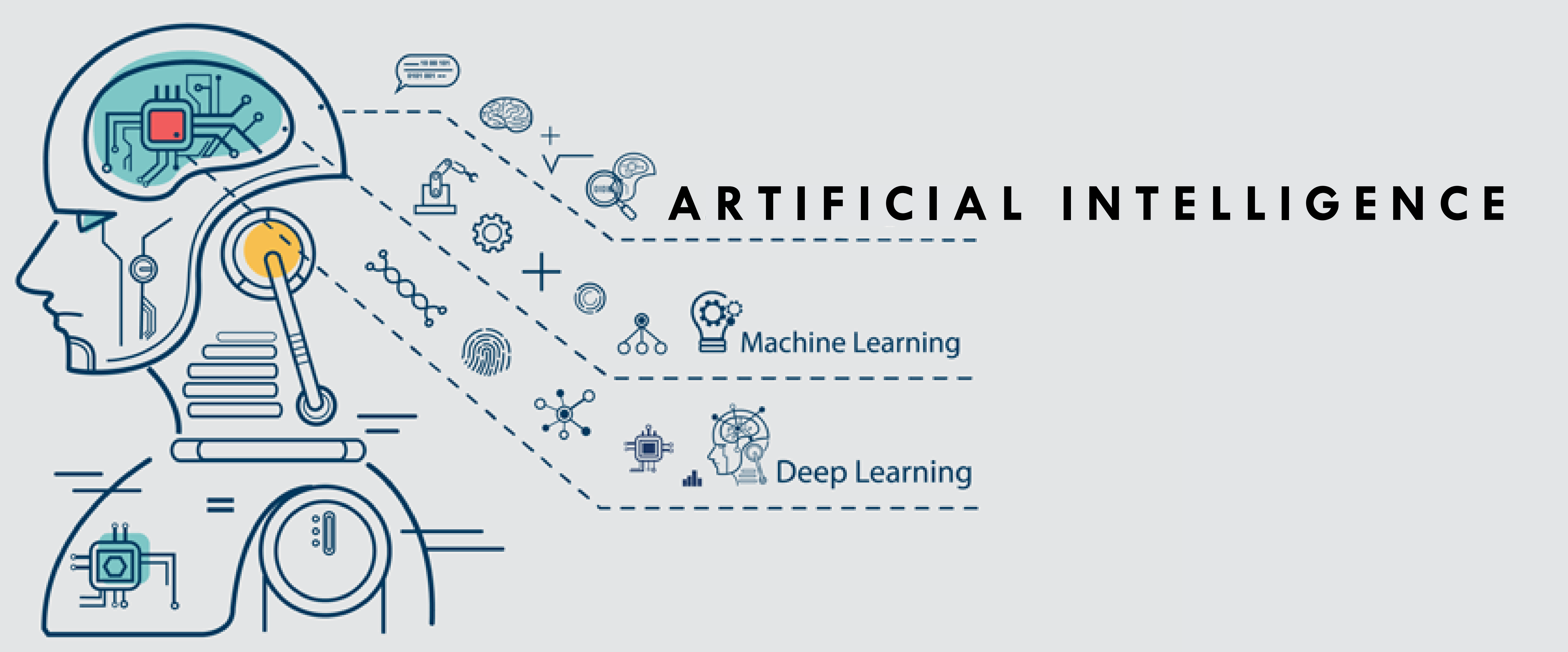


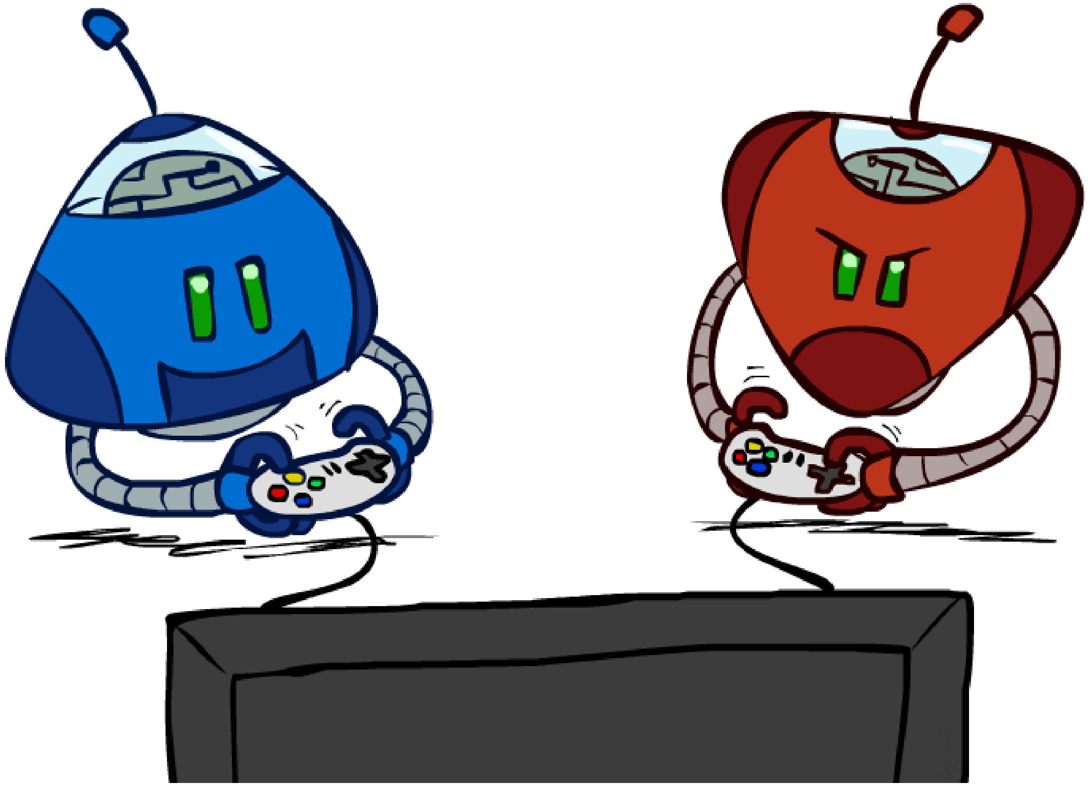
Dr. Seemab latif

Lecture 7

24th Oct 2024

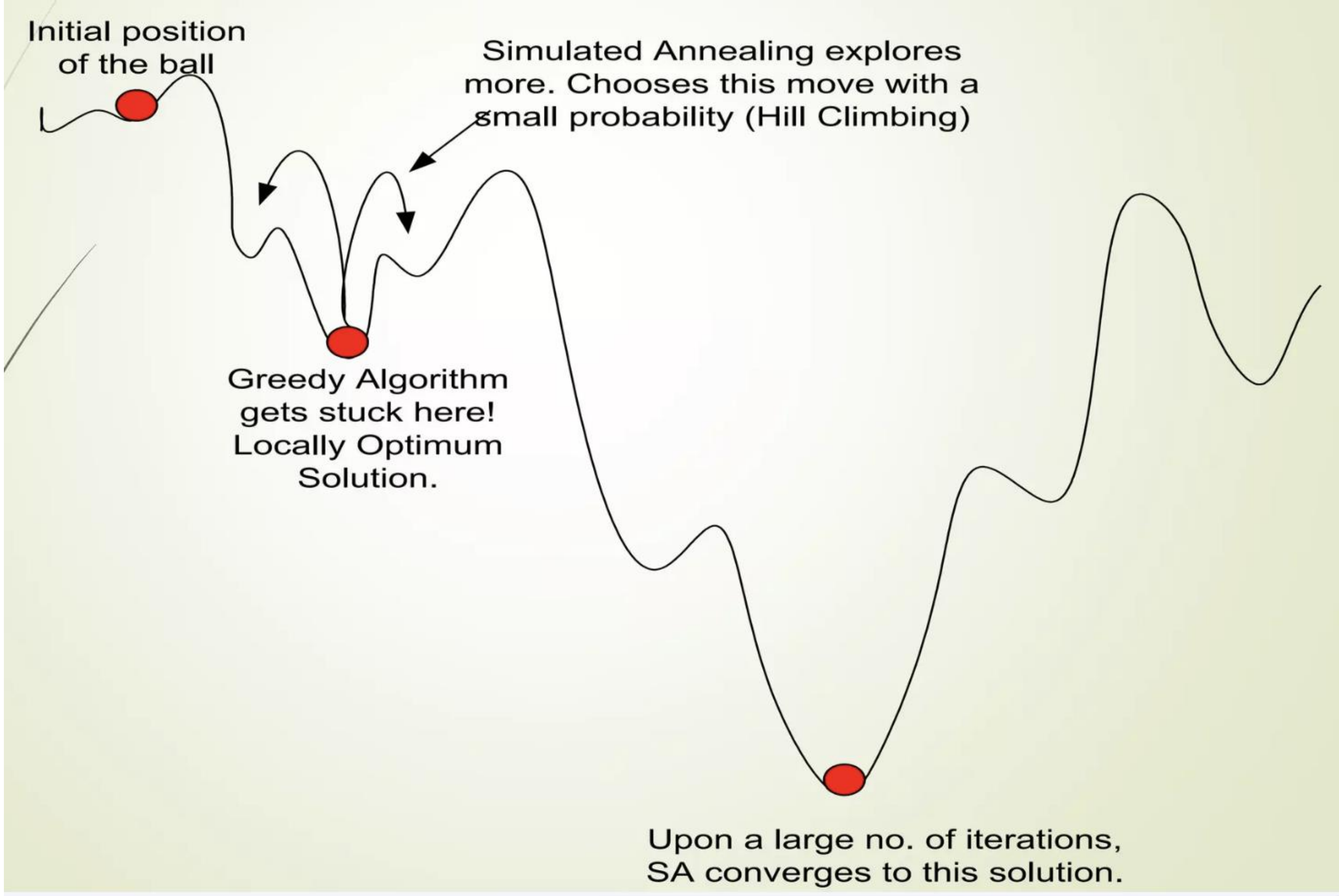
AI: Representation and Problem Solving

Local Search

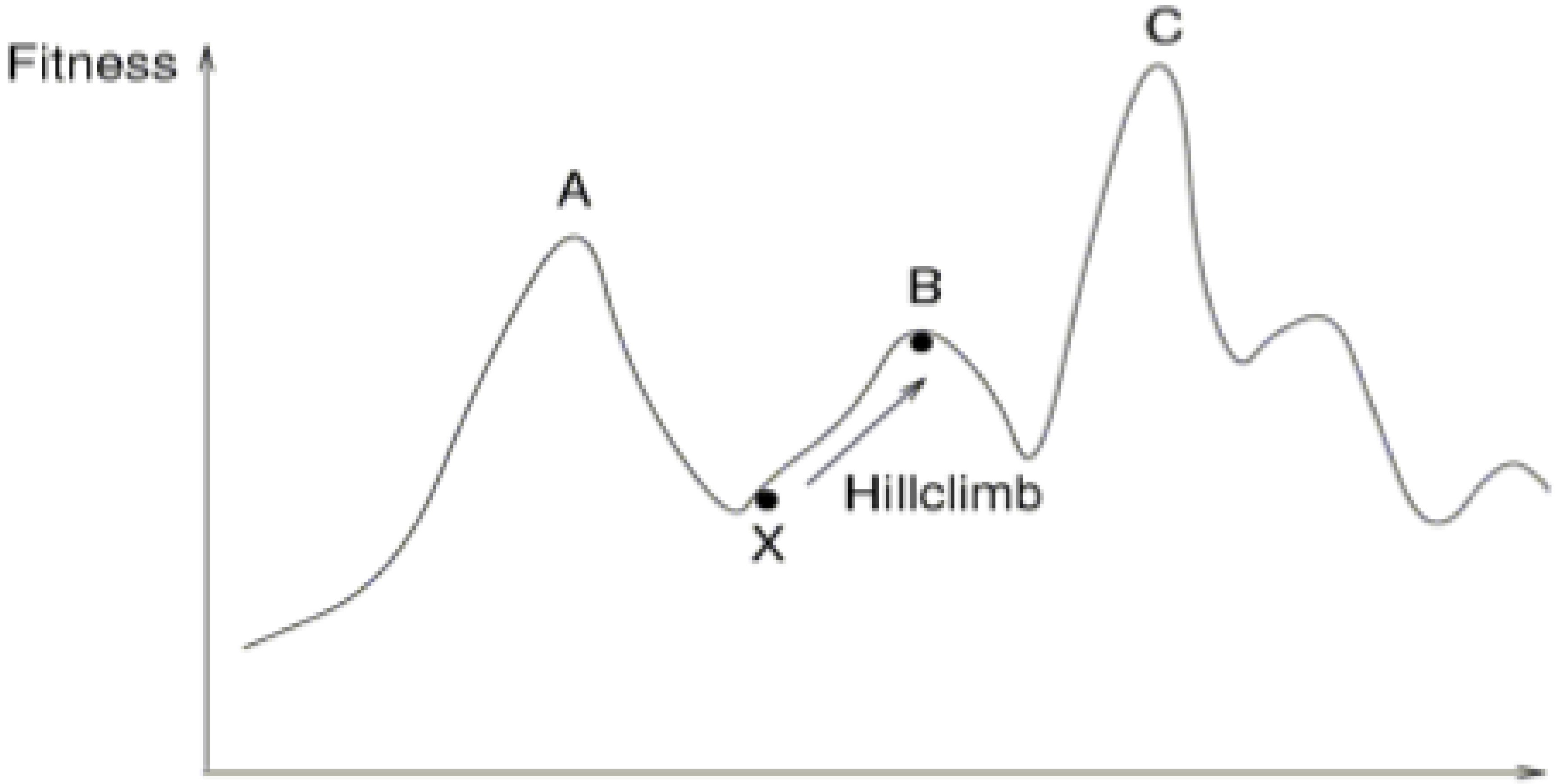


Slide credits: Pat Virtue, http://ai.berkeley.edu

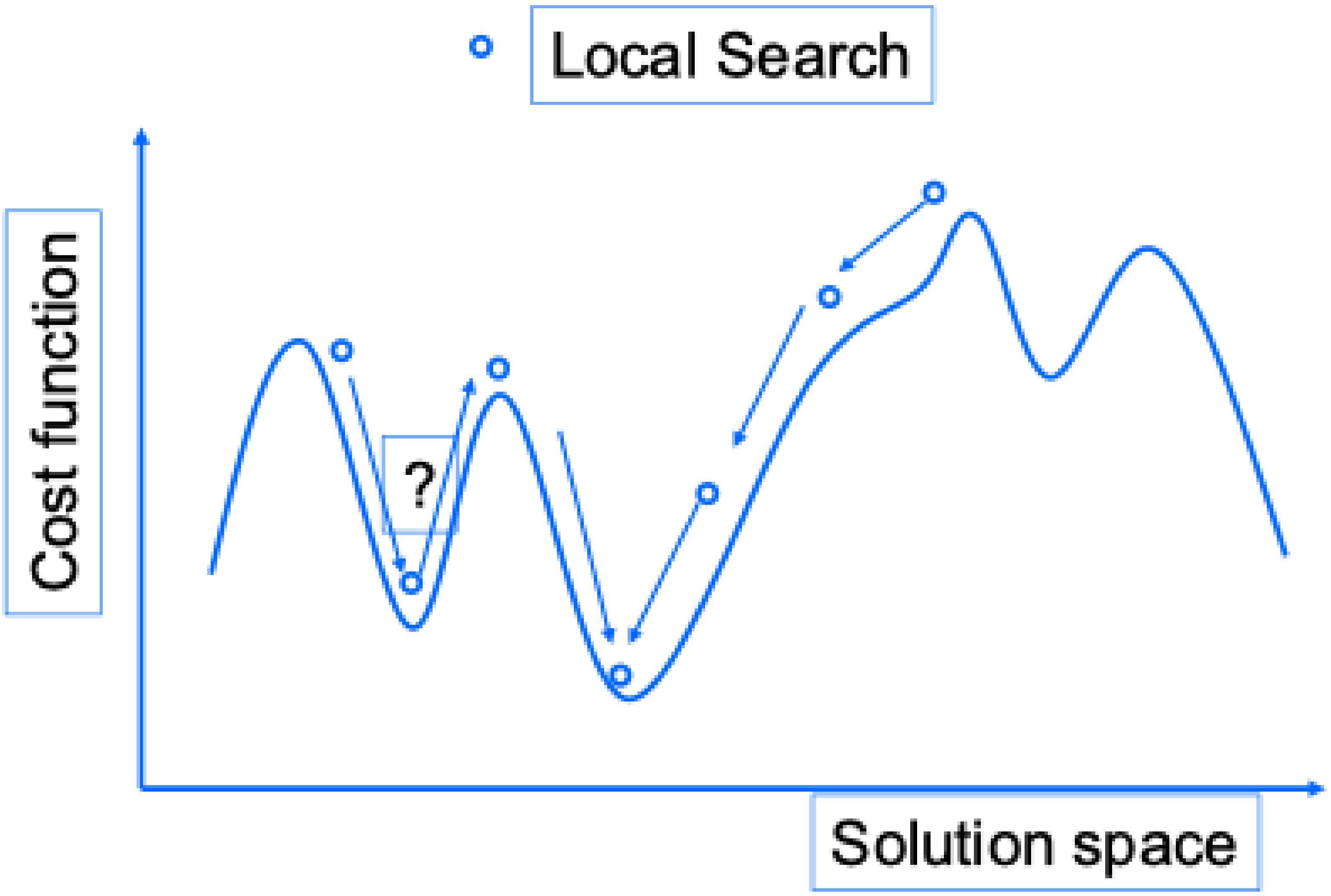
Hill climbing



Hill climbing



Simulated Annealing



Annealing

- Annealing is a thermal process for obtaining low energy states of a solid in a heat bath.
- The process contains two steps:
  - Increase the temperature of the heat bath to a maximum value at which the solid melts.
