كلية الحاسبات والذكاء الاصطناعي

FACULTY OF COMPUTERS & ARTIFICIAL INTELLIGENCE

Planning Techniques for Robotics
Lab 01 - Introduction

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2025/2026

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- **Teaching Assistant – AI Department** | Faculty of Computers and Artificial Intelligence – BU
- **Specialized in Artificial Intelligence and Machine Learning** (ML – Computer Vision – Optimization - Speech)
- **Specialized in Data Science** (Data Modeling – Databases – Data analytics – Data Orchestration – Big Data)
- **AWS Academy Graduate – Data Engineering**
- **Soon to be Huawei associate certified in HCIA – Big Data** (Huawei Certified ICT Associate)
- **Head member of training and job guidance unit** in BFCAI

SCAN ME

Join "Planning Techniques for Robotics – AI 25/26" Google Classroom

GUIDELINES

- You don't need to memorize what will be mentioned. Instead, try to understand
- Each PowerPoint Presentation will be available as PDF file on Google Drive Folder of the Course
- Any miscellaneous for the course (i.e. Software, packages, libraries … etc) will be available
- The grade system will be out of **(100 Points)** to guarantee a fair grading for each student
- There are (5) points based on **Attendance**, as there will be approximately **11 Labs**
- There are (20) points based on **Activities**, as there will be 5 assignments , 5 tasks along the semester and 10 worksheets
- There are (25) points based on **Quizzes**, as there will be 5 quizzes along the semester.
- There are (50) points based on **RR and Project**, as there will be a research report and project along the semester.

International Journal of Data Science and Analytics
https://doi.org/10.1007/s41060-025-00876-y

REGULAR PAPER

Check for updates

Mayfly-based federated learning approach for early detection of fire

Mustafa Abdul Salam[1,2] · Elsayed Badr[2,3] · Aya Elbohoty[2]

Received: 16 January 2025 / Accepted: 9 July 2025
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Wide Use of Planning Techniques

Abstract

Fires pose serious threats to life and infrastructure, demanding fast and reliable detection. While traditional machine learning and deep learning models provide promising results, they often struggle with privacy risks, communication delays, and centralized data dependency. To address these challenges, we propose FedMA, a federated learning framework integrated with the Mayfly Optimization Algorithm (MA) and a Convolutional Neural Network (CNN) for early fire detection. MA enhances the optimization of local client models by balancing exploration and exploitation, leading to improved convergence and communication efficiency. The CNN model is trained on a balanced dataset of 28,600 fire and non-fire images sourced from Kaggle, Yandex, and Google Images. Experimental results show that FedMA achieves a detection accuracy of 97.76%, outperforming traditional Federated Averaging and Particle Swarm Optimization (FedPSO) in both accuracy and training efficiency. FedMA offers a scalable and privacy-preserving fire detection solution for real-world deployment.

Even in Routing

International Journal of Research and Engineering
ISSN: 2348-7860 (O) | 2348-7852 (P) | Vol. 5 No. 9 | September-October 2018 | PP. 500-507
Digital Object Identifier DOI® http://dx.doi.org/10.21276/ijre.2018.5.9.2
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IJRE

Solving Vehicle Routing Problem using Ant Colony Optimisation (ACO) Algorithm

ORIGINAL ARTICLE

Author(s): [1]*Wan Amir Fuad Wajdi Othman, [1]Aeizaal Azman Abd Wahab
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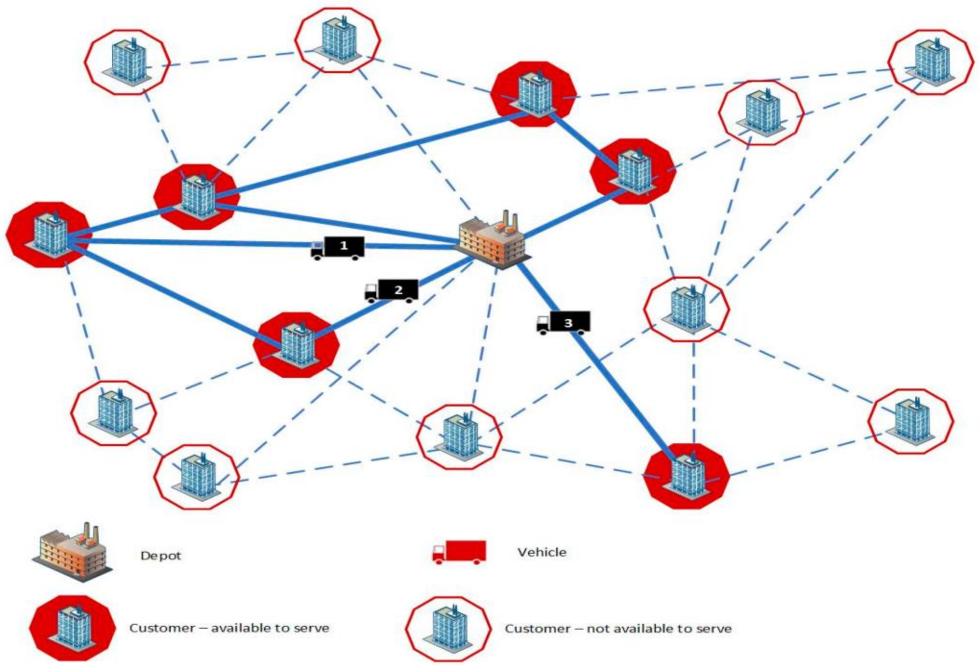
Abstract - Engineering field usually requires having the best design for an optimum performance, thus optimization plays an important part in this field. The vehicle routing problem (VRP) has been an important problem in the field of distribution and logistics since at least the early 1960s. Hence, this study was about the application of ant colony optimization (ACO) algorithm to

Keywords: *Vehicle Routing Problem, Ant Colony Optimization, ACO, VRP, Swarm Algorithm*

I. INTRODUCTION

The study is about solving vehicle routing problem (VRP) using ant colony optimization (ACO) algorithm. This is a software-based project. VRP generalizes the well-known travelling salesman problem (TSP). The study can be



What is “Planning Techniques” ?

They are applied in various fields, such as business, project management, urban development, education, and personal life, to ensure efficient resource allocation, time management, and decision-making.

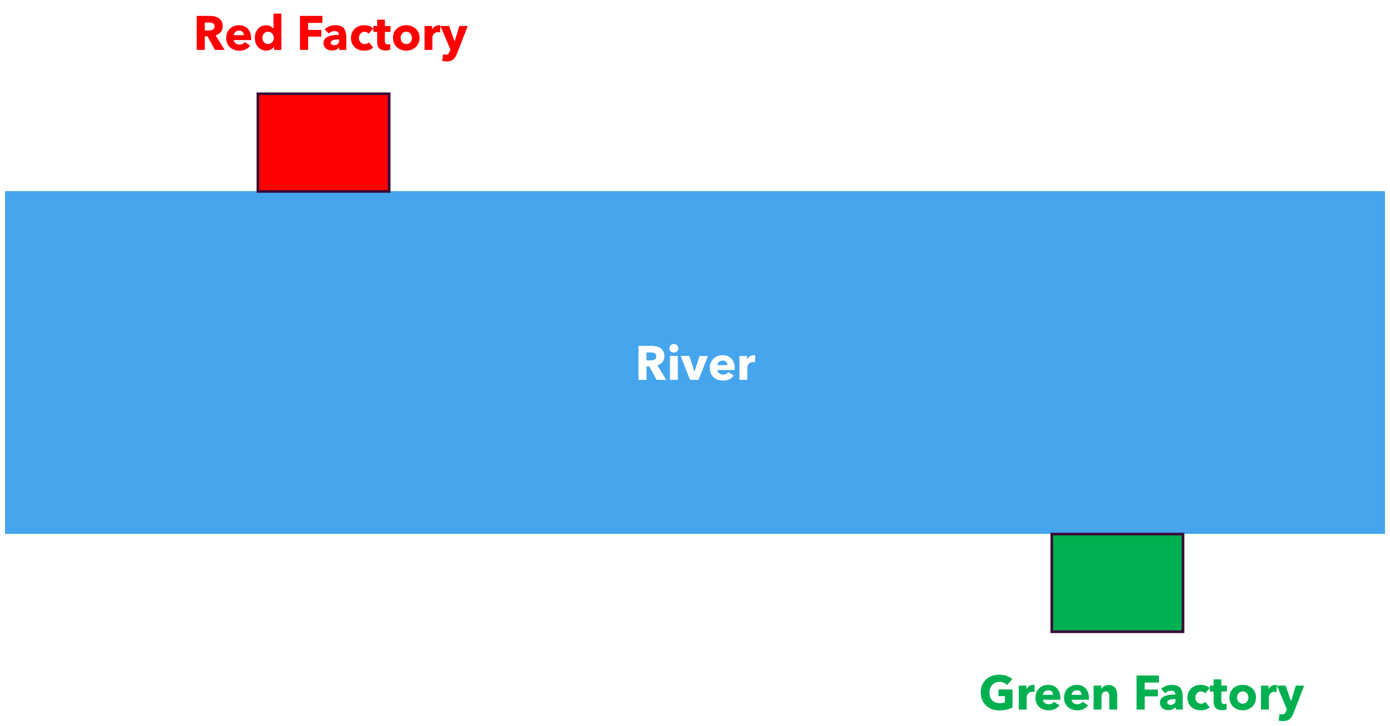
Efficient utilization

The efficient utilization means that we need to make THE BEST benefit of something !

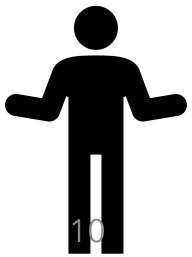
- **"THE BEST" in scientific manner is Optimization process, which is a systematic approach to get benefit of something**
- **Optimization is found in all life aspects, even in your study, in the making of the semester schedule, EVERYTHING NEEDS OPTIMIZATION**

