

# Modelling and Optimization

INF170

#1:Introduction

AHMAD HEMMATI

Optimization Group  
Dept. of Informatics  
University of Bergen

Fall Semester  
2018



# AGENDA

- Practical information
- Course plan
- What is optimization?
- Applications
- **Warning:** Today's lecture contains many different subjects, and it is easy to get lost somewhere on the way. Don't despair, as we will repeat the important points several times!



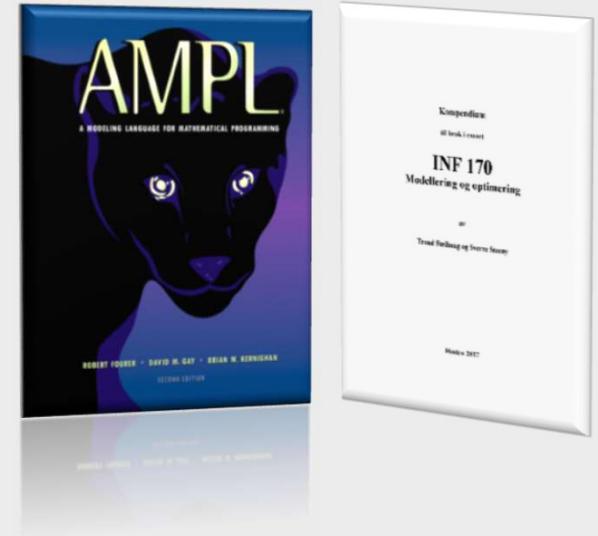
# PRACTICAL INFO

- The lecturer:
  - Ahmad Hemmati
  - E-mail: [Ahmad.Hemmati@uib.no](mailto:Ahmad.Hemmati@uib.no)
  - Office: 410M2, Thormøhlens Gate 55
  - Drop by or email if you have any questions!
- Lectures:
  - Tuesdays 10:15 – 12:00 (HiB, Lille Auditorium)  
W#:36,37,38,39 →(VilVite, TM51 Konf.rom B)
  - Fridays 10:15 – 12:00 (HiB, Seminarrom 510N3)
- Software and TA session:
  - Thursdays 10:15 – 12:00 (HiB, Grupperom 209N1)
  - TA e-mail: [Wrya.Kadir@uib.no](mailto:Wrya.Kadir@uib.no)



# COURSE PLAN

- Literature
  - AMPL book (on mitt.uib.no)
  - Kompendium INF170 (on mitt.uib.no)
  - Lecture slides (on mitt.uib.no)
    - Adapted from similar courses @ MIT, Purdue, Chalmers, NHH,...
- Software
  - AMPL
  - MATLAB
- Assignments
  - 10 assignments including:
  - One mandatory assignment (October 24) → 10%
- Tests (in-class assignments)
  - September 11 → 10%
  - October 12 → 10%
- Final exam
  - Written Exam (14.12.2018, 15:00) → 70%



# OPTIMIZATION

## What is optimization?

- Fastest way to reach school/Skyss.no (that departs in 15min)
- Cheapest flight (from Bergen to somewhere that doesn't rain)
- Biggest TV (that fits in a 10m<sup>2</sup> dorm)
- Fastest laptop (that fits in your bag)
- Smallest laptop (that fits to your budget)
- Minimum calorie (when you bake and the output is supposed to be a cupcake!)
- Best courses for this semester (to learn sth., not difficult)
- ...
- Objective + fulfilling the constraints

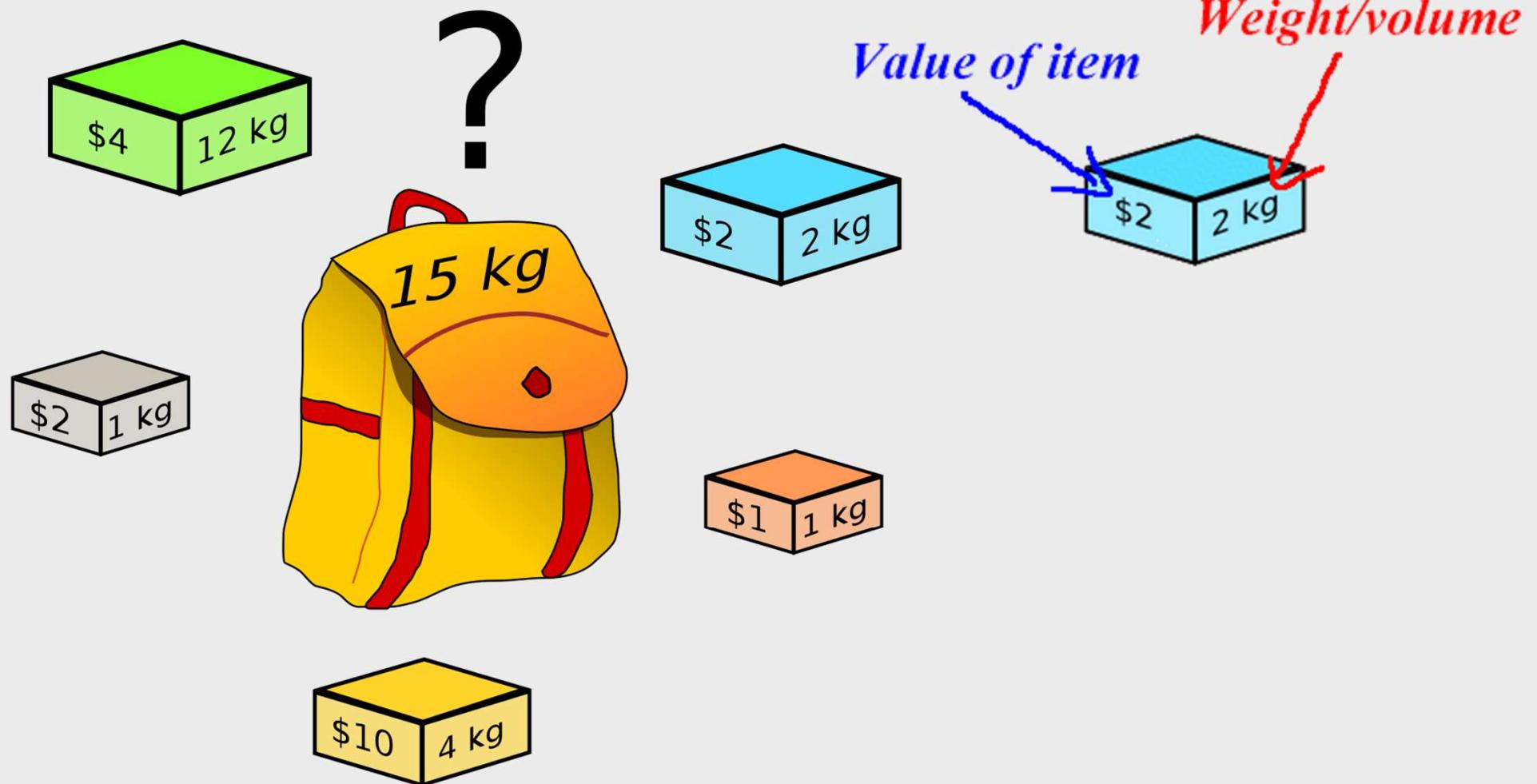


# OPTIMIZATION

**Optimization** is the science of making  
the best decision or, more precisely,  
*making the best possible decision.*



# KNAPSACK PROBLEM



# TRAVELLING SALESMAN PROBLEM (TSP)



# TRAVELLING SALESMAN PROBLEM (TSP)

- A saleswoman located in Indianapolis wants to visit all 48 state capitals of the United States to sell her wares
- What is shortest way of visiting all the capitals and then returning to Indianapolis?