  - Decrease carefully the temperature of the heat bath until the particles arrange themselves in the ground state of the solid. Ground state is a minimum energy state of the solid.
- The ground state of the solid is obtained only if the maximum temperature is high enough and the cooling is done slowly.

https://www.youtube.com/watch?v=9kWWKgiBh-Q

Simulated Annealing

- To apply simulated annealing with optimization purposes we require the following:
  - A successor function that returns a “close” neighboring solution given the actual one. This will work as the “disturbance” for the particles of the system.
  - A target function to optimize that depends on the current state of the system. This function will work as the energy of the system.
- The search is started with a randomized state. In a polling loop we will move to neighboring states always accepting the moves that decrease the energy while only accepting bad moves accordingly to a probability distribution dependent on the “temperature” of the system.

Simulated Annealing

- Decrease the temperature slowly, accepting less bad moves at each temperature level until at very low temperatures the algorithm becomes a greedy hill-climbing algorithm.
- The distribution used to decide if we accept a bad movement is know as Boltzman distribution.
- This distribution is very well known is in solid physics and plays a central role in simulated annealing. Where γ is the current configuration of the system, E γ is the energy related with it, and Z is a normalization constant.

$$P(\gamma) = \frac{e^{-E_\gamma/T}}{Z(T)},$$

$$Z(T) = \sum_{\gamma'} e^{-E_{\gamma'}/T},$$

Annealing Process

- Raising the temperature up to a very high level (melting temperature, for example), the atoms have a higher energy state and a high possibility to re-arrange the crystalline structure.
- Cooling down slowly, the atoms have a lower and lower energy state and a smaller and smaller possibility to re-arrange the crystalline structure.