Optimization/Searching

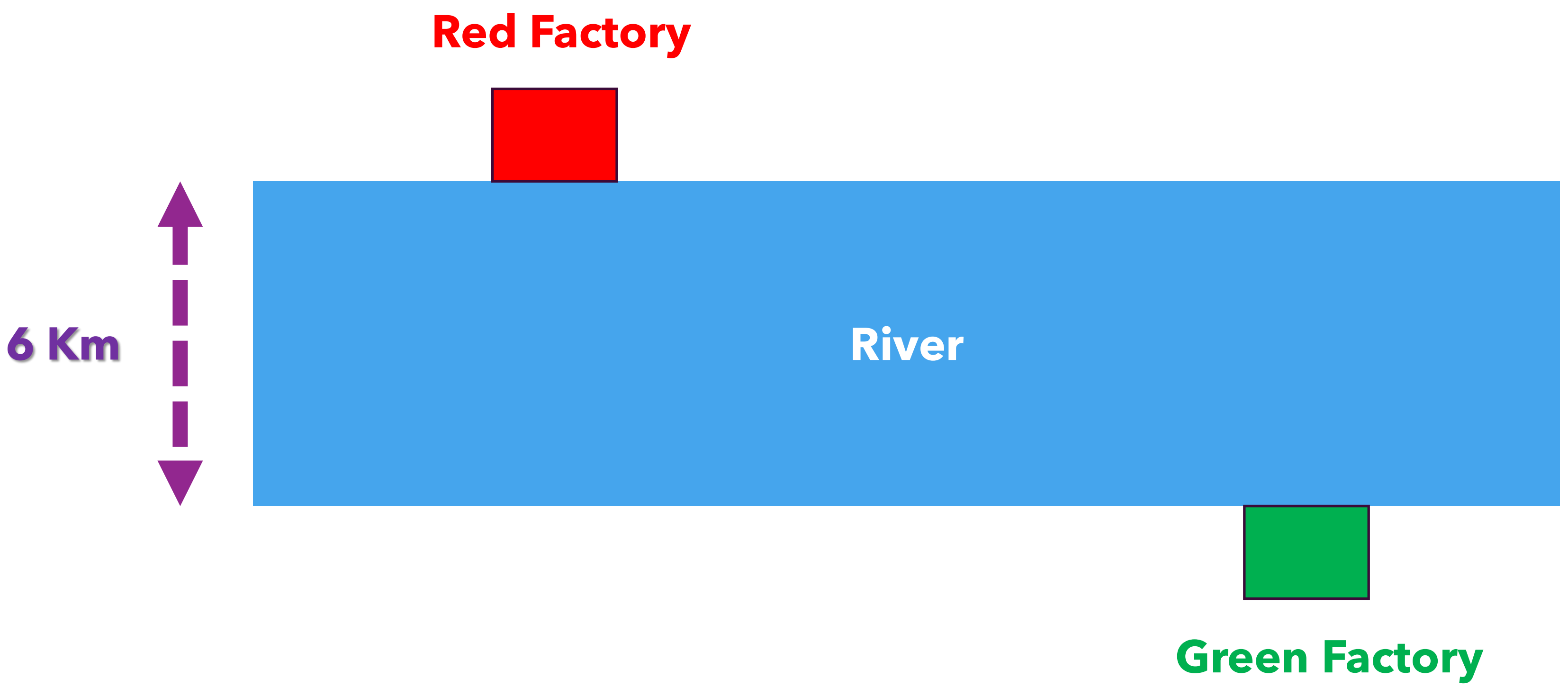
Real-life example



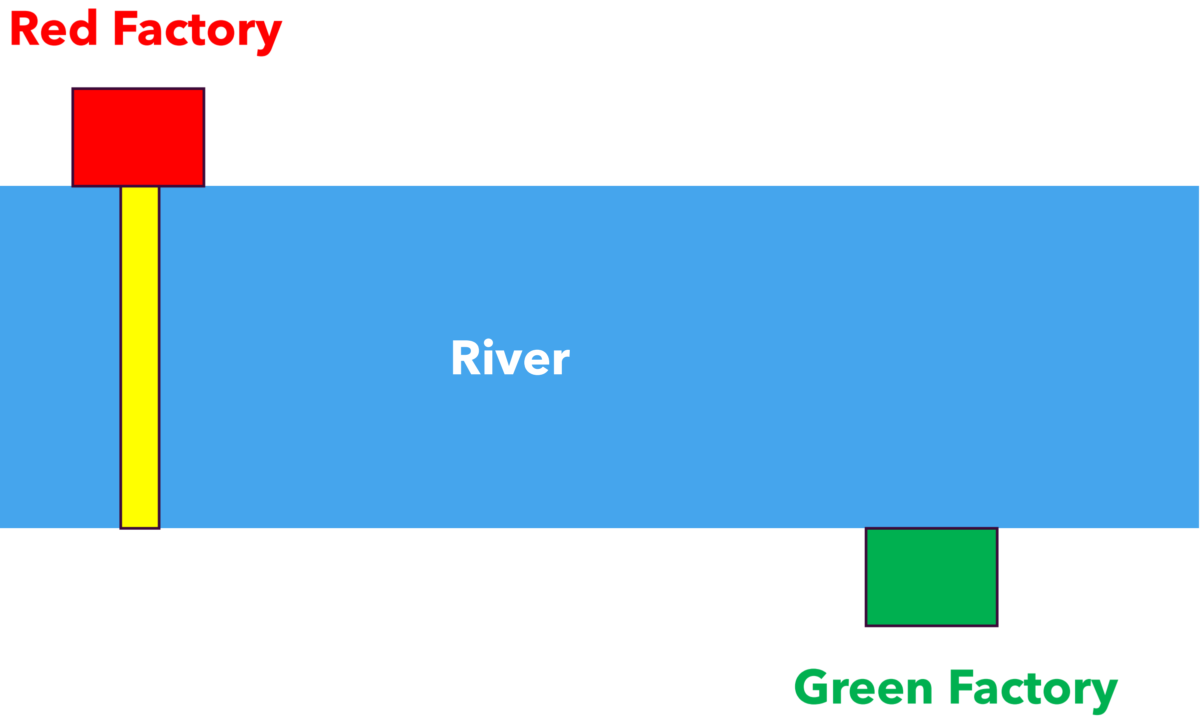
I need to get some stuff from Red factory to my green factory



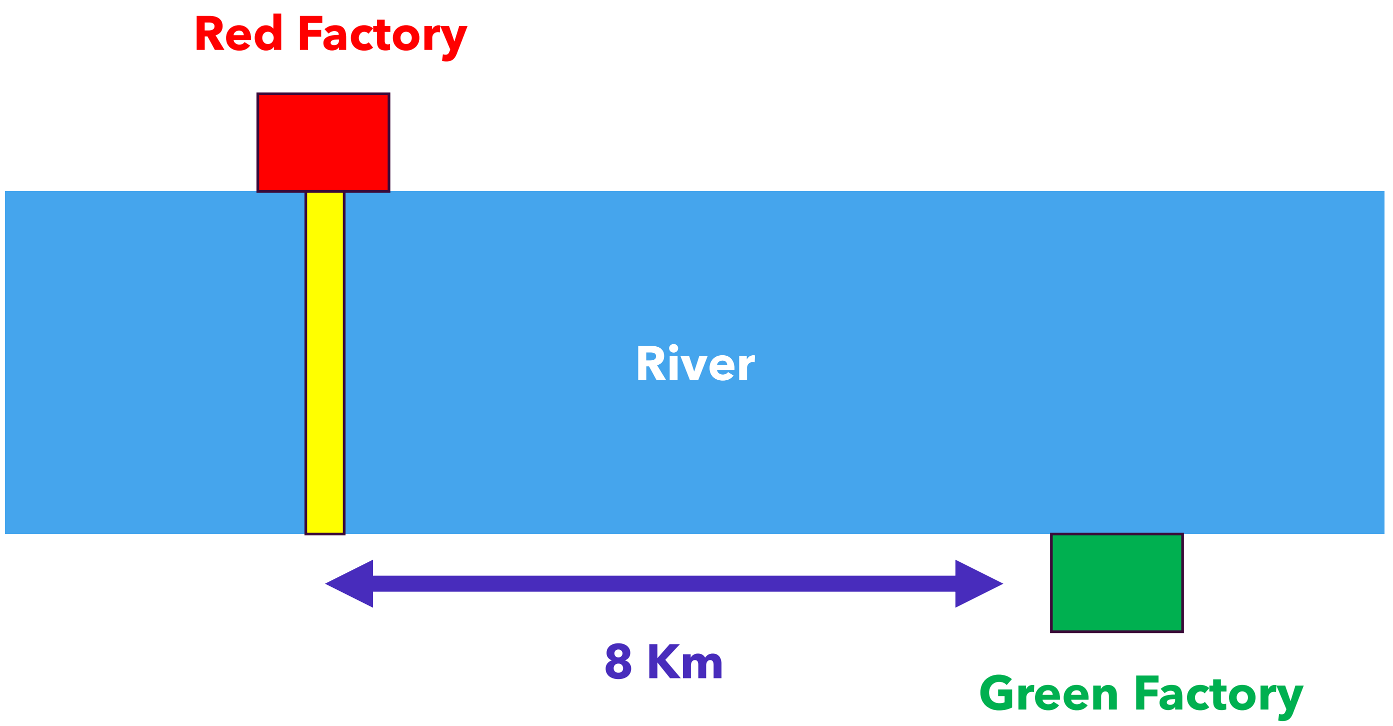
Real-life example



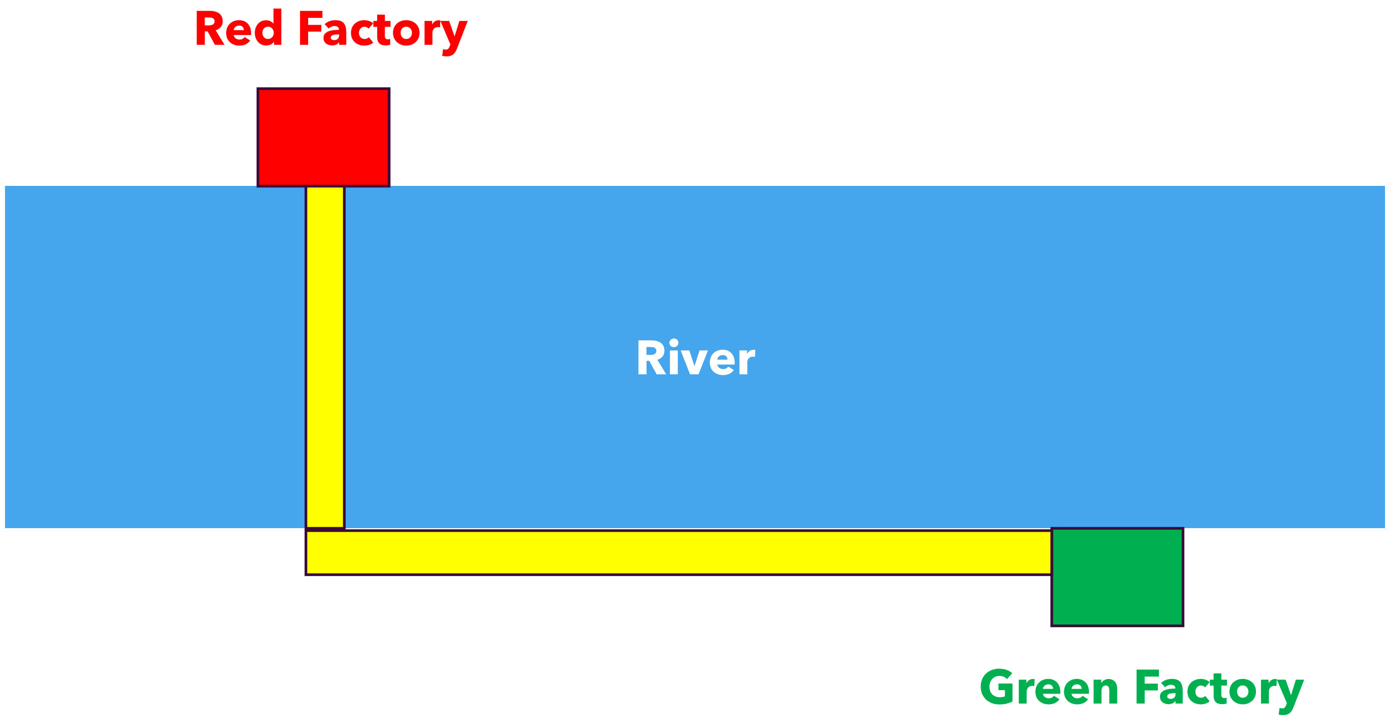
Suggested Solution



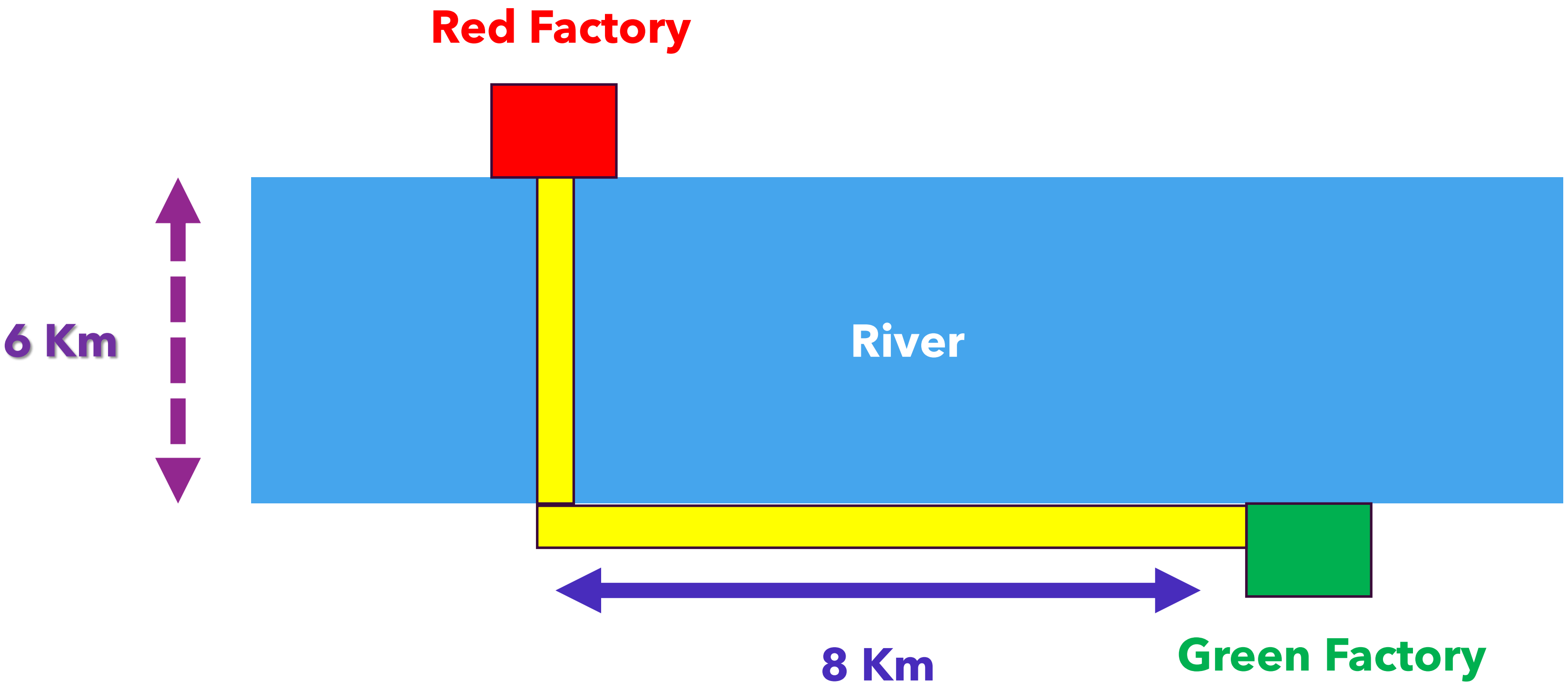
Suggested Solution



Suggested Solution



Suggested Solution



Happy now ?