**TRY TO SOLVE IT!**

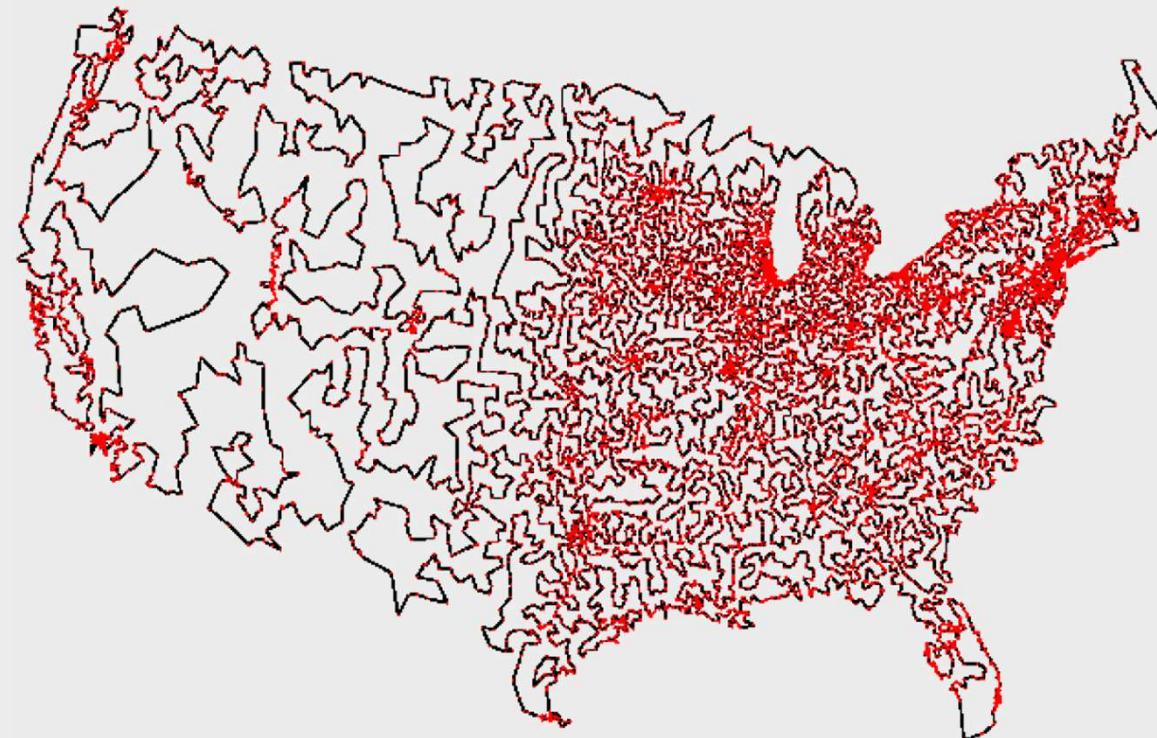


# TRAVELLING SALESMAN PROBLEM (TSP)



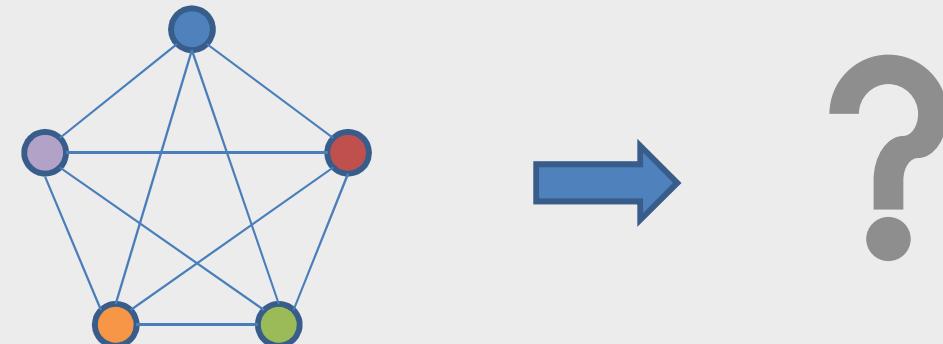
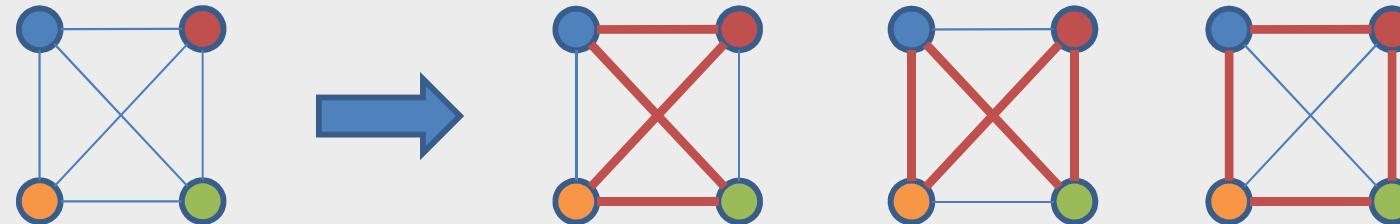
# TRAVELLING SALESMAN PROBLEM (TSP)

- 13,509 cities in the US!



