MetaHeuristics

INF273

#3: MetaHeuristics Components

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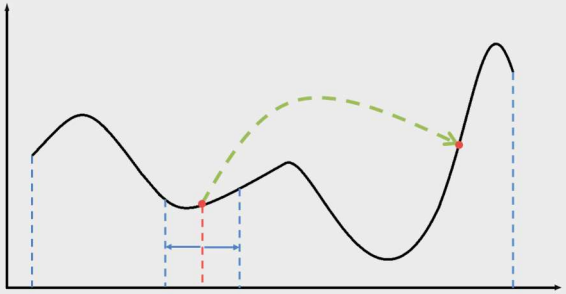
Agenda

Metaheuristics components:



- Solution representation
- Intensification
- Diversification
- Termination (Stopping Criteria)

METAHEURISTICS

- Meta-heuristics can be considered as an efficient way to produce acceptable solutions by trial and error/learn to a complex problem in a reasonably practical time.
- The complexity of the problem of interest makes it impossible to search every possible solution or combination
- The aim is to find a good feasible solution in an acceptable time scale.
- There is no guarantee that the global best solutions can be found

METAHEURISTICS

- The idea is to have an efficient and practical algorithm that works most of the time and is able to produce good quality solutions.
- Using smart components increase the chance of getting good quality solutions.
- Among the found quality solutions, it is expected that some of them are nearly optimal, though there is often no guarantee for such optimality

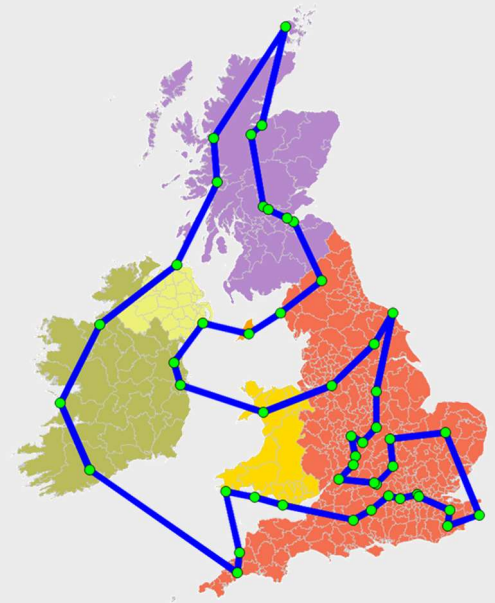
Solution Representation

- In order to tackle a problem using a Metaheuristic, candidate solutions must be encoded in a suitable form
- Representation of complex objects by a vector (or more) of simple components
  - Binary bit strings
  - Ordered lists (permutation)
  - Continuous variables

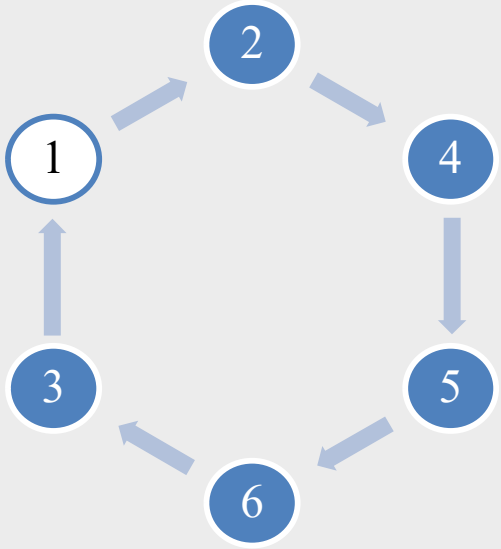
Solution Representation

TSP (Binary)

- Binary Matrix



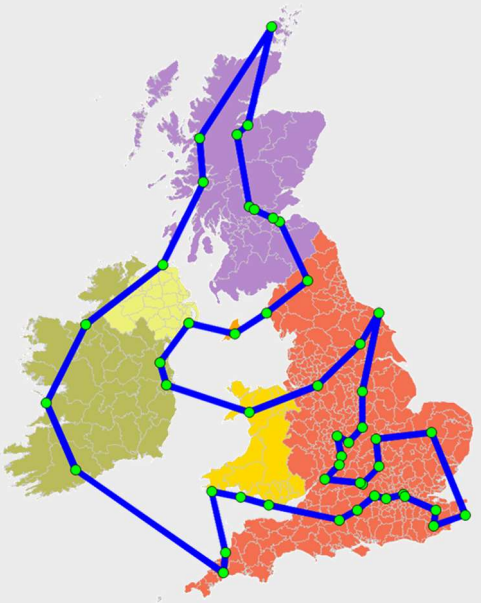
	1	2	3	4	5	6
1	0	1	0	0	0	0
2	0	0	0	1	0	0
3	1	0	0	0	0	0
4	0	0	0	0	1	0
5	0	0	0	0	0	1
6	0	0	1	0	0	0