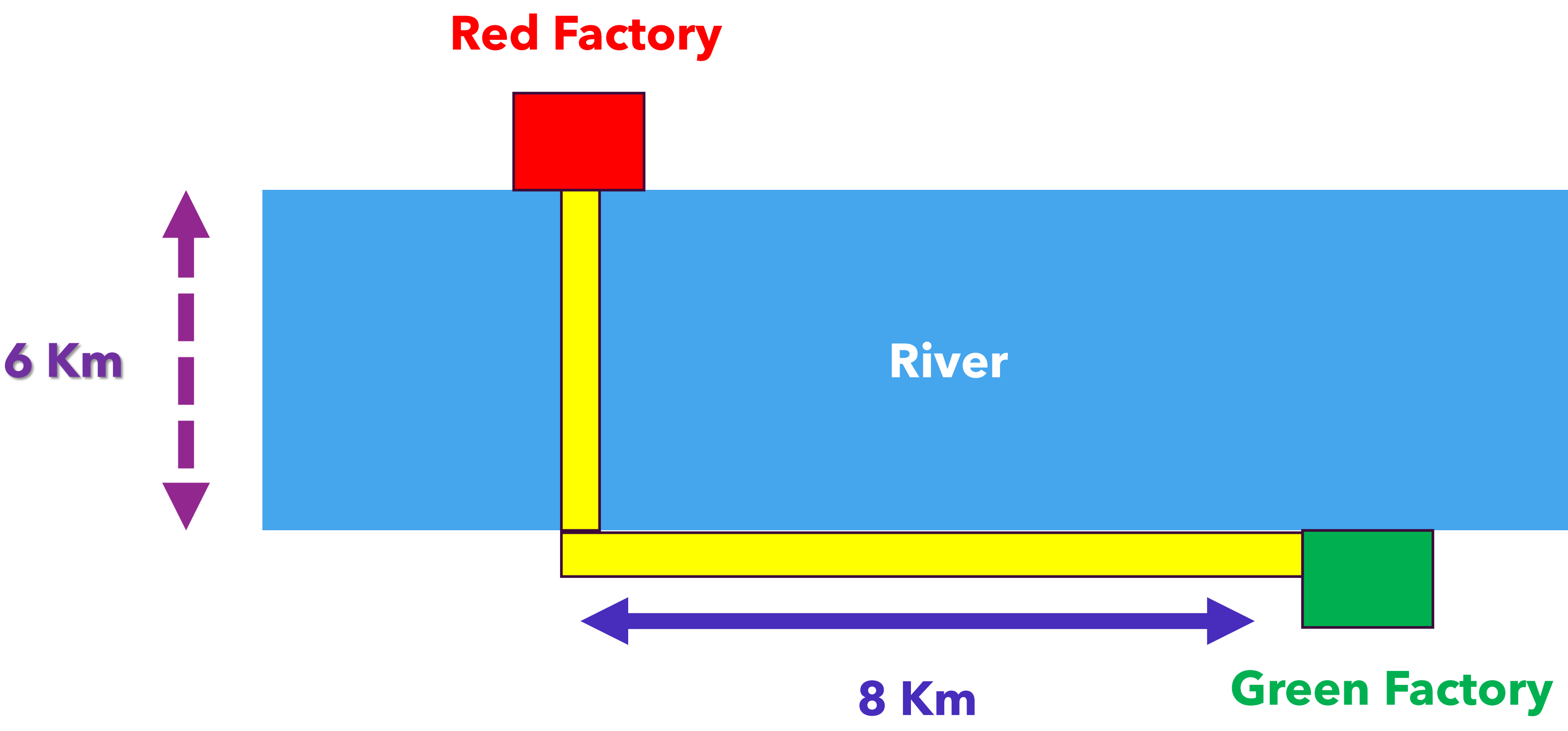
!

Sure not

The cost of the bridge is $40,000 per Km

The cost of the road is $20,000 per Km

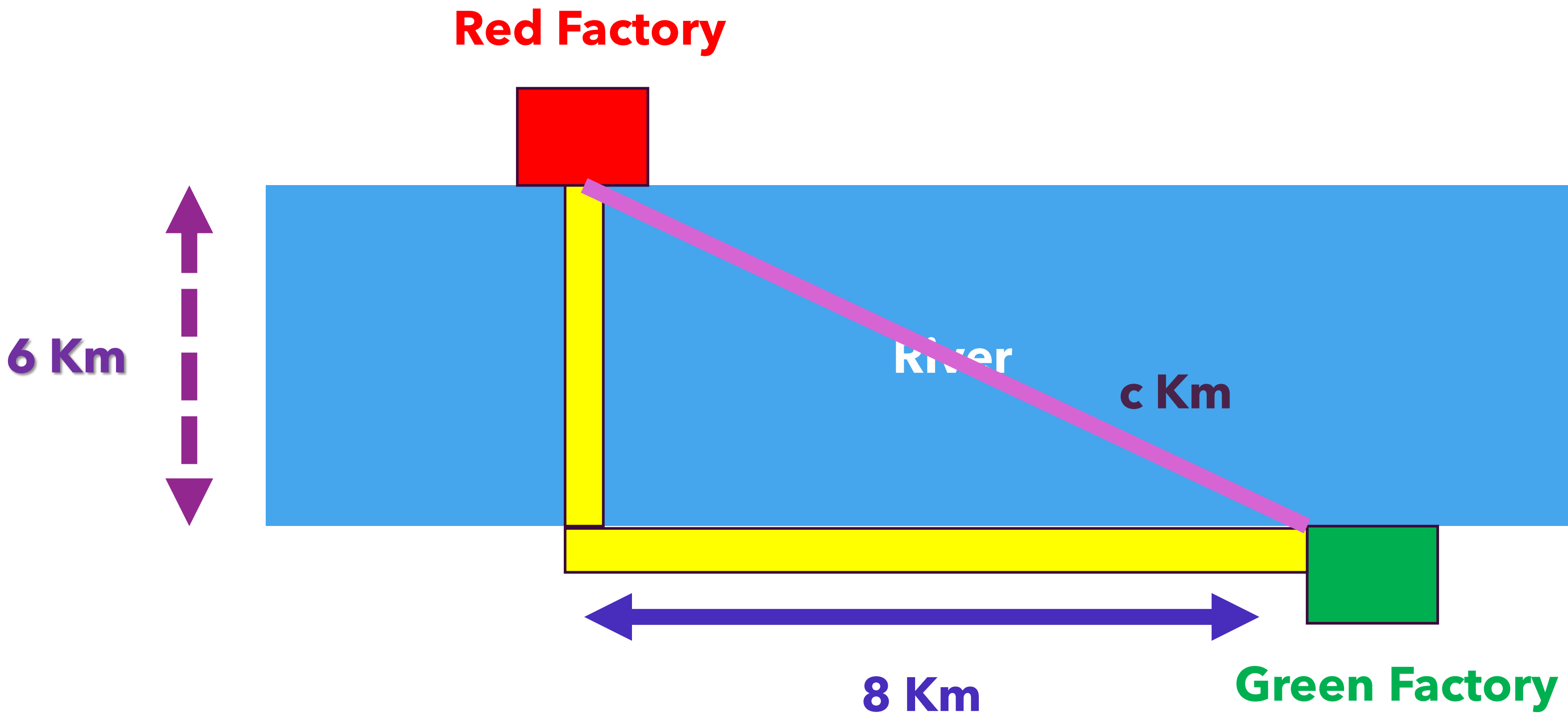
Suggested Solution



Bridge cost = 6 Km x $40,000 = $240,000
Road cost = 8 Km x $20,000 = $160,000
Total = $240,000 + $160,000 = $400,000

Another Solution ?