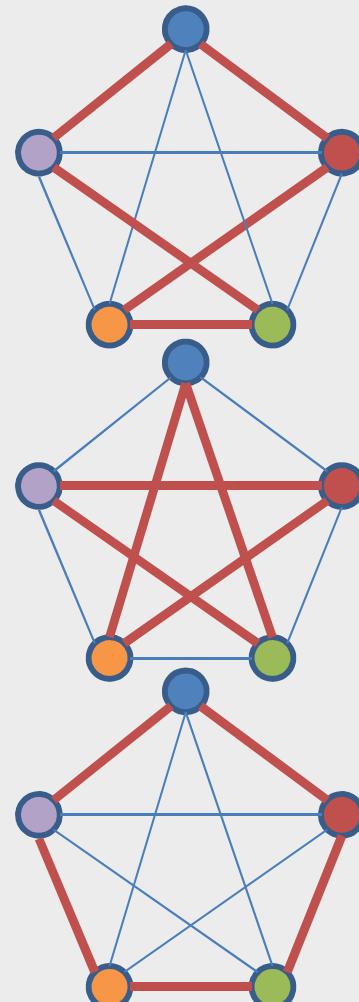
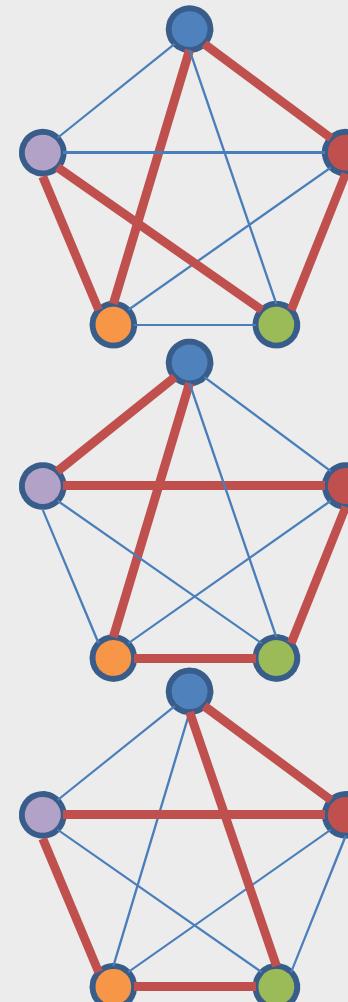
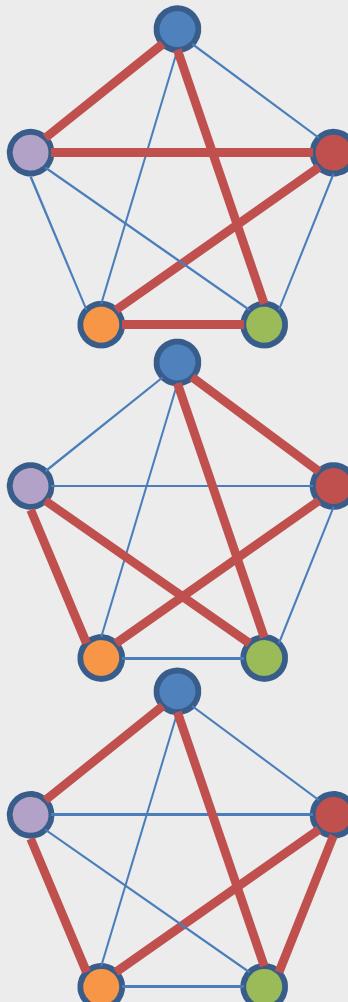
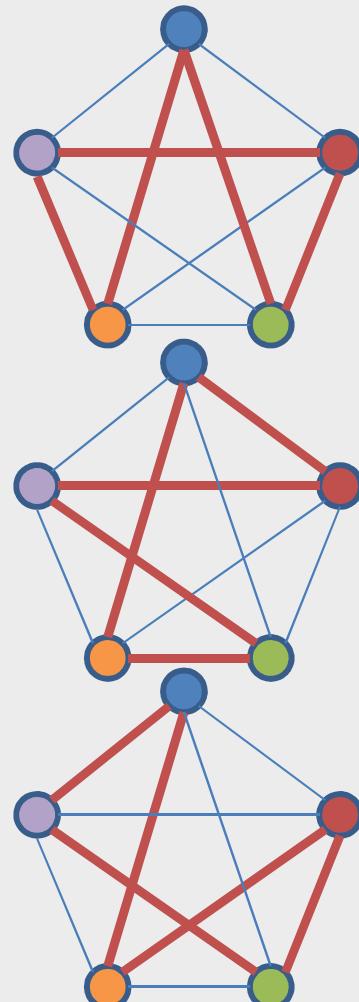
# TRAVELLING SALESMAN PROBLEM (TSP)

- How many solutions?!



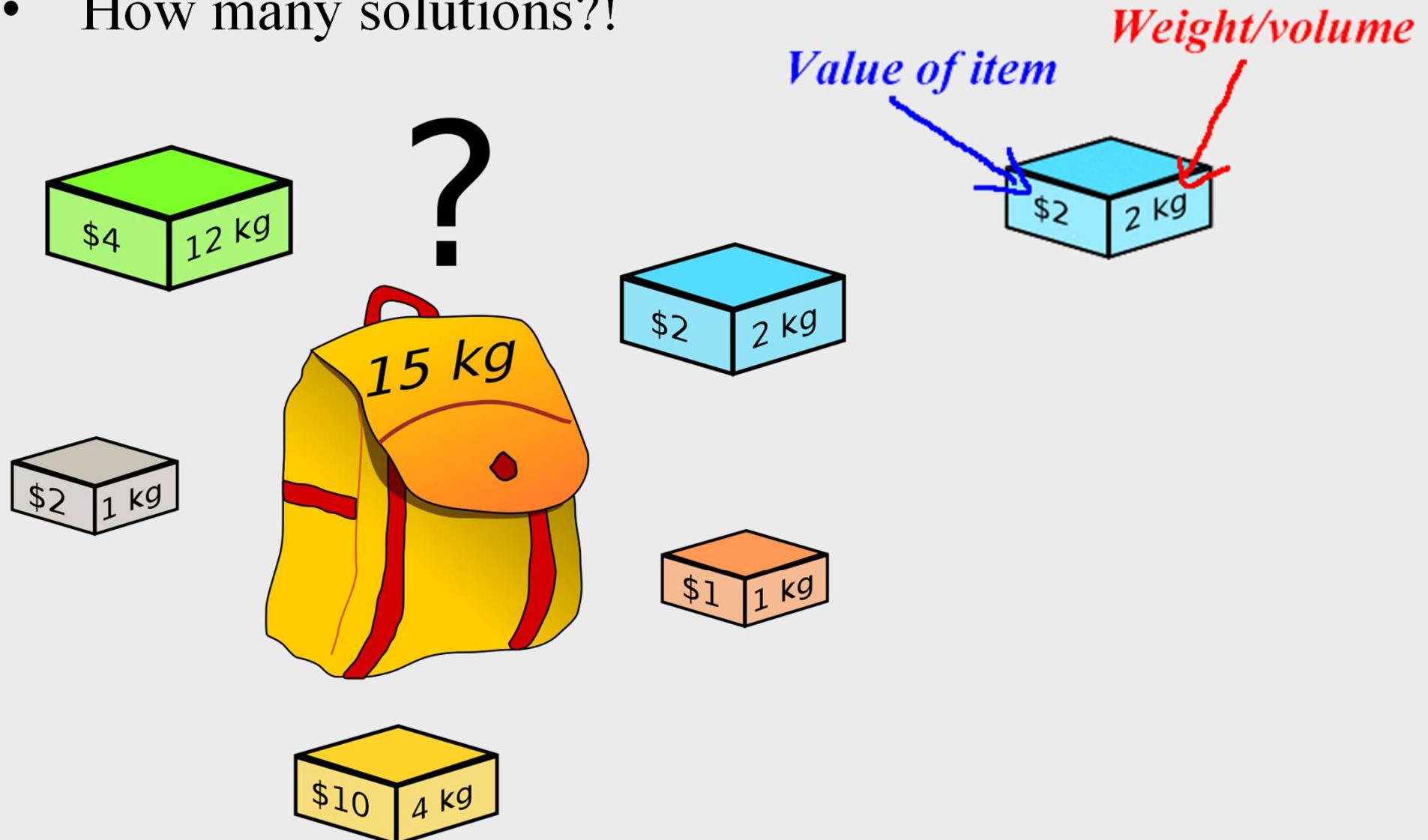
# TRAVELLING SALESMAN PROBLEM (TSP)