Annealing - Analogy

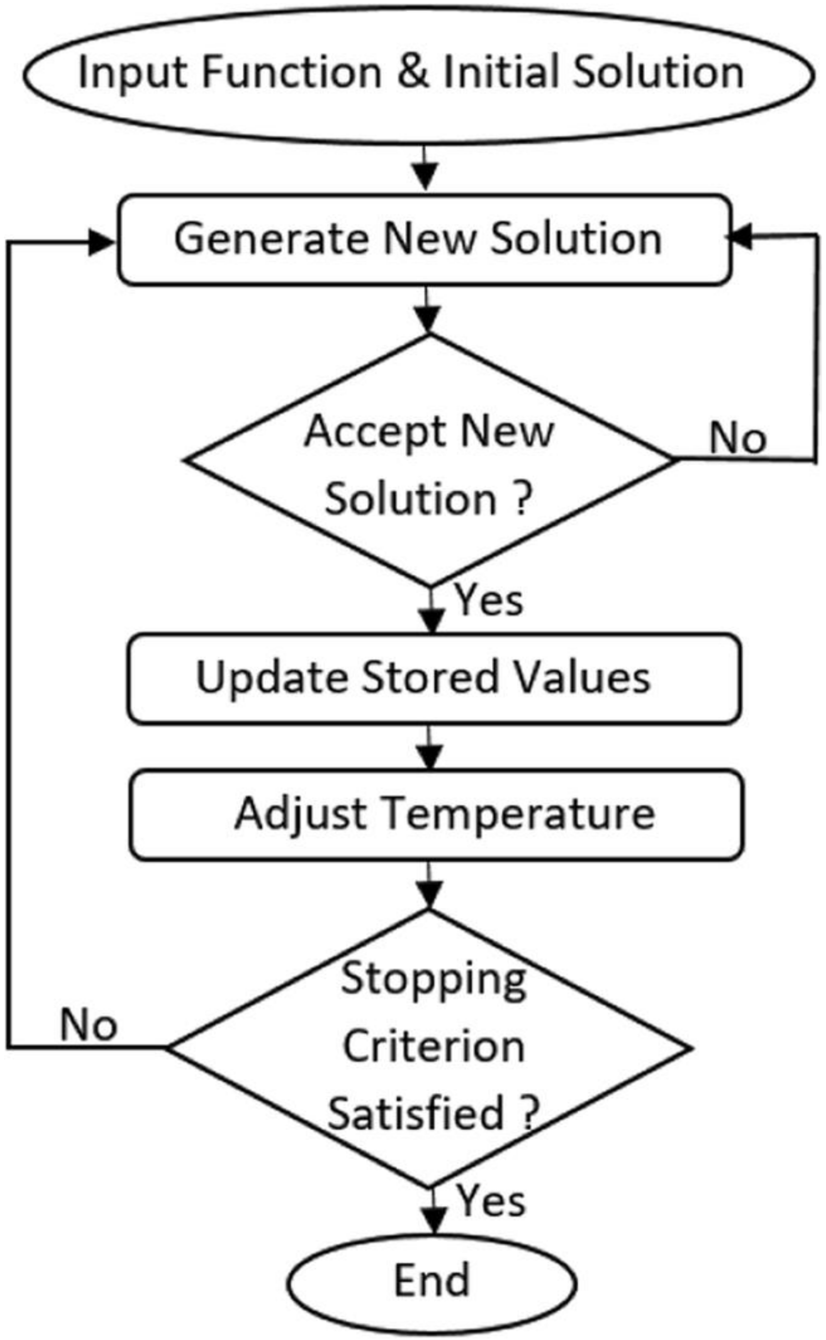
Physical System	Optimization Problem
State (configuration) →	Solution
Energy →	Cost function
Ground State →	Optimal solution
Rapid Quenching →	Iteration improvement
Careful Annealing →	Simulated annealing