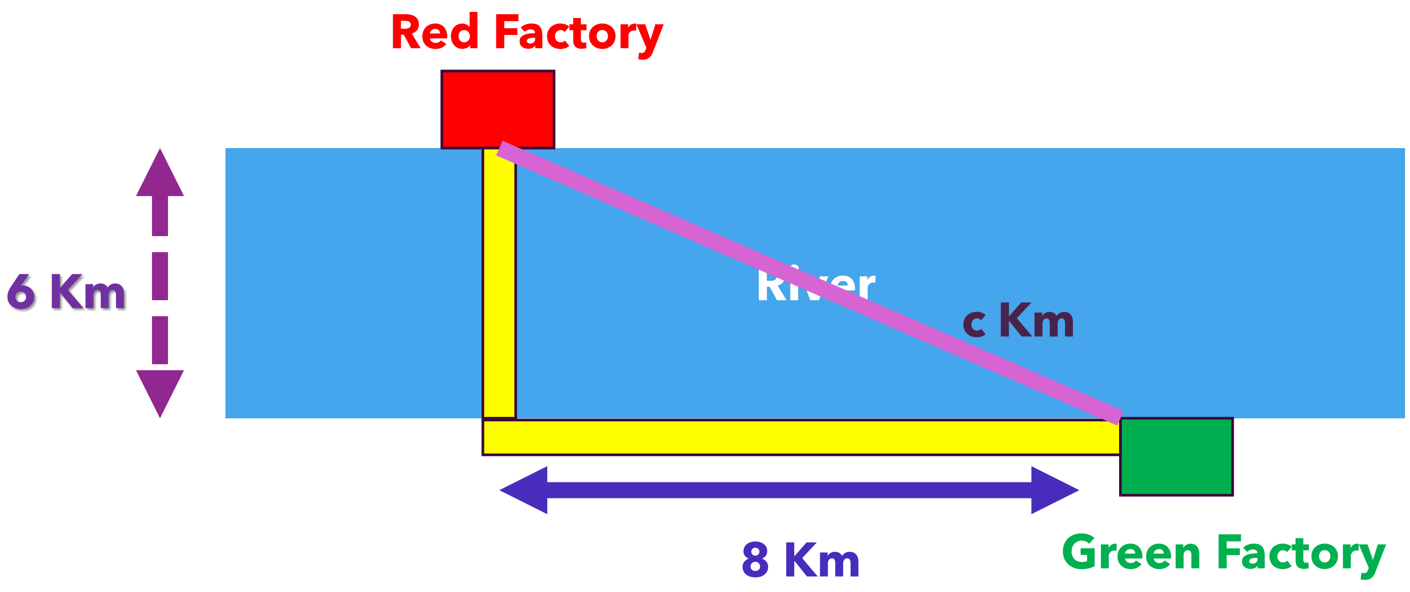
Another Solution



Pythagorean Theorem 😎

Pythagorean Theorem

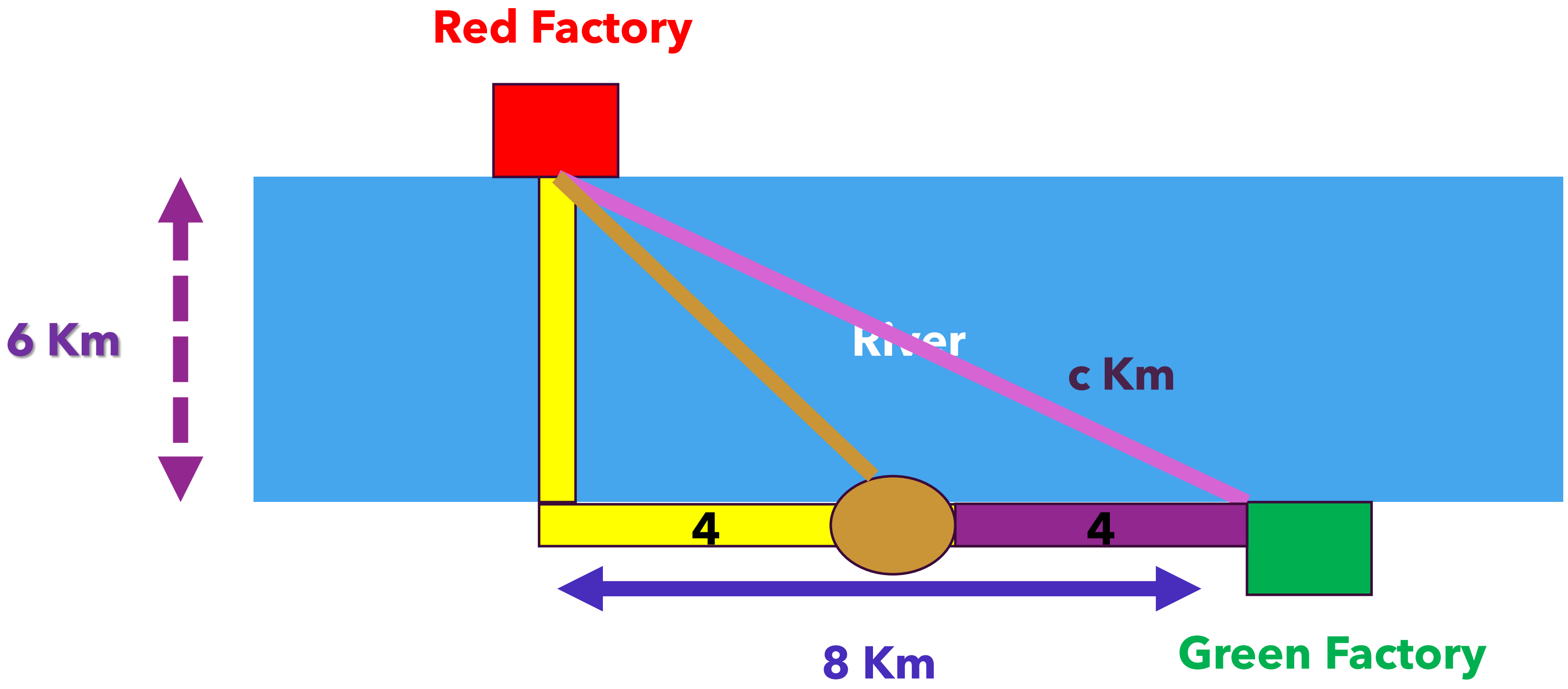
$$c^2 = a^2 + b^2$$
$$c^2 = 6^2 + 8^2$$
$$c^2 = 100$$
$$c = 10$$



Bridge cost = 10 Km x $40,000 = $400,000

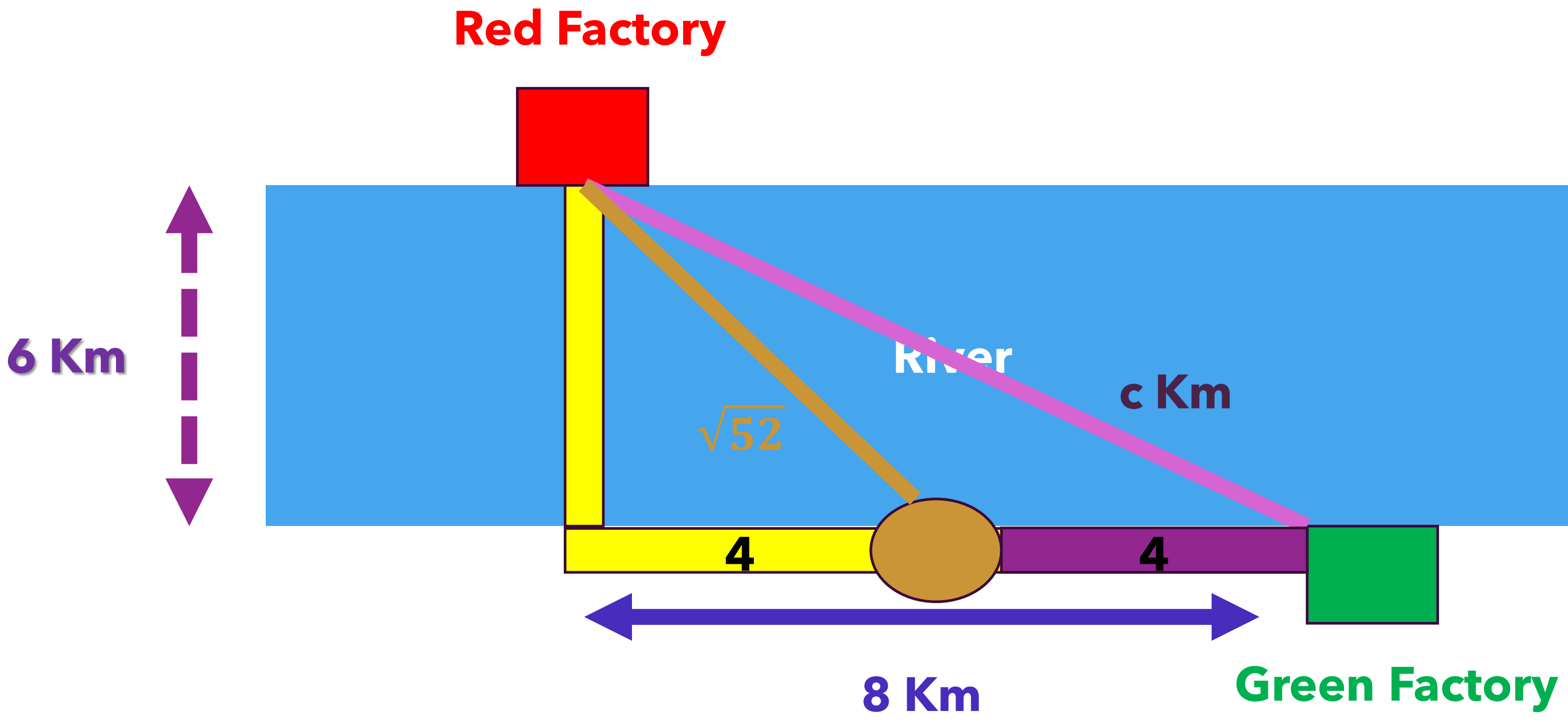

شنغل
و
منغل

Solution 3



Road cost = 4 Km x $20,000 = $80,000

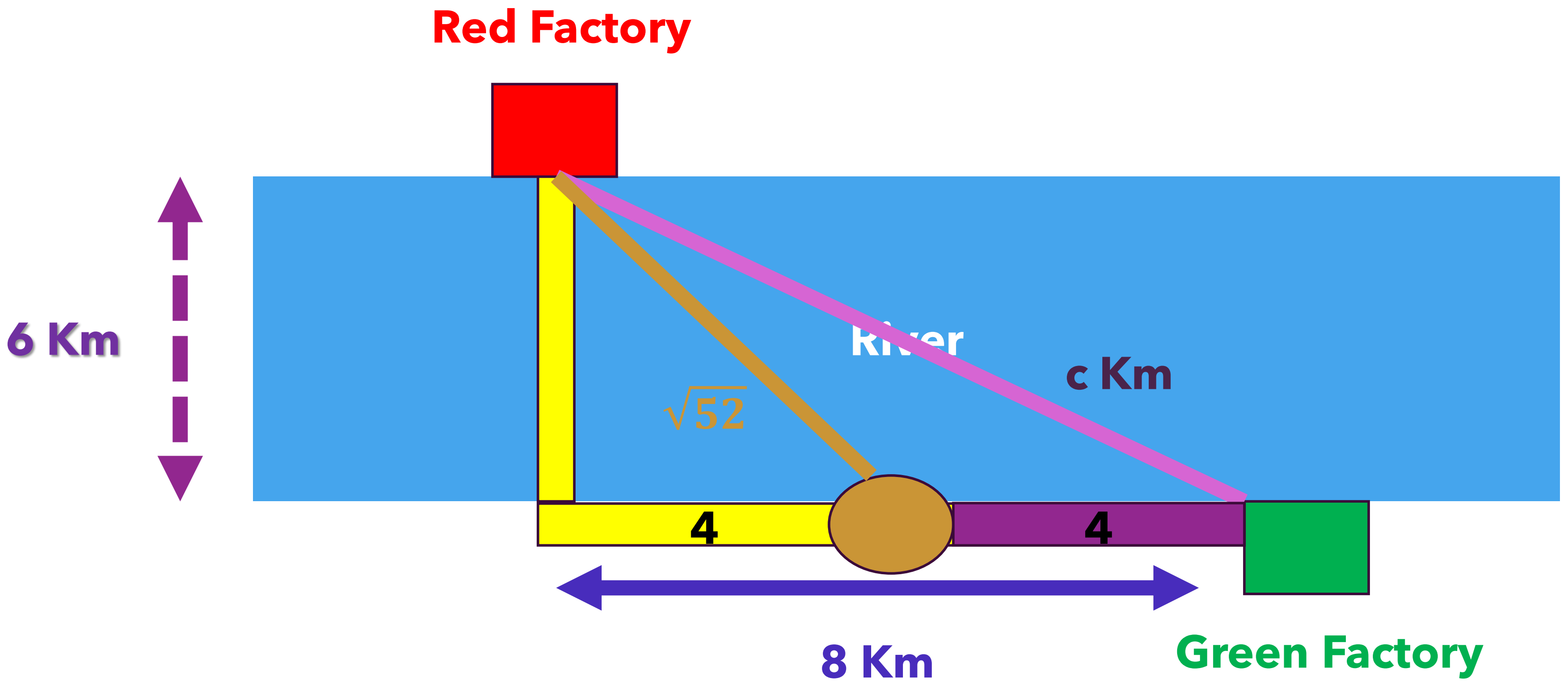
Solution 3



$c^2 = a^2 + b^2$
$c^2 = 6^2 + 4^2$
$c^2 = 52$
$c = \sqrt{52}$

Bridge cost = √52 Km x $40,000 = $288,444.10

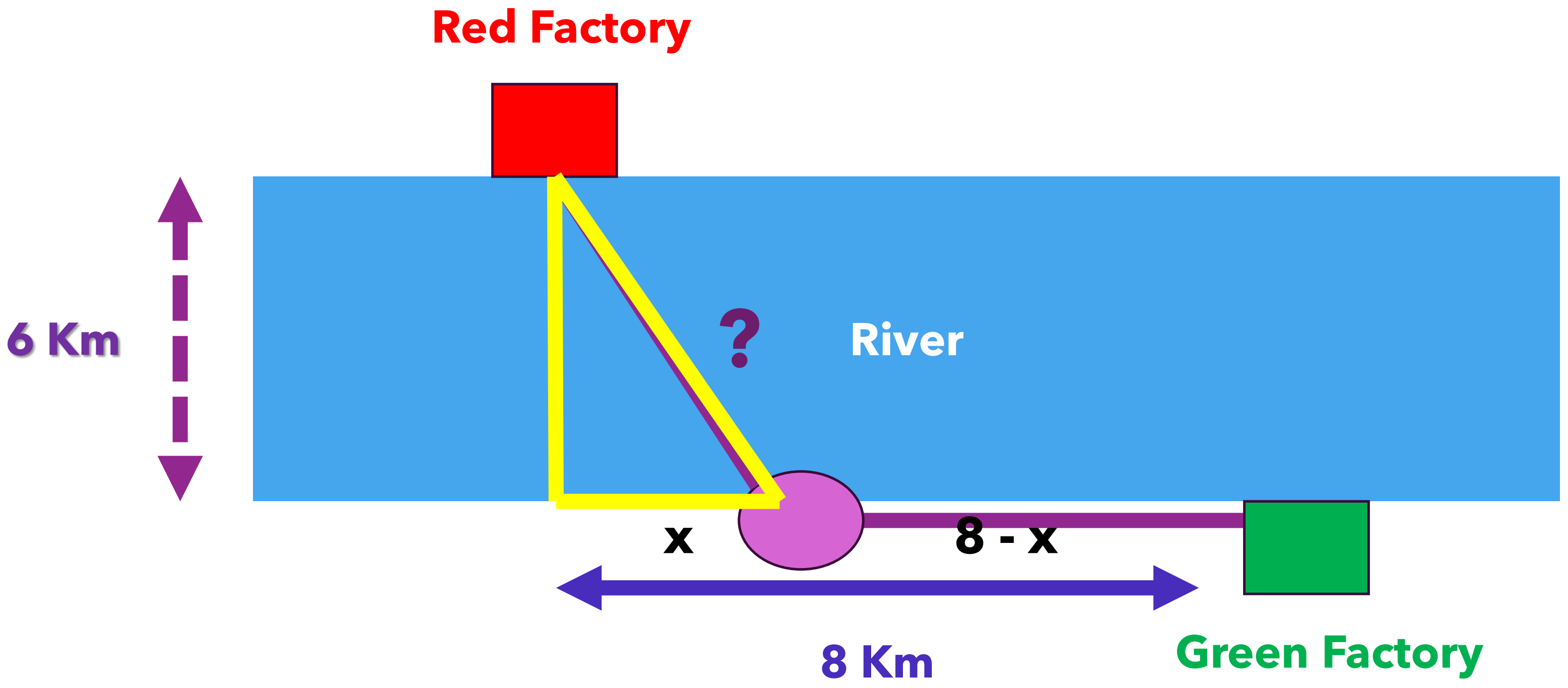
Solution 3



Road cost = 4 Km x $20,000 = $80,000
Bridge cost = √52 Km x $40,000 = $288,444.10
Total = $240,000 + $160,000 = $368,444.10

Better Solution ?