➤  $\frac{1}{2}(n-1)!$



# KNAPSACK PROBLEM

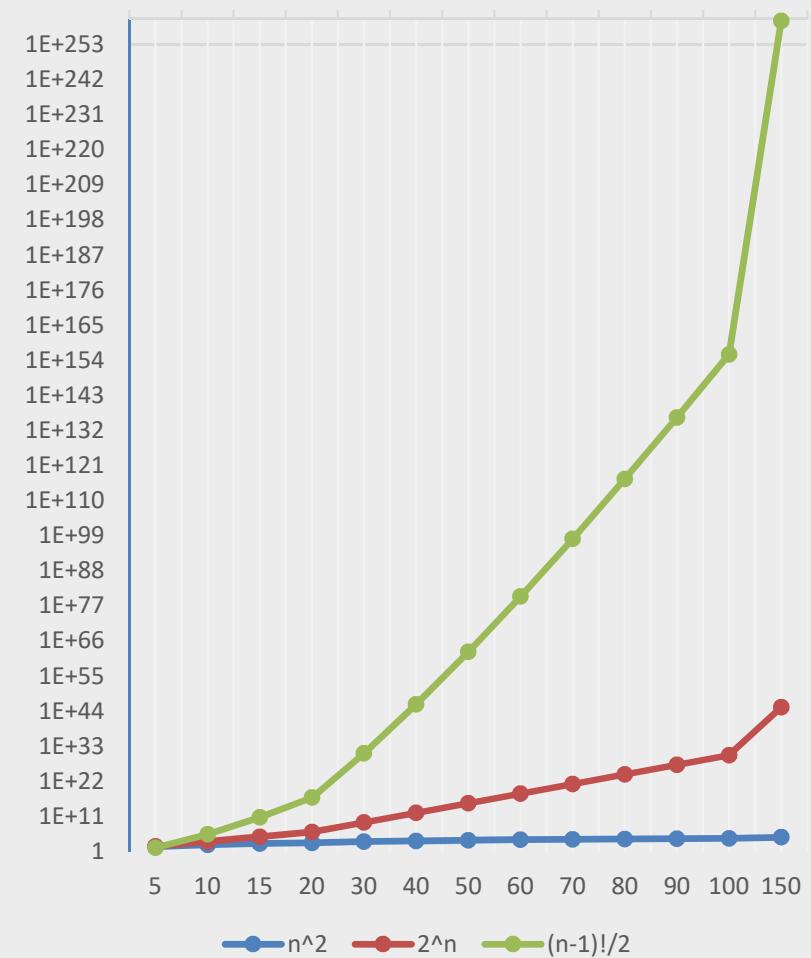
- How many solutions?!



# THE COMBINATORIAL EXPLOSION

- Knapsack problem:  $2^n$
- TSP:  $\frac{1}{2}(n-1)!$

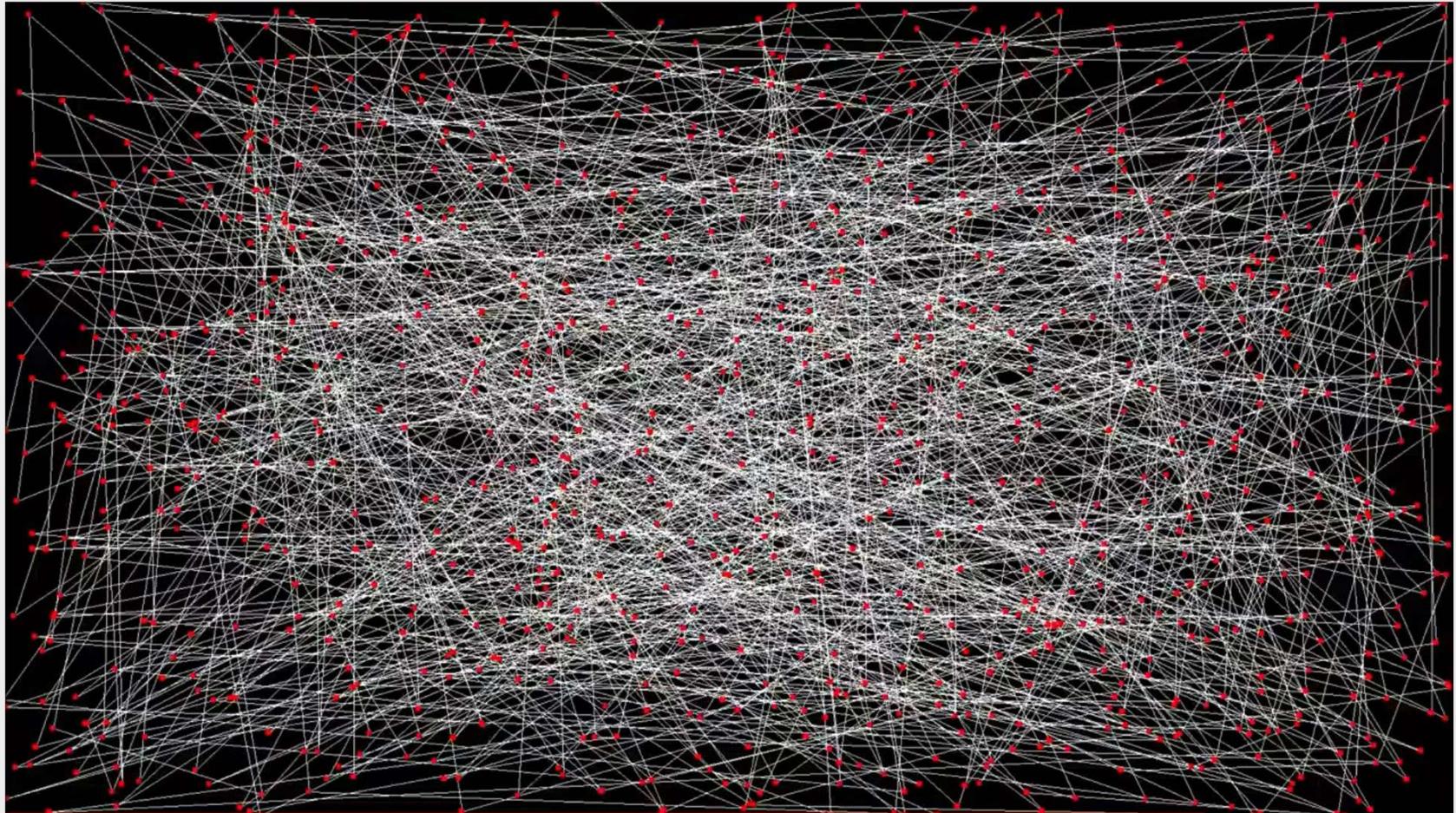
n	$n^2$	$2^n$	$\frac{1}{2}(n-1)!$
5	25	32	12
10	100	1024	181440
20	400	1048576	6.08E+16
30	900	1.07E+09	4.42E+30
50	2500	1.13E+15	3.04E+62
100	10000	1.27E+30	4.70E+155
150	22500	1.43E+45	1.90E+260