Simulated Annealing - Analogy

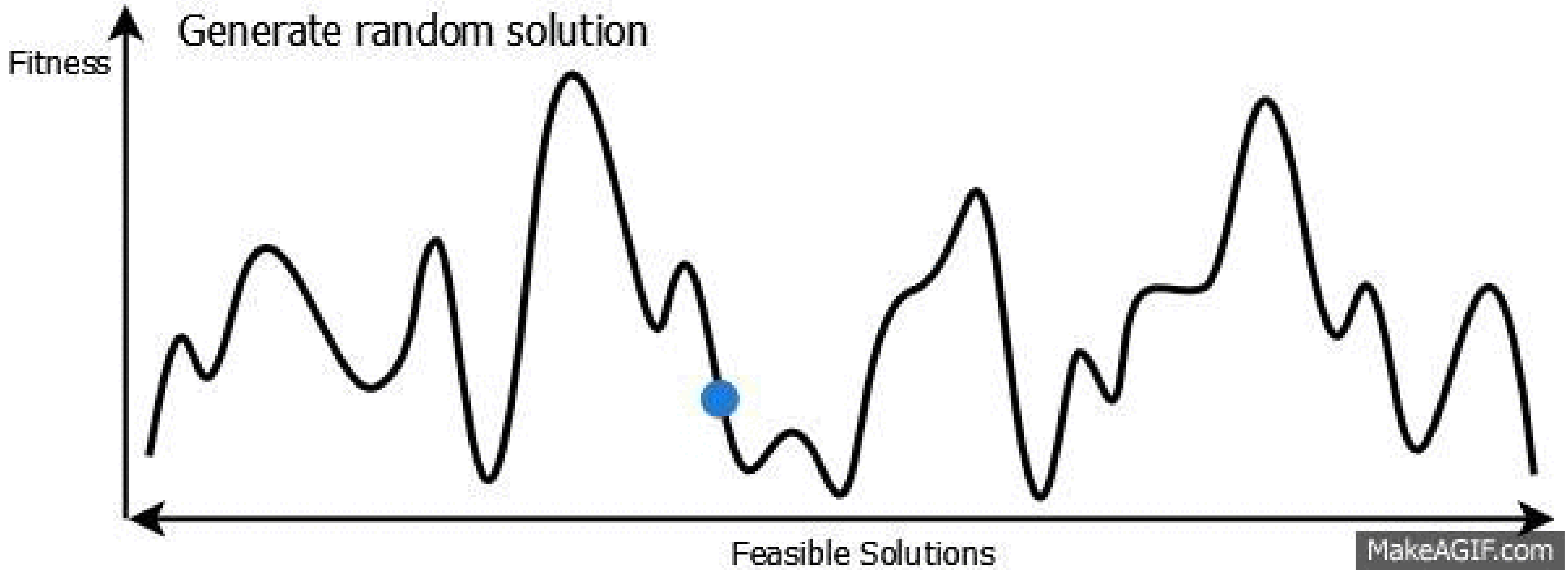
- Metal ←→ Problem
- Energy State ←→ Cost Function
- Temperature ←→ Control Parameter
- A completely ordered crystalline structure ←→ the optimal solution for the problem