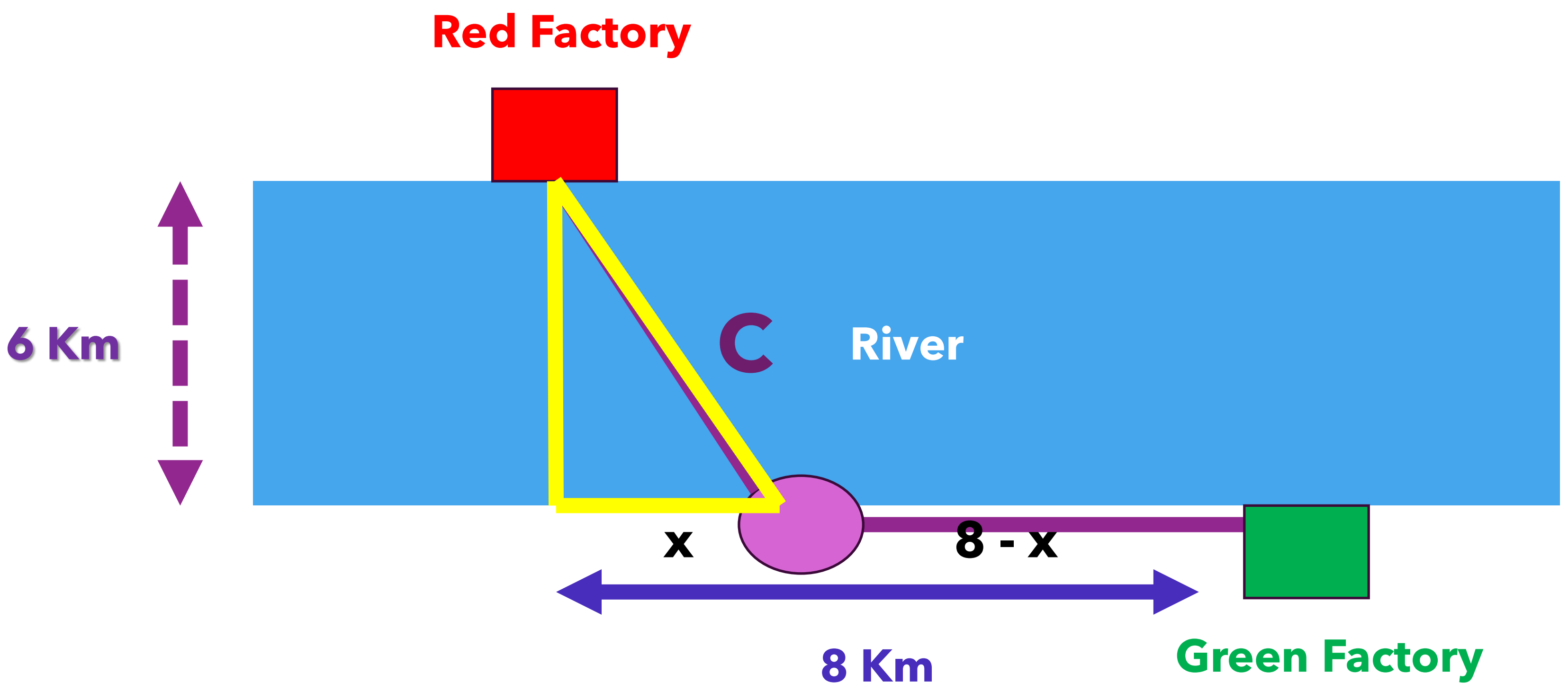
Better Solution (Random Point Location)



$c^2 = a^2 + b^2$

?($40,000) + (8 – x)($20,000)

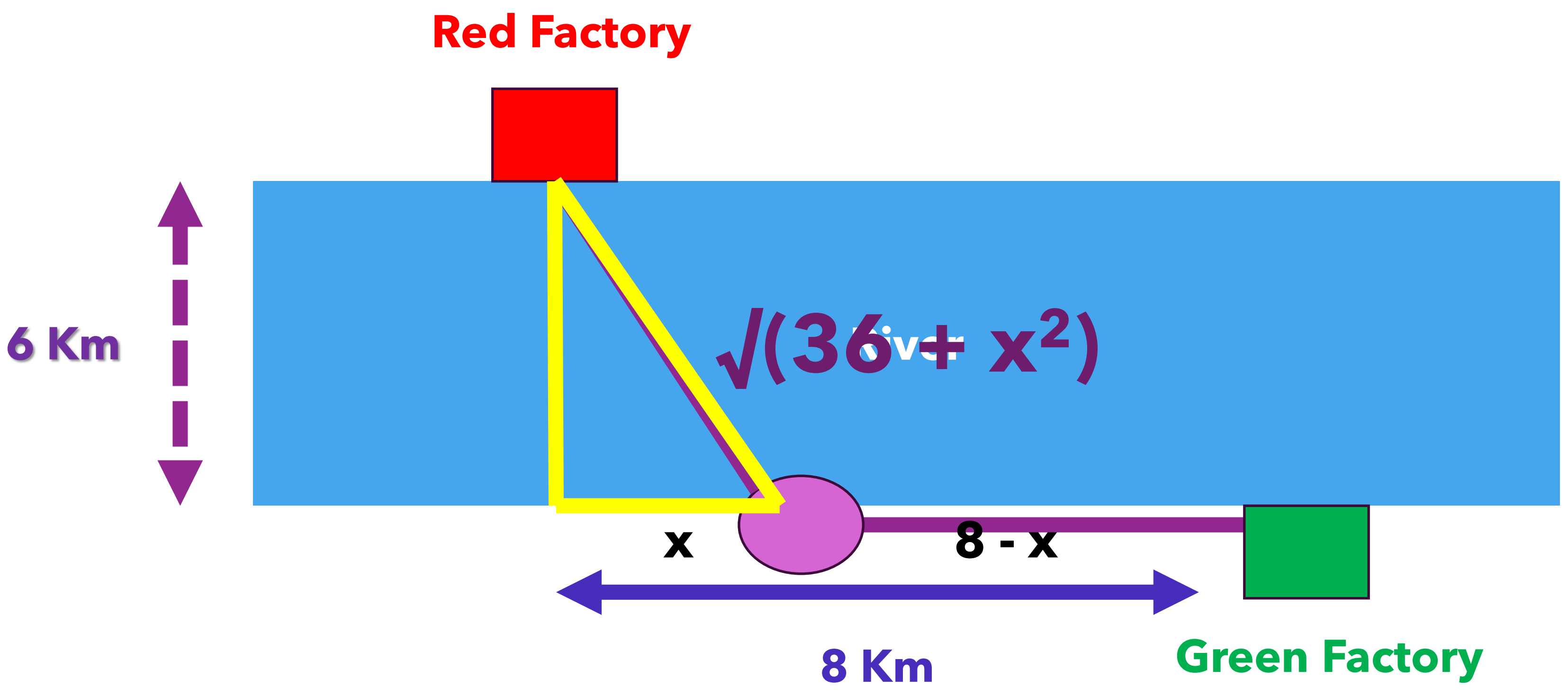
Better Solution (Random Point Location)



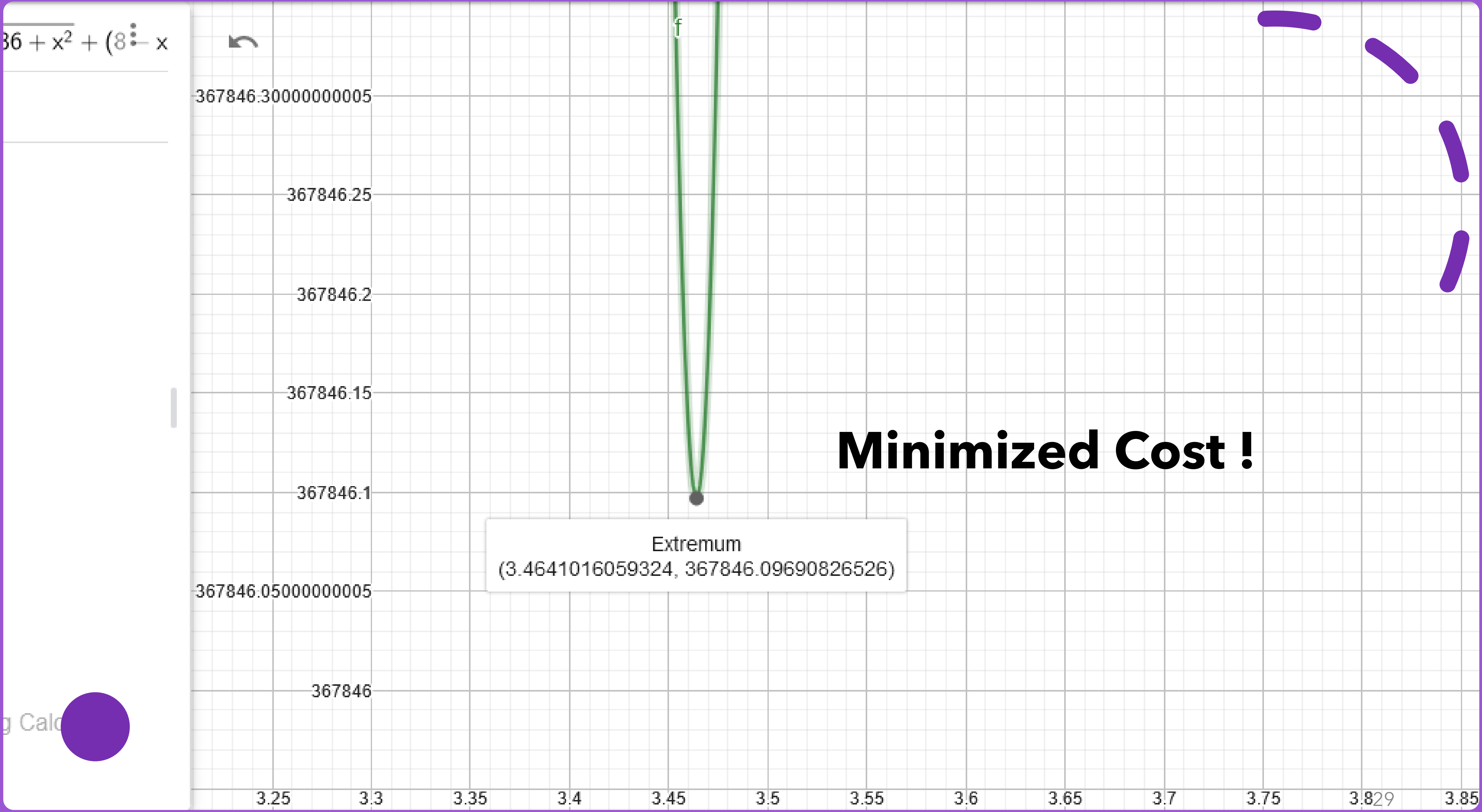
$c^2 = a^2 + b^2$
$c^2 = 6^2 + b^2$
$c^2 = 6^2 + x^2$
$c = \sqrt{(36 + x^2)}$

c(\$40,000) + (8 – x)(\$20,000)

Better Solution (Random Point Location)



$$f(x) = \sqrt{(36 + x^2)}(\$40,000) + (8 - x)(\$20,000)$$



Minimized Cost !