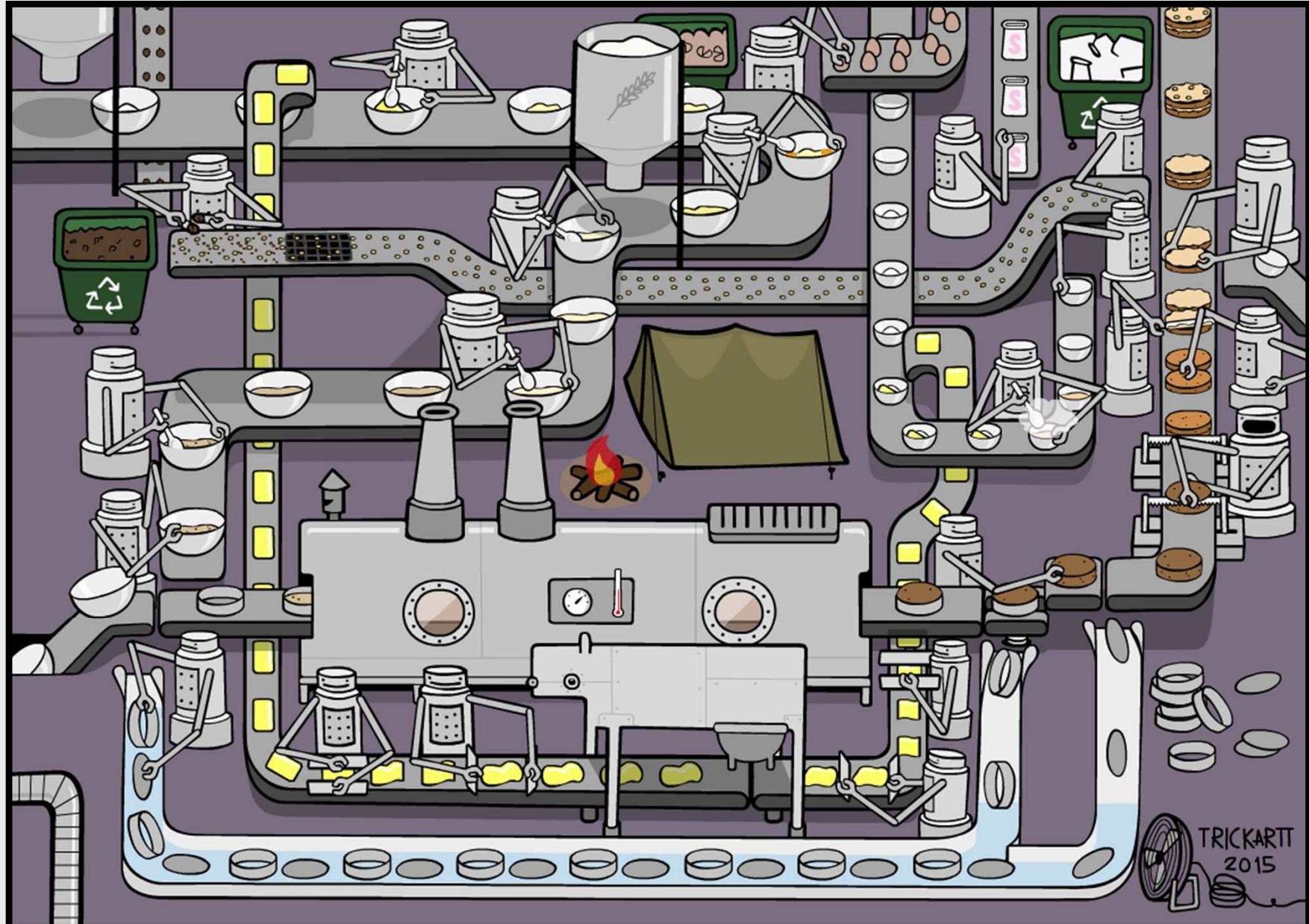
# METAHEURISTICS-TSP (304 CITIES)



# METAHEURISTICS-TSP (1000 CITIES)



# PRODUCTION SCHEDULING



# APPLICATIONS

## Numerous applications, including:

- **Logistics:** production and transport
  - Manufacturing, Production planning and scheduling
  - Optimize routes for transports, snow removal, school buses, ...
  - Location of stores
  - Packing of containers
  - Resource allocation (processing capacity, staff)
  - Inventory Management
- **Energy** (electricity, gas, wind, etc.)
  - Design and use of the supply network
  - Infrastructure investments
  - Pricing
  - Location of power plants, turbines and infrastructure