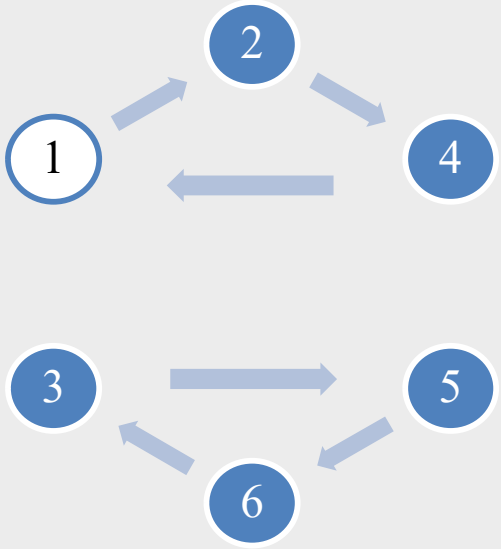
Solution Representation

TSP (Binary)

- Binary Matrix
- Easy to violate the legality

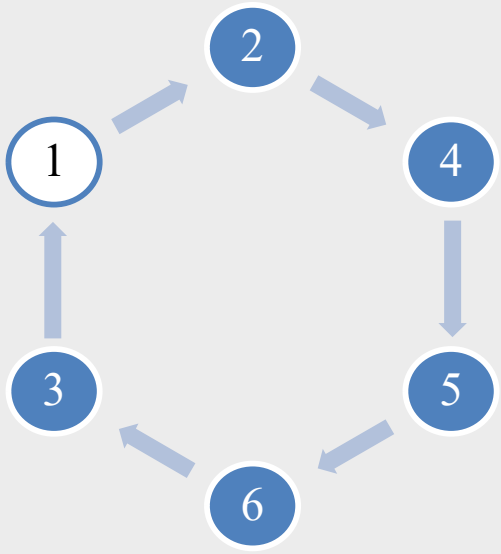


	1	2	3	4	5	6
1	0	1	0	0	0	0
2	0	0	0	1	0	0
3	0	0	0	0	1	0
4	1	0	0	0	0	0
5	0	0	0	0	0	1
6	0	0	1	0	0	0



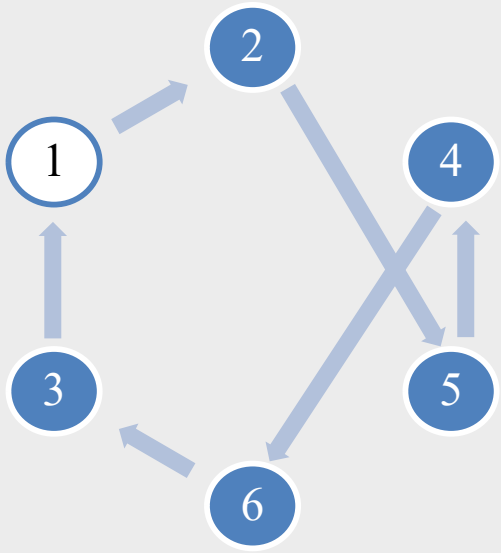
TSP (Permutation)

1	2	4	5	6	3



TSP (Permutation)