$

when x = 3.464

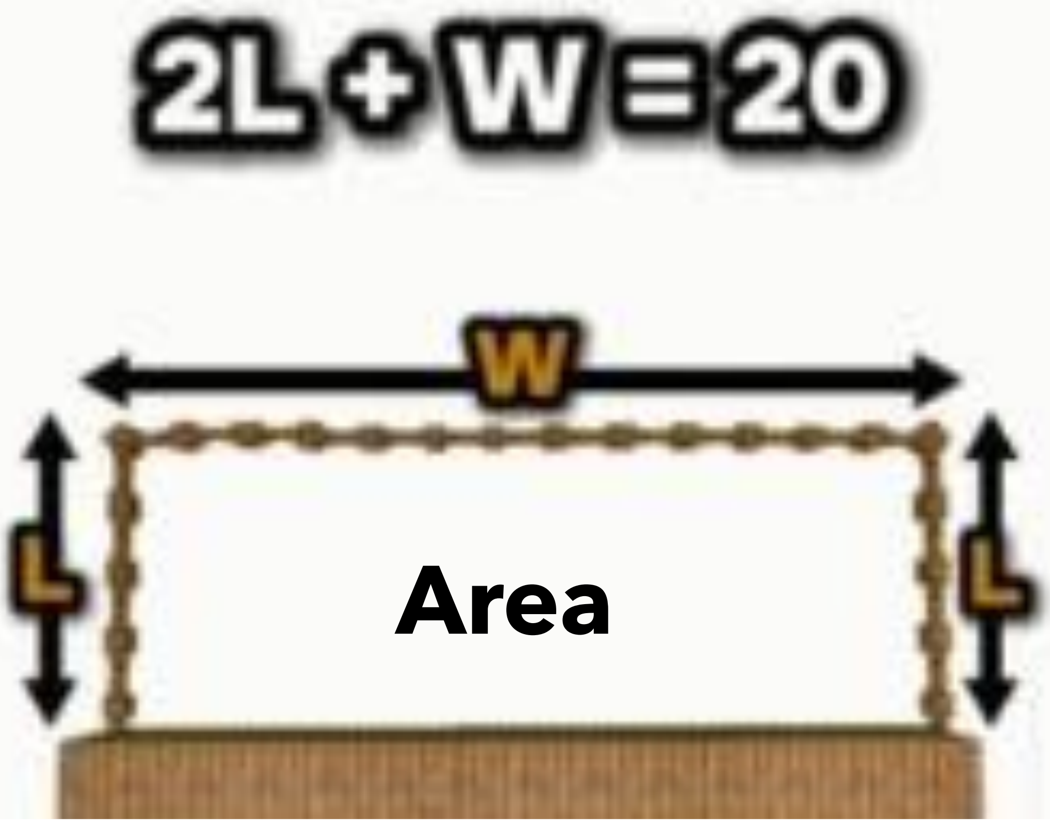
the total cost = $367,846.09

Optimized

Want to play Minecraft ?

Check out this problem

What could be the biggest area using only 20 fences ?