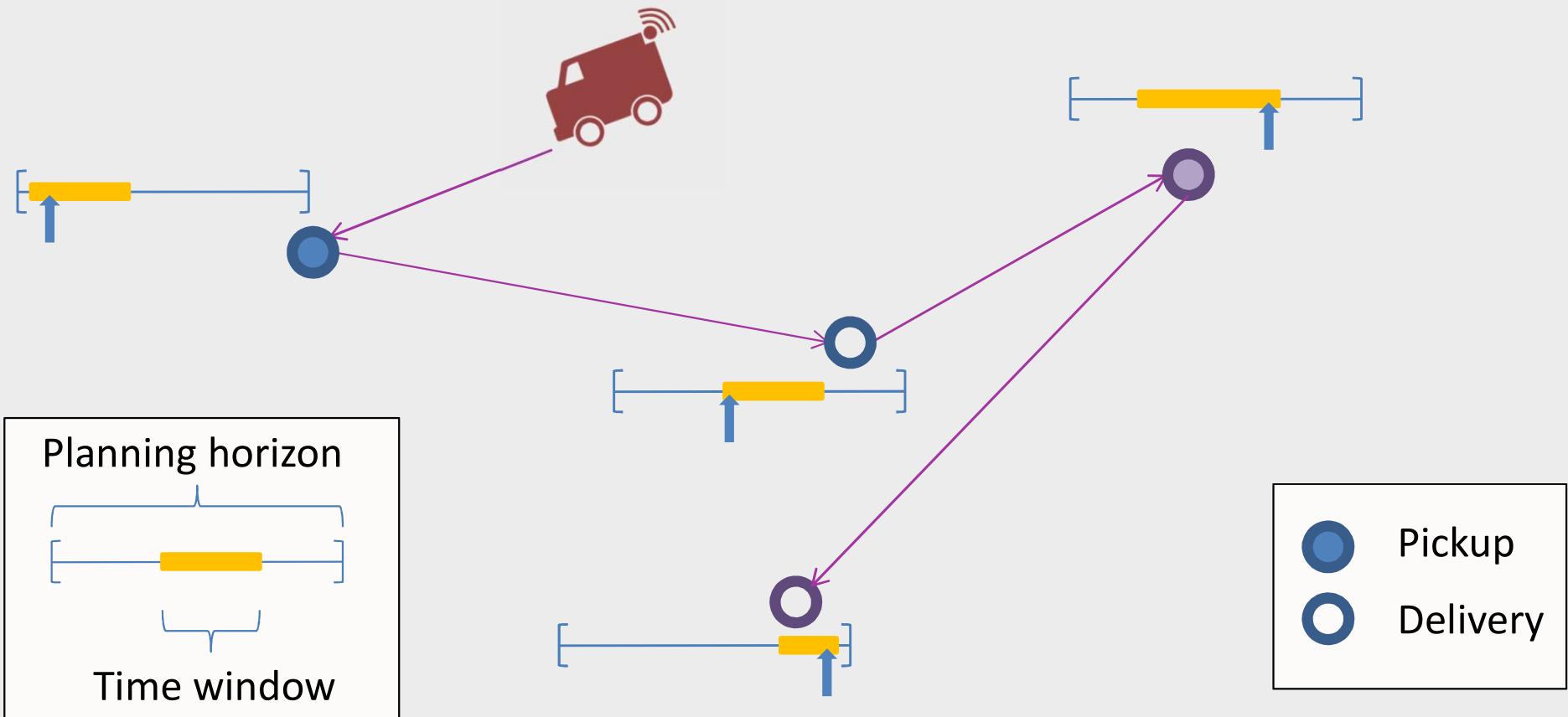


# APPLICATIONS

- **Finance**
  - Financial risk management
  - Portfolio optimization
  - Investment planning
  - Airline Pricing
- **Petroleum industry**
  - Where to buy crude oil
  - How to ship
  - Which products to produce
- **Communications**
- **Marketing**
- **Healthcare**



# PICKUP AND DELIVERY



**Request:** Origin, Destination, Size, Time windows at origin and destination

# SHIP ROUTING AND SCHEDULING

- A heterogeneous fleet of ships (speed, capacity, compatibility, etc.)
- Given set of cargoes
- Given time windows at pickup and delivery
- Designing routes & schedules



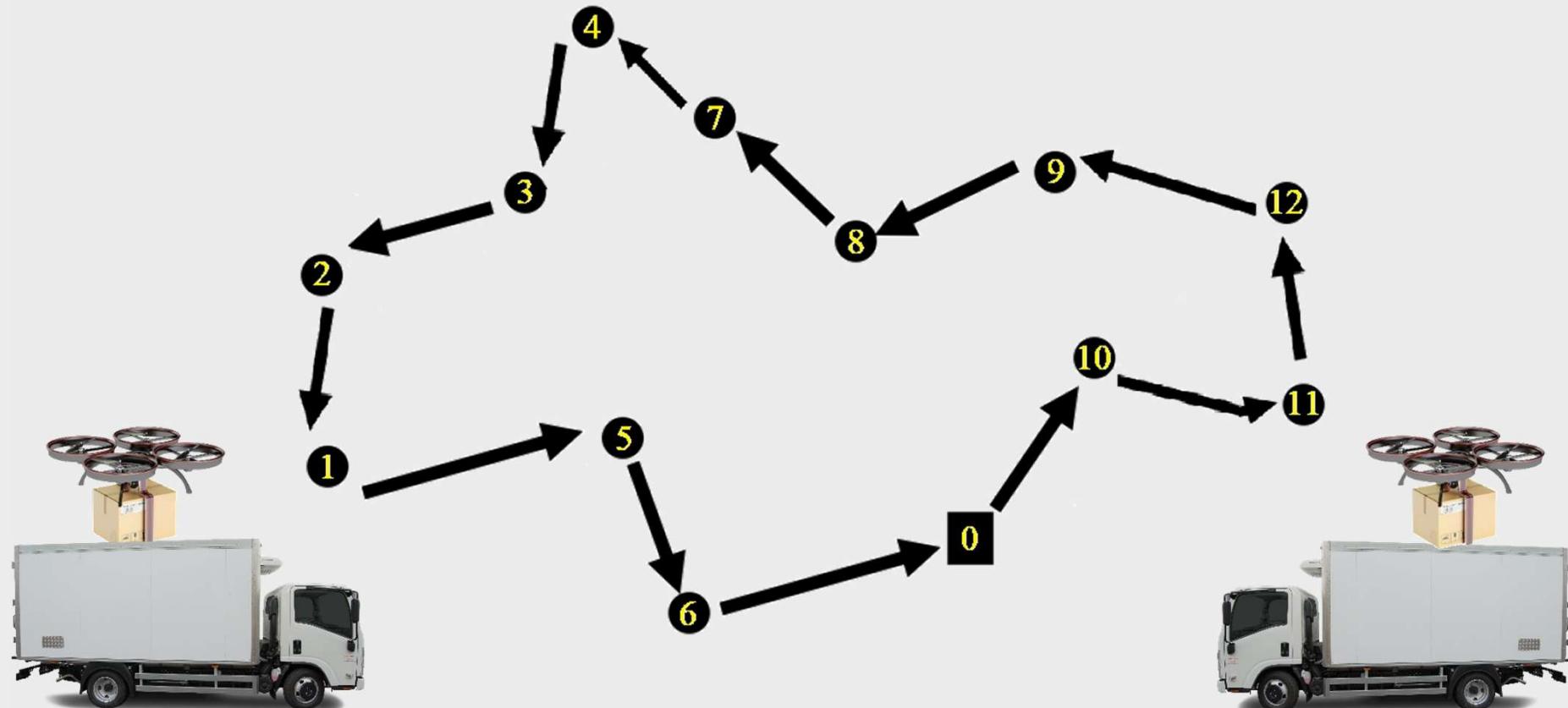
# MARITIME INVENTORY ROUTING

- Multiple products
- Products are produced and/or consumed at any number of ports
- Heterogeneous fleet
- Fully flexible system (many-to-many)
- Designing routes & schedules
- Determining the quantities handled at each port call
- Not exceeding the storage limits



# TRUCK-DRONE DELIVERY

- Instead of only trucks/vans for delivery service ...