1	2	5	4	6	3



Solution Representation

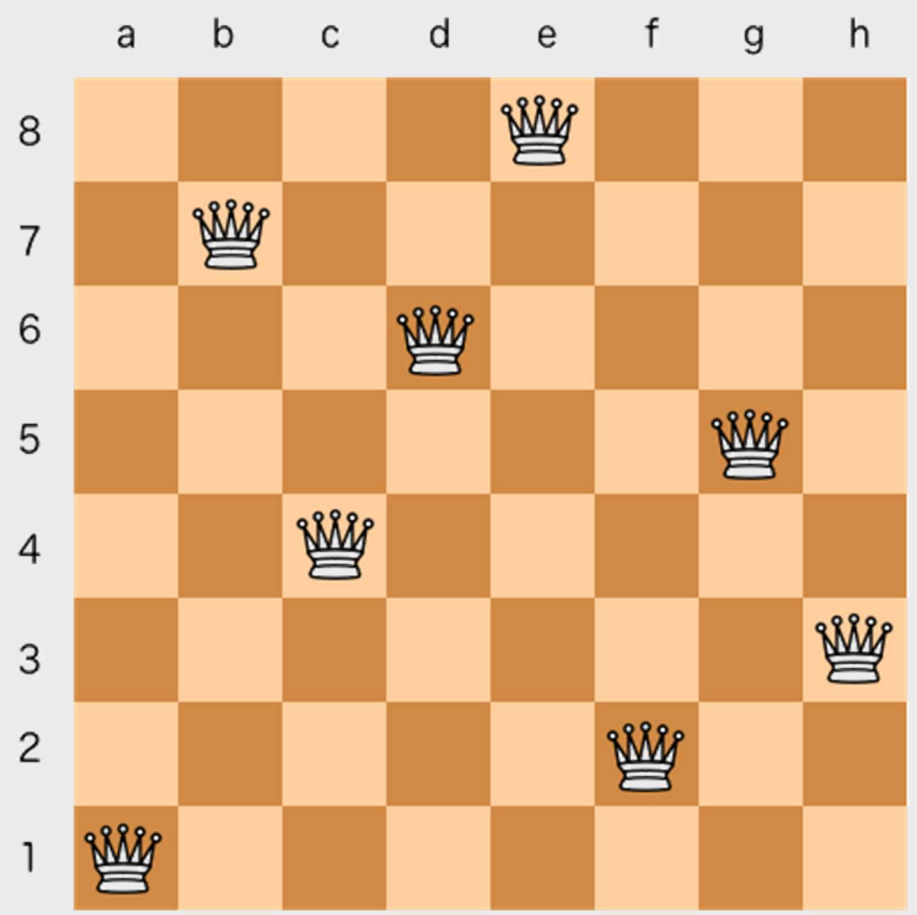
Knapsack

1	2	3	4	5
0	0	1	0	1

Solution Representation

N queens

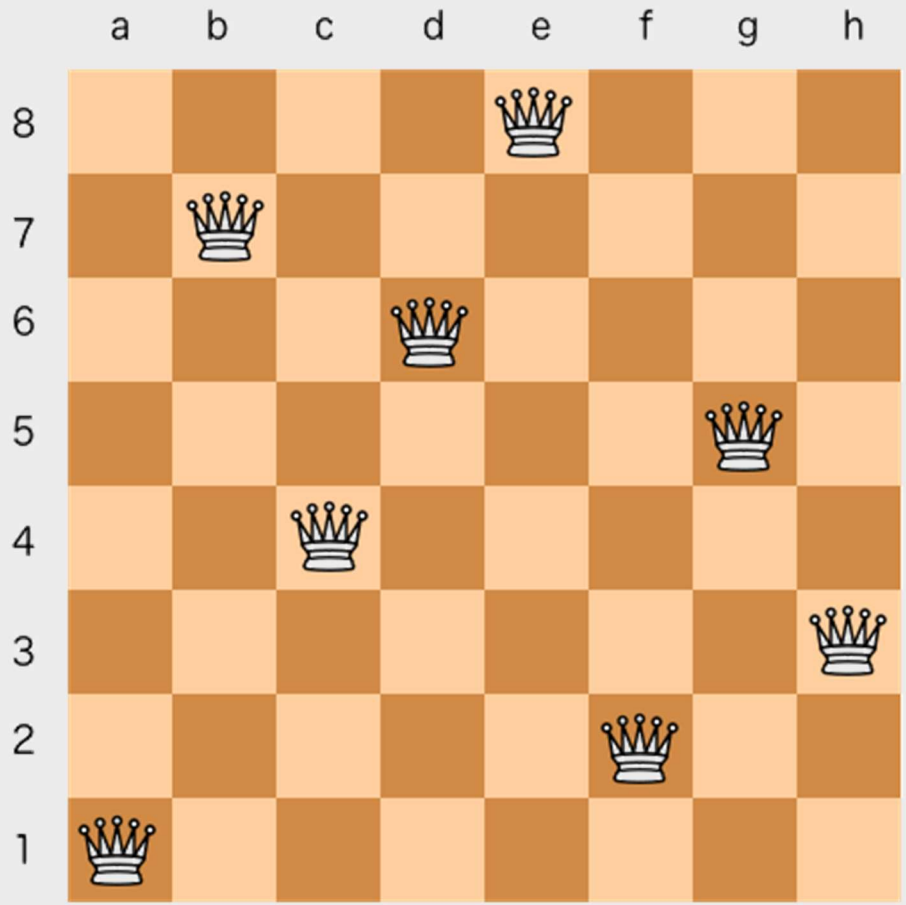
- No two queens threaten each other.
- Thus, a solution requires that no two queens share the same row, column, or diagonal



Solution Representation

N queens