Lets take a deep look

Remember, we want to maximize the area

Lets do some calculations

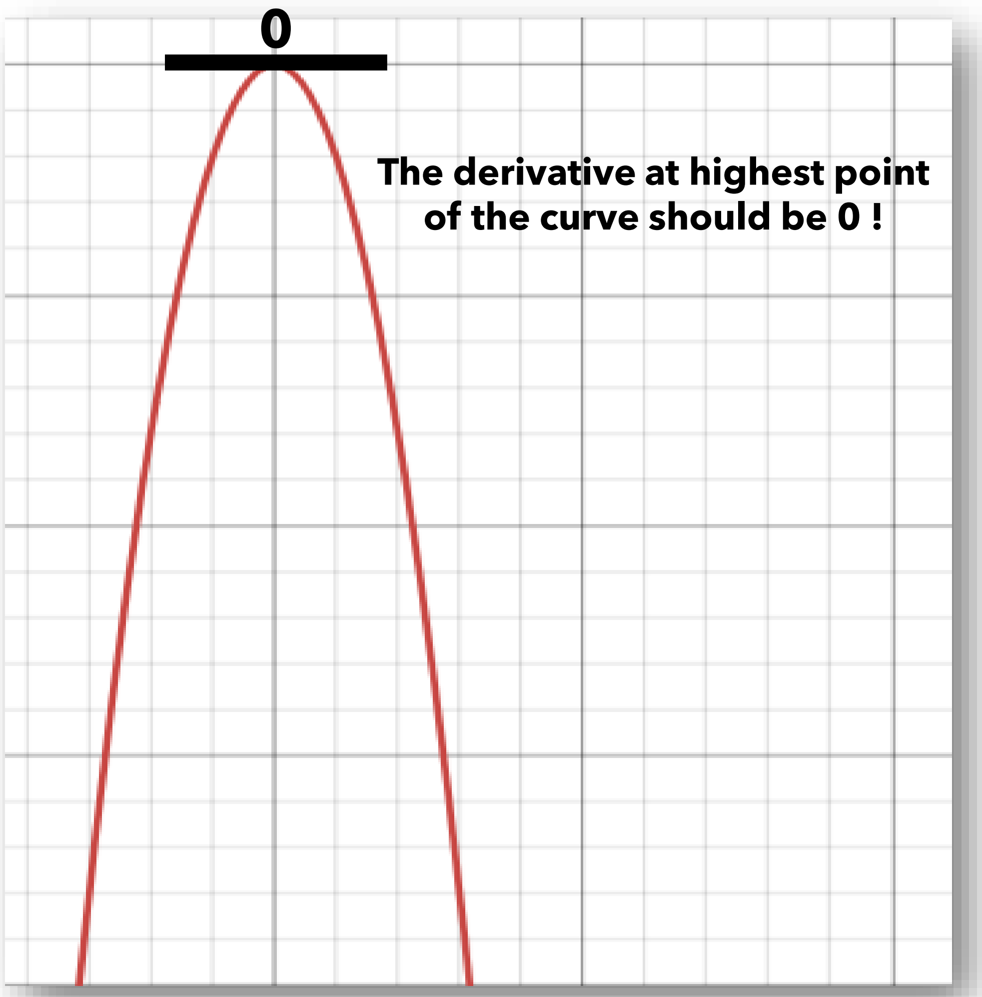
$2L + W = 20$

$A = LW$

$\rightarrow W = 20 - 2L$

$\rightarrow A = L(20 - 2L)$

$\rightarrow A = 20L - 2L^2$



Still, you have to use differentiation

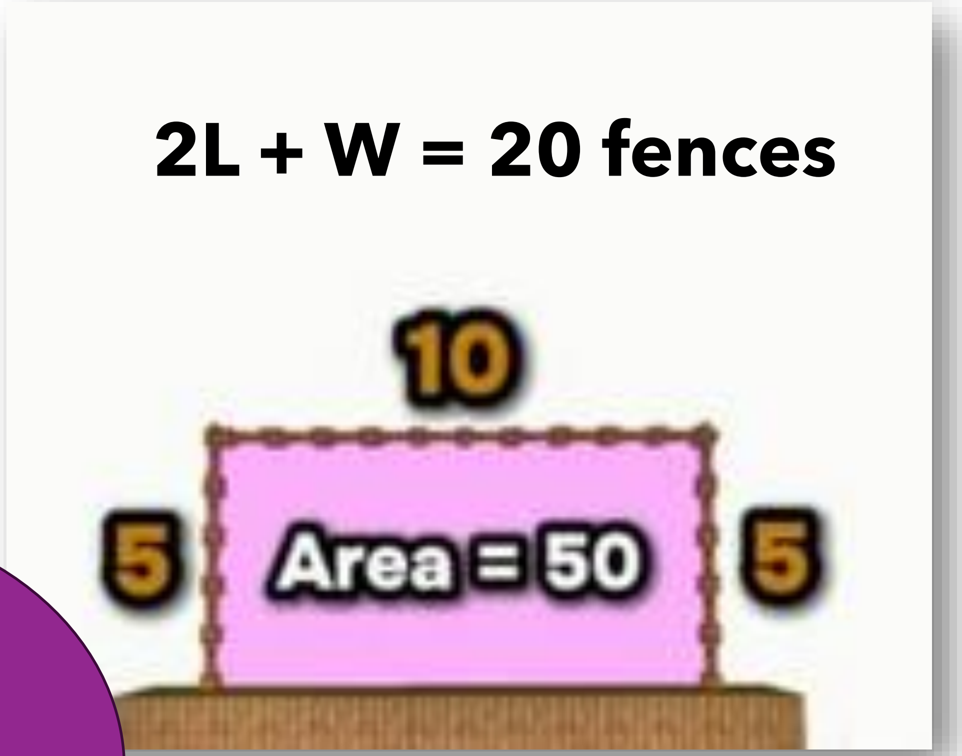
$A(L) = 20L - 2L^2$

$A`(L) = 20 - 4L$

$\rightarrow 0 = 20 - 4L$

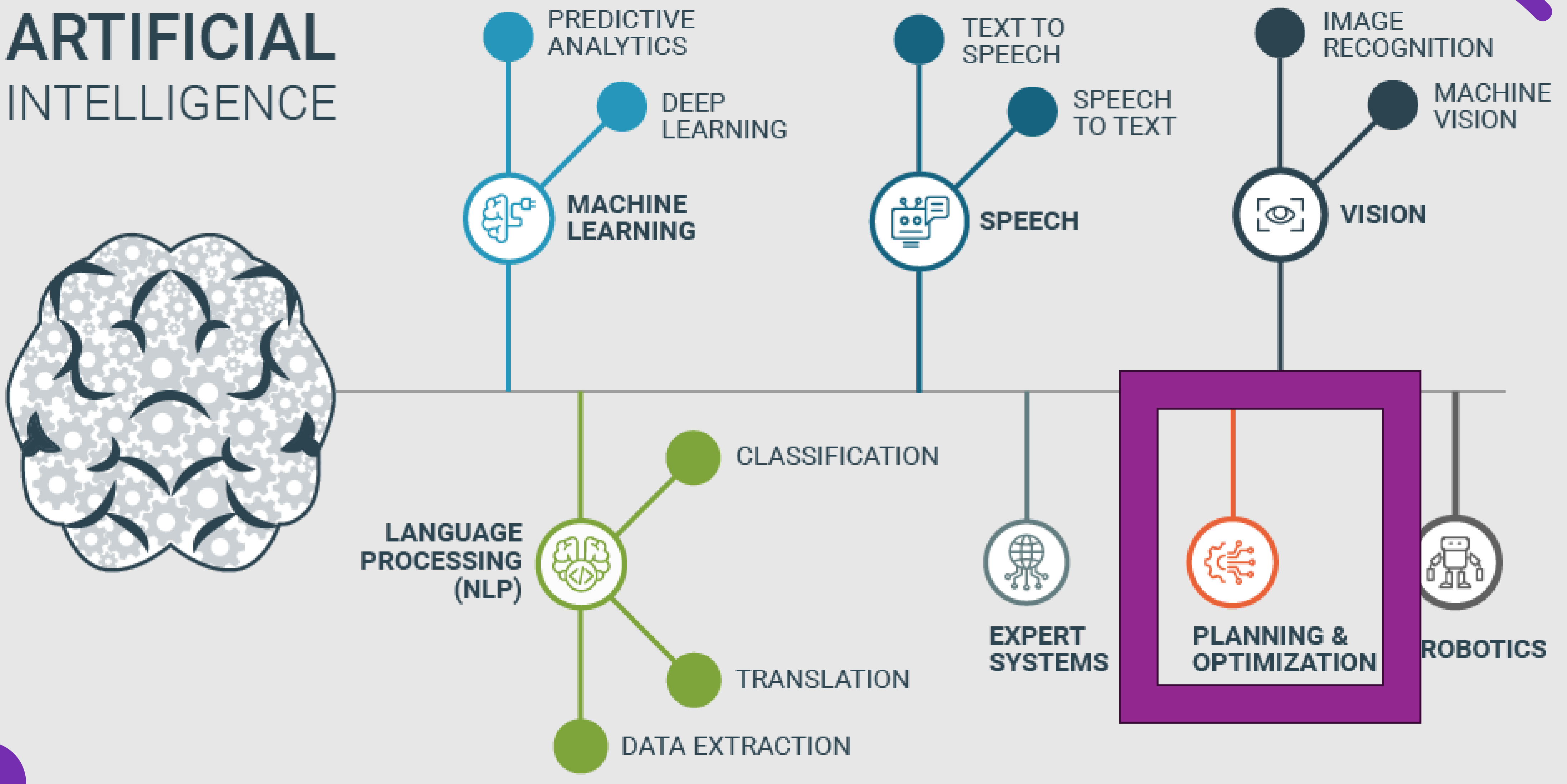
$\rightarrow -20 = -4L$

$\rightarrow L = 5$



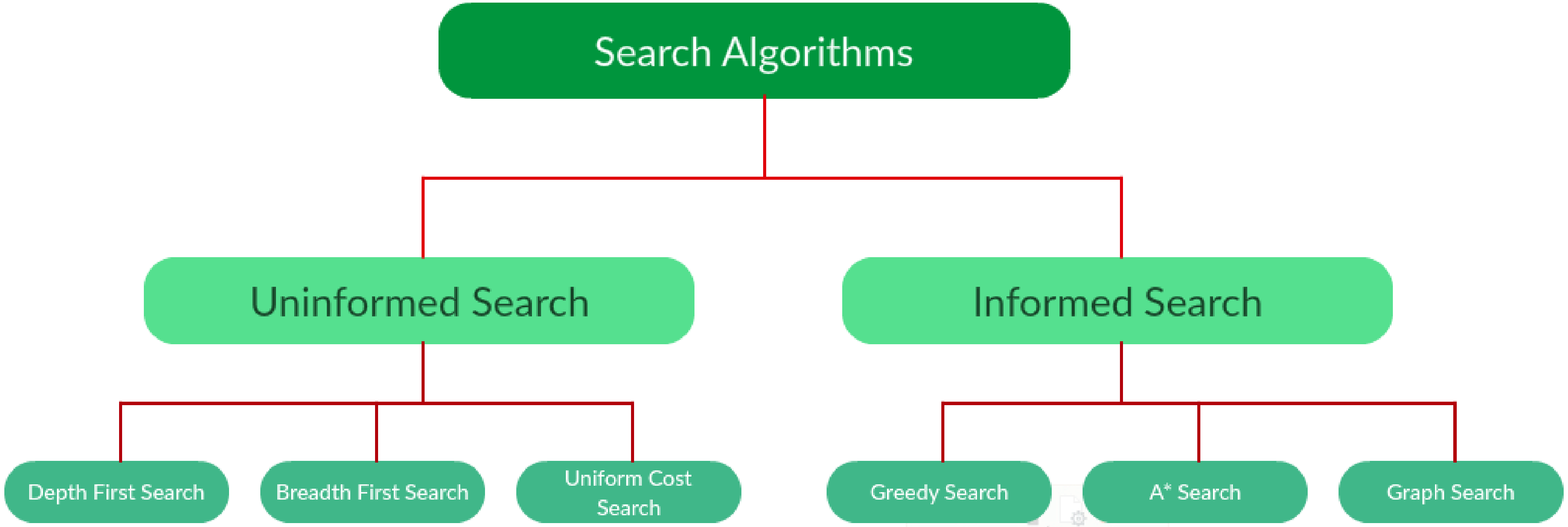
Optimized

ARTIFICIAL INTELLIGENCE



Cont. "AI" Course

- As mentioned, optimization and searching are two faces of the same coin

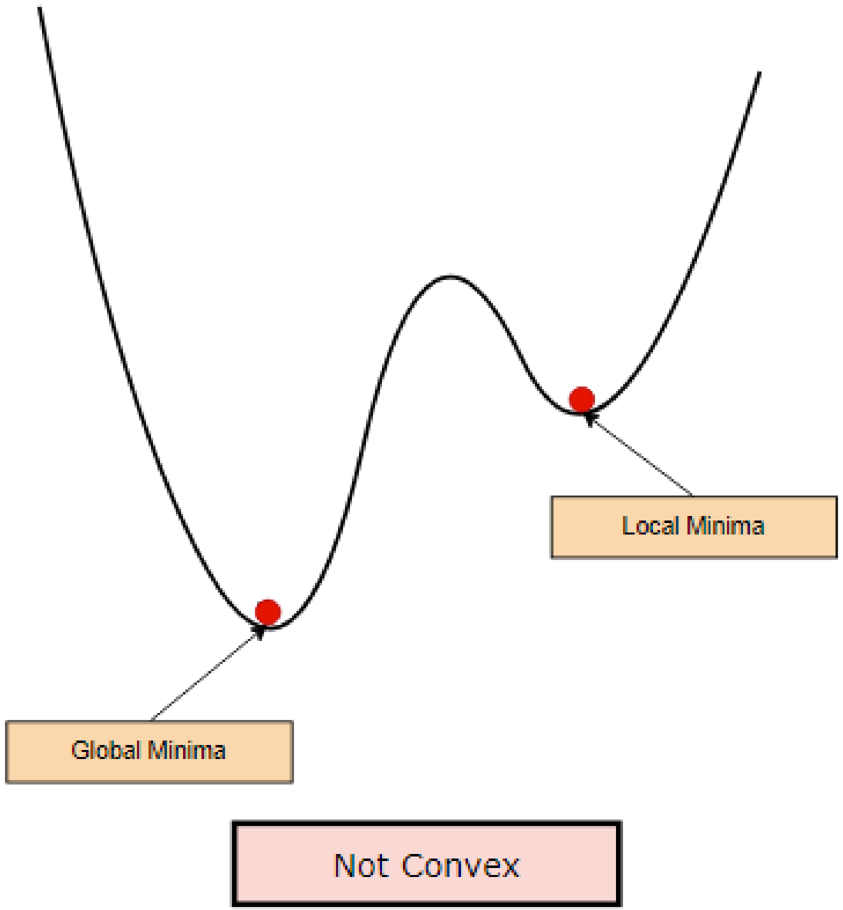


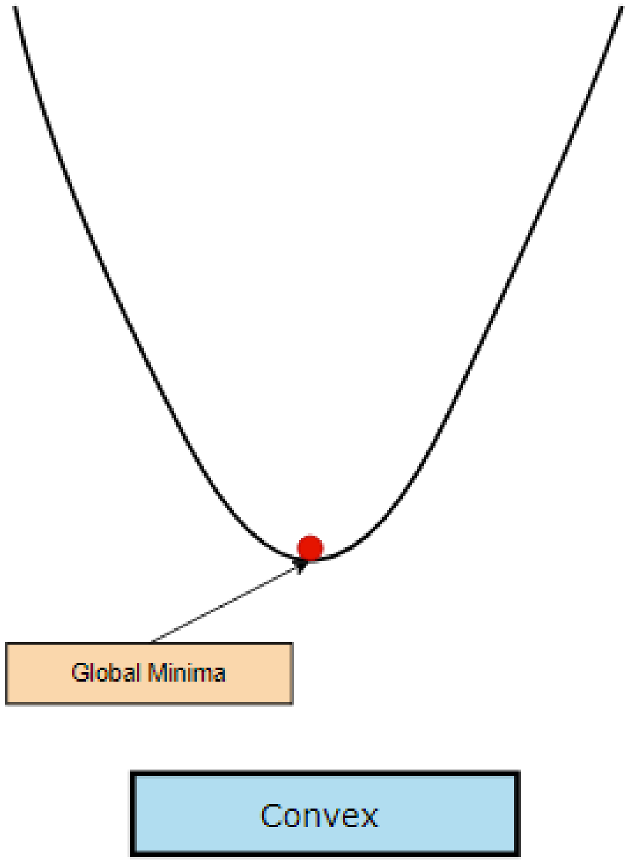
Are these only the searching algorithms?

Types of problems

Graphs	Mathematics	Linear	Non-Linear
Exact	Approximate	Heuristics	Convex
Non-convex	Continues	Dynamic	Stochastic
Combinatorial	Multi-objective	Single Objective	Constrained
Unconstrained	Differentiable	Nondifferentiable	Integer
	Mixed Integer		

Convex Vs. Non-Convex Problems





Exact Vs. Approximate Problems

Exact

solved using algorithms that **guarantee finding the optimal (best possible) solution**.

solved using algorithms that find **near-optimal solutions** within reasonable time, without guaranteeing global optimality.

Approximate

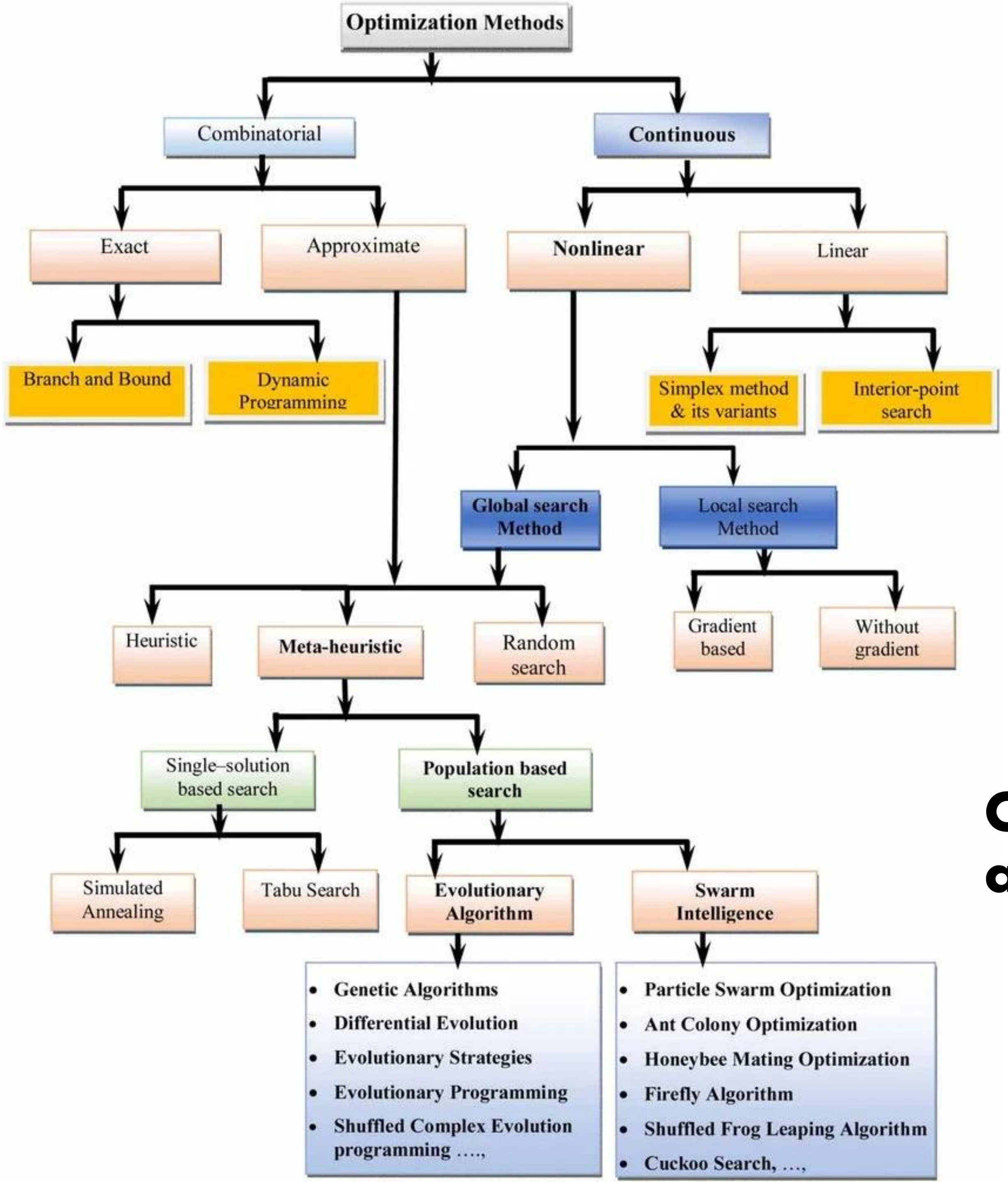
Combinatorial Problems

- **Combinatorial optimization:** is a branch of optimization that deals with finding the **best solution from a finite or countable set of discrete solutions**, where variables take **integer or discrete values**.