# DRONE DELIVERY

2013	2015	2016	2017	2018
Amazon Prime Air 	Workhorse 	Mercedes Benz 	UPS 	Drone Delivery Canada 
Matternet 	Domino's 	Alphabet, Google Wing 	DHL 	Zipline 
MIT 				



# TRUCK-DRONE DELIVERY

**TRUCK MODE**

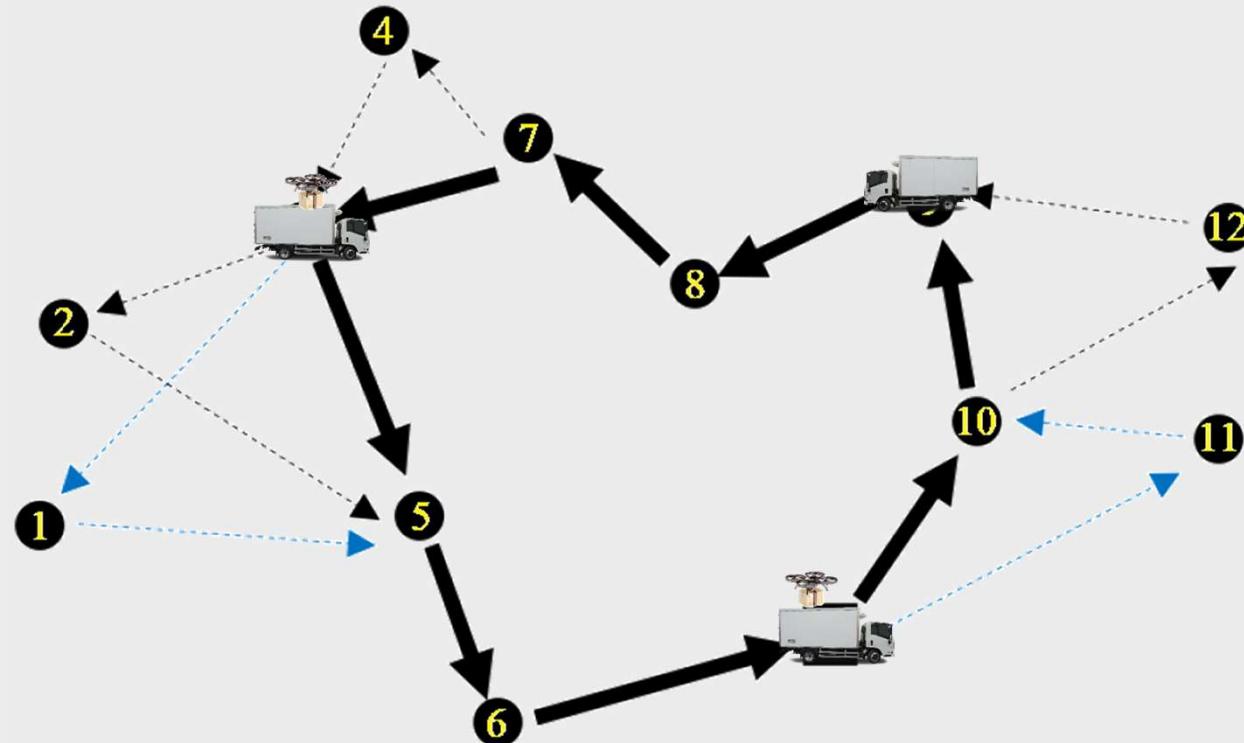


**TRUCK CARRYING THE DRONE**

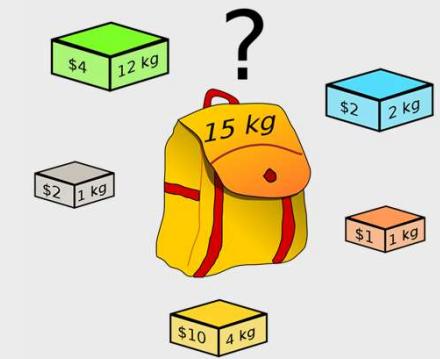
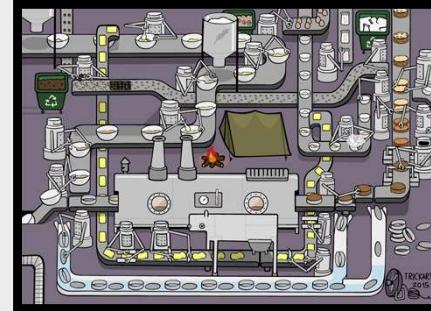
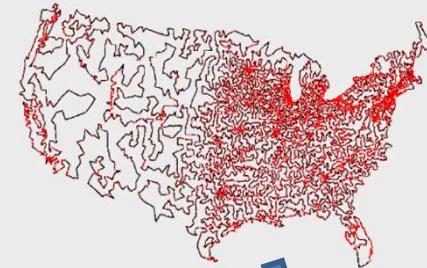


# TRUCK-DRONE DELIVERY

- Let's assign some customers to drones!