Global optimal solution can be achieved as long as the cooling process is slow enough.

Simulated Annealing Flow Chart



How SA explores the solution space



Conclusion

- SA is a global optimization technique.

- SA distinguishes between different local optima.
- SA is a memory less algorithm, the algorithm does not use any information gathered during the search
- SA is motivated by an analogy to annealing in solids.
- Simulated Annealing - an iterative improvement algorithm

Solving Sudku using SA

3			8		1			2
2		1		3		6		4
			2		4			
8		9				1		6
	6						5	
7		2				4		9
			5		9			
9		4		8		7		5
6			1		7			3

Steps for solving Sudoku

1- Generating random states

5	2	4	4	3	7	6	8	9
6	7	9	1	5	9	2	7	3
8	1	3	6	8	2	4	1	5
4	3	1	6	7	5	4	8	1
5	8	6	1	8	9	9	3	2
7	9	2	2	3	4	7	6	5
2	8	9	7	1	5	8	4	2
6	4	5	2	9	3	9	1	3
3	1	7	8	6	4	7	5	6

Steps for solving Sudoku

1- Generating random states

2- Writing a cost function

1	5	2	4	4	3	7	6	8	9
2	6	9	7	1	5	9	2	7	3
2	8	1	3	6	8	2	4	1	5
1	4	3	1	6	7	5	4	8	1
2	5	8	6	1	8	9	9	3	2
2	7	9	2	2	3	4	7	6	5
2	2	8	9	7	1	5	8	4	2
2	6	4	5	2	9	3	9	1	3
2	3	1	7	8	6	4	7	5	6
	2	3	1	3	2	3	3	2	3

Total cost $= 38$

Steps for solving Sudoku

1- Generating random states

2- Writing a cost function

3- Selecting starting temperature

1	5	2	4	4	3	7	6	8	9
2	6	9	7	1	5	9	2	7	3
2	8	1	3	6	8	2	4	1	5
1	4	3	1	6	7	5	4	8	1
2	5	8	6	1	8	9	9	3	2
2	7	9	2	2	3	4	7	6	5
2	2	8	9	7	1	5	8	4	2
2	6	4	5	2	9	3	9	1	3
2	3	1	7	8	6	4	7	5	6
	2	3	1	3	2	3	3	2	3

Total cost = 38

Steps for solving Sudoku

1- Generating random states

2- Writing a cost function

3- Selecting starting temperature

4- Calculating iterations per T

1	5	2	4	4	3	7	6	8	9
2	6	9	7	1	5	9	2	7	3
2	8	1	3	6	8	2	4	1	5
1	4	3	1	6	7	5	4	8	1
2	5	8	6	1	8	9	9	3	2
2	7	9	2	2	3	4	7	6	5
2	2	8	9	7	1	5	8	4	2
2	6	4	5	2	9	3	9	1	3
2	3	1	7	8	6	4	7	5	6
	2	3	1	3	2	3	3	2	3

Total cost = 38

Steps for solving Sudoku

1- Generating random states

2- Writing a cost function

3- Selecting starting temperature

4- Calculating iterations per T

5- Choosing a cooling rate

1	5	2	4	4	3	7	6	8	9
2	6	9	7	1	5	9	2	7	3
2	8	1	3	6	8	2	4	1	5
1	4	3	1	6	7	5	4	8	1
2	5	8	6	1	8	9	9	3	2
2	7	9	2	2	3	4	7	6	5
2	2	8	9	7	1	5	8	4	2
2	6	4	5	2	9	3	9	1	3
2	3	1	7	8	6	4	7	5	6
	2	3	1	3	2	3	3	2	3

Total cost $= 38$