Key Idea
You are choosing the **best combination** among many possible combinations.

Discrete Search Space	Often NP-Problems	Exact or approximate solutions used

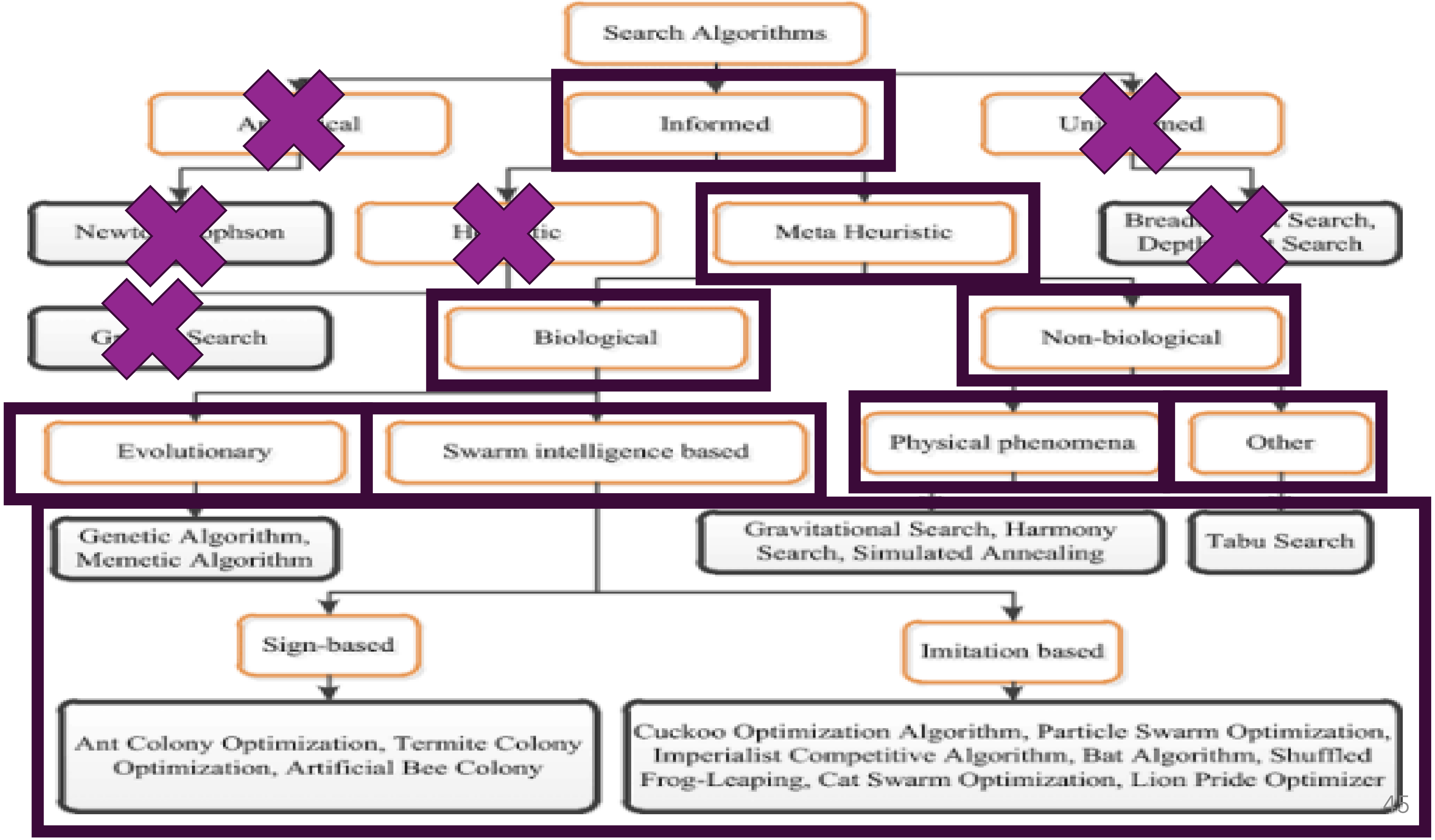
Objective: **minimize or maximize a cost function**



Optimization/Searching algorithms

The classification of Searching Algorithms

This is the target of the course



Definitions

- **Informed Search**: a type of search algorithm used in artificial intelligence and computer science that leverages additional information or knowledge about the problem domain to find solutions more efficiently.

- **Meta-Heuristic**: high-level, problem-independent strategies or frameworks designed to solve complex optimization problems.

- **Biological algorithms**: computational methods inspired by biological processes. These algorithms mimic natural phenomena like **evolution**, **neural processing**, and **collective intelligence** to solve complex problems efficiently.

- **Non-biological algorithms**: optimization methods that are **not inspired by biological systems** *(like evolution, animals, or the human brain)*. Instead, they are based on **mathematics, physics, logic, or deterministic rules**.

Definitions (Cont.)

- **Swarm Intelligence**: a type of artificial intelligence inspired by the collective behavior of social organisms such as ants, bees, birds, and fish. It involves decentralized, self-organized systems where simple agents follow basic rules and interact locally, leading to intelligent global behavior.

- **Evolutionary**: a population-based stochastic optimization algorithms inspired by natural evolution, which iteratively improve solutions using mechanisms such as selection, crossover, and mutation.

- **Physical phenomena**: an optimization algorithms inspired by laws and processes of physics, such as thermodynamics, gravity, or electromagnetism, to search for optimal or near-optimal solutions.

Definitions (Cont.)

- **Sign-based algorithms**: an optimization algorithms that make decisions based on signals, symbols, or indirect indicators rather than explicit biological or physical processes.

- **Imitation-based algorithms**: an optimization algorithms inspired by learning through imitation, where candidate solutions copy or follow successful behaviors of other solutions.

Sign-based	Imitation-based
They rely on **information cues** (signs) to guide the search toward better solutions	They model **social learning**, not biological evolution

Feature	Heuristic	Meta-heuristic
Definition	Problem-specific rules or techniques to find a good solution quickly.	Higher-level strategies guiding heuristics to explore the solution space efficiently.
Search Strategy	Focuses on local search and problem-specific knowledge.	Uses **exploration and exploitation** to balance local and global search.
Solution Quality	Provides a good solution but not necessarily the optimal one.	Finds near-optimal solutions, often better than heuristics alone.
Generalization	Designed for specific problems and lacks adaptability.	Can be applied to a wide range of optimization problems.
Computational Complexity	Generally fast but may get stuck in local optima.	More computationally expensive but explores the solution space better.
Examples	- Greedy Algorithm - Nearest Neighbor - Hill Climbing	- Genetic Algorithms (GA) - Particle Swarm Optimization (PSO) - Ant Colony Optimization (ACO)

Meta-heuristic VS. Heuristic

Key Concepts of Meta-heuristic algorithms

- Inspired from Artificial Intelligence rather than pure math, which means <u>they are not based on algebraic models</u>
- There is no theoretical, which means lack of proofs
- Capability of addressing both discrete and continues optimization problems
- Efficiently explore the search space in order to find near-optimal feasible solutions
- Provide no guarantee of global or local optima (BEST BENEFIT) which can lead to computational complexity
- They balance exploration and exploitation, and incorporate randomness to avoid getting stuck in local solutions

Exploration and Exploitation

Exploration

- Searching new, unexplored areas of the solution space.
- Discover diverse solutions and avoid local optima.
- **Randomness**, **diversification**, and wide search space coverage.
- May explore unnecessary regions, increasing computational cost.

Exploitation

- Refining known good solutions to improve performance.
- Optimize the best-known solutions for higher quality results.
- Focused, intensification, and local optimization.
- May get trapped in local optima and miss the global best solution.

Types of Meta-heuristic algorithms

The first Category
Based on Inspiration

- Nature
  - Genetic Algorithms
  - Ant Colony Optimization
- Non-nature
  - Tabu Search
  - Iterated Local Search

Types of Meta-heuristic algorithms

The second Category
Based on whether objective changes along execution

Static objective		Dynamic objective	
Tabu Search	Iterated Local Search	Guided Local Search	…

Types of Meta-heuristic algorithms

The third Category
Based on whether they remember the search history

Using memory		Memory-less ("Markov" property)		
Tabu Search	Ant Colony Optimization	Simulated Annealing	GRASP	Most NLP local optimization algorithms

Markov Property

- The future state of a process depends only on the **current state** and not on the sequence of events that preceded it.

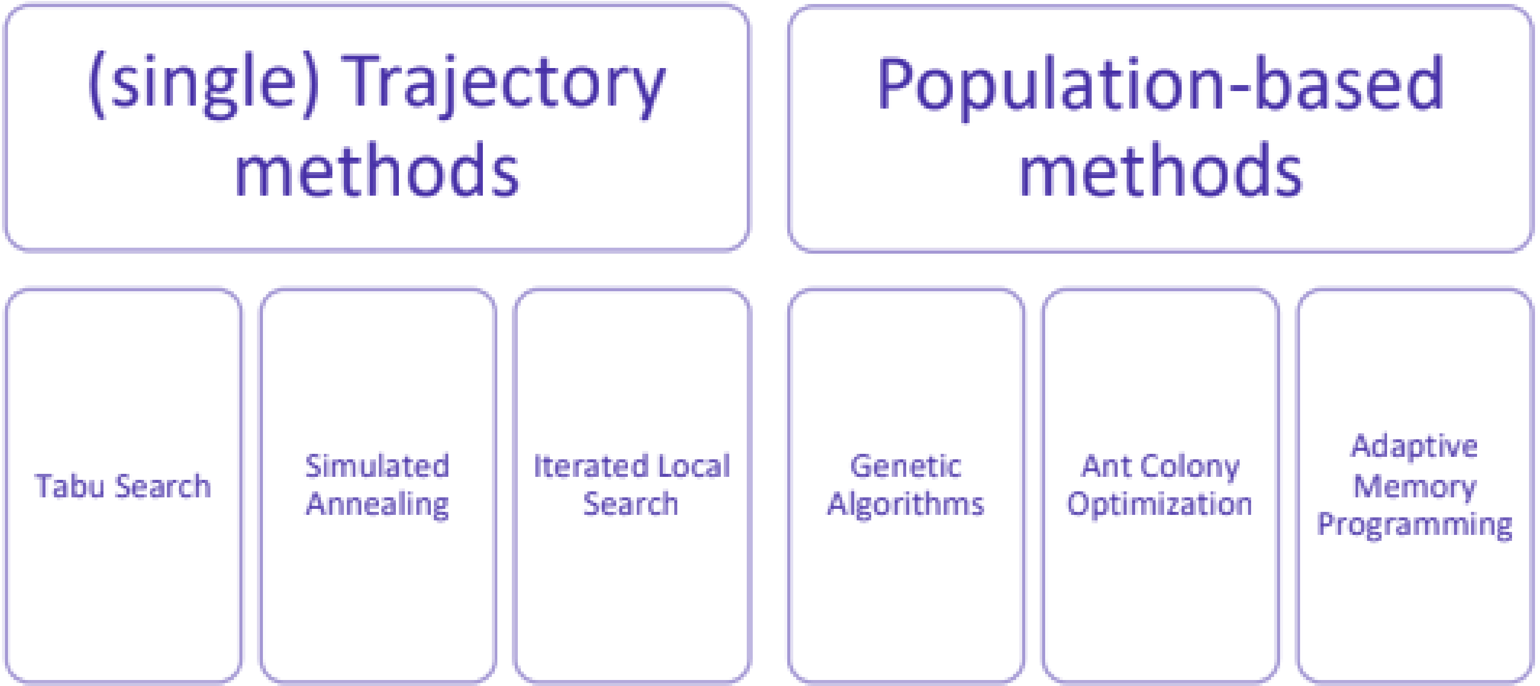
Types of Meta-heuristic algorithms

The fourth Category
Based on directions of search

One neighborhood	Multiple neighborhoods
Most algorithms	Variable Neighborhood Search

Types of Meta-heuristic algorithms

The fifth Category
Based on whether the search has one or more solutions



Required to prepare

NumPy

[NumPy: A powerful tool for scientific calculations]

Thank You

Next Lab:
Genetic Algorithm (Theoretical)