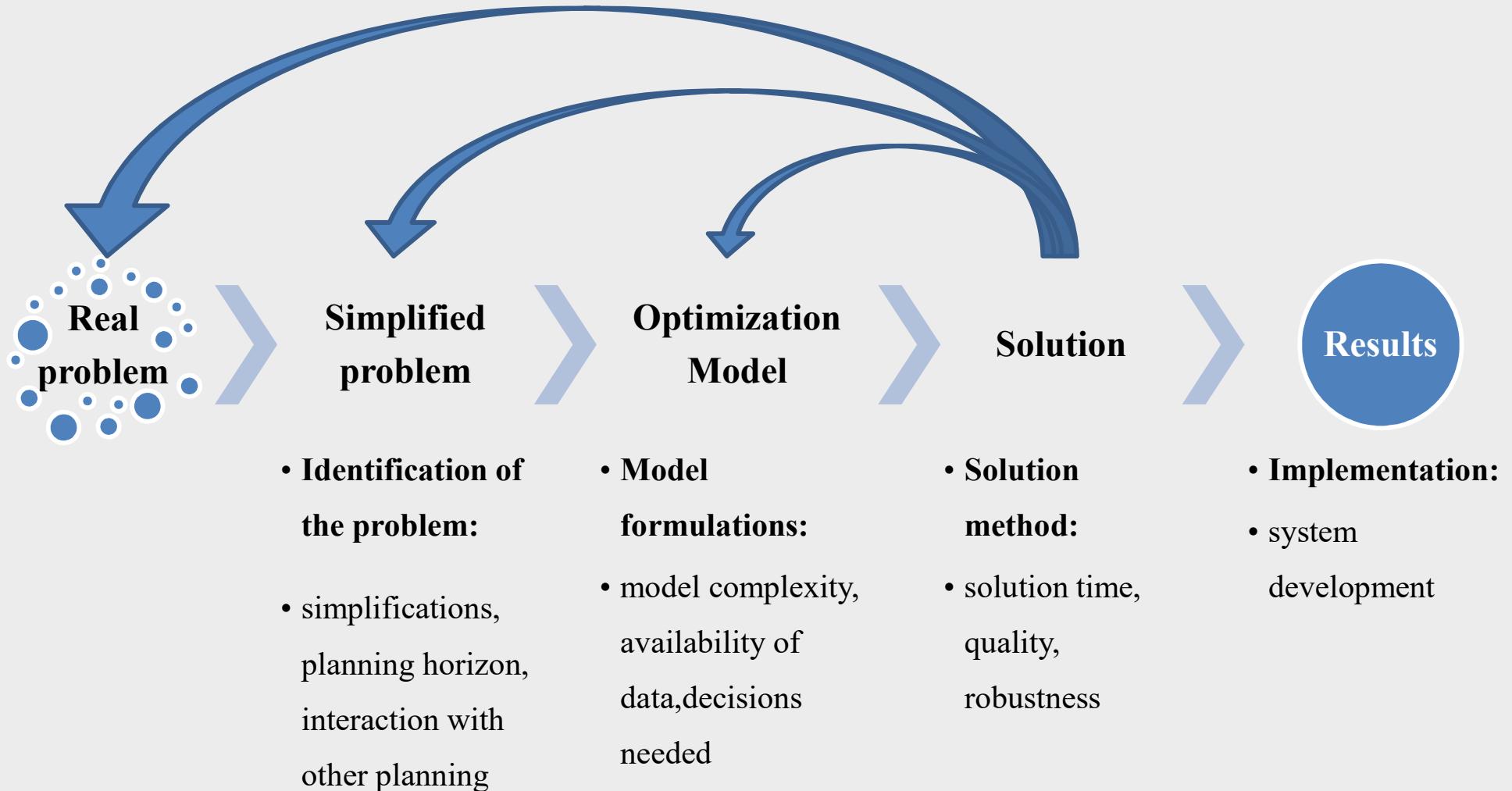


# OPTIMIZATION



$$\begin{aligned} & \min f(x) \\ \textit{st} \quad & g(x) \leq b \\ & x \in X \end{aligned}$$

# OPTIMIZATION PROCESS

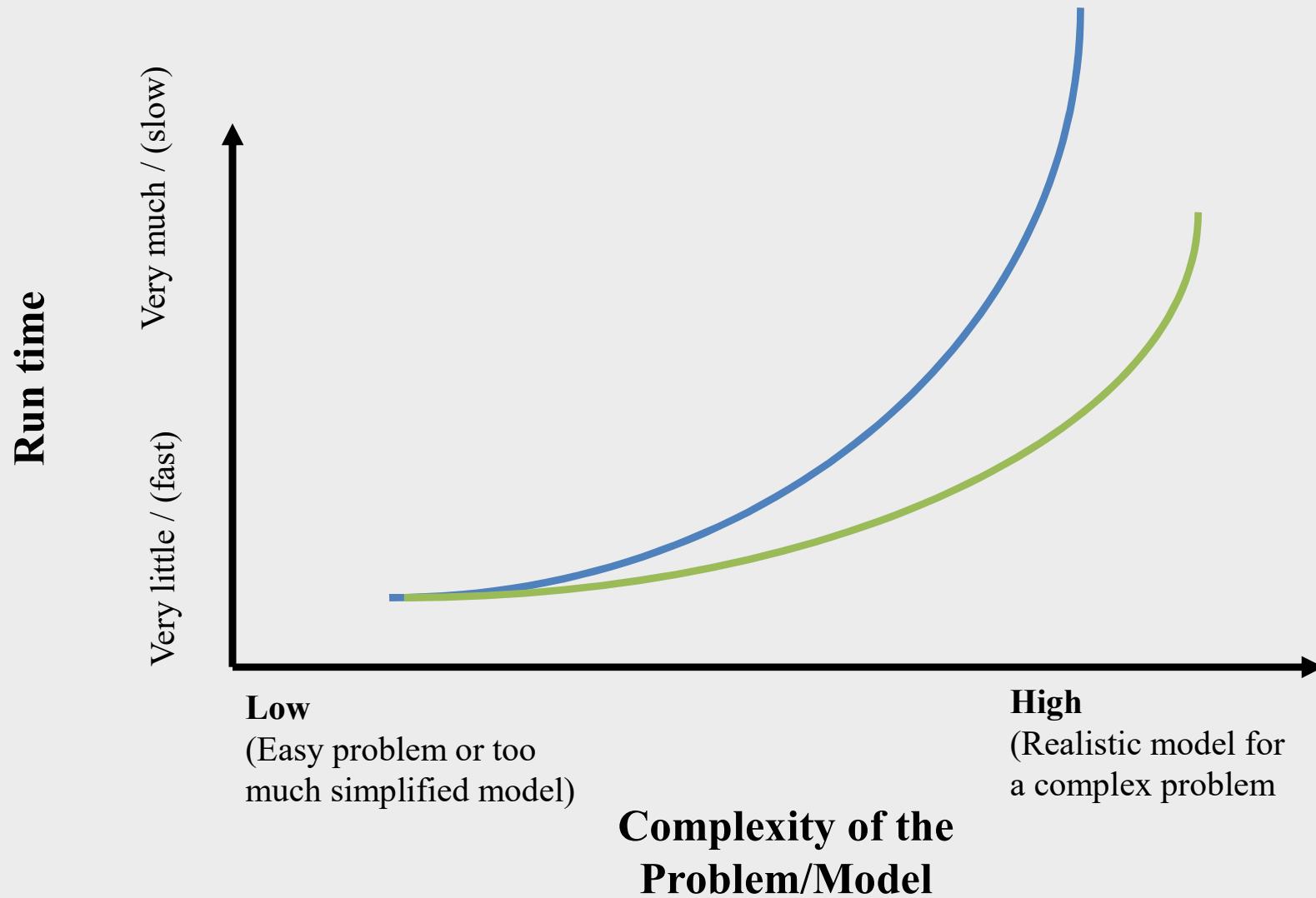


# MOTIVATION TO MODELS

- Building models reveals relations which were not apparent.
- Possibility to analyze it mathematically.
- Experimenting provides many insights.
- Provide practical/useful solutions for many situations.



# COMPLEXITY OF THE MODEL VS. RUNTIME



# THE ART OF MODELLING



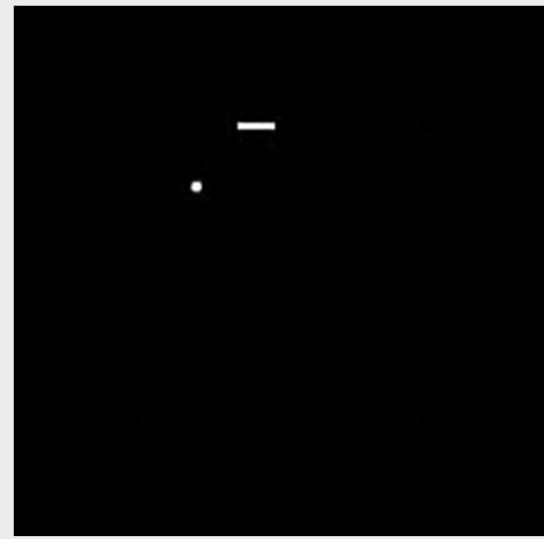
© Louvre Museum



NEXT LECTURE

# LECTURE #2: UNCONSTRAINED OPTIMIZATION





SEE YOU ON FRIDAY!  
@ HiB, Seminarrom 510N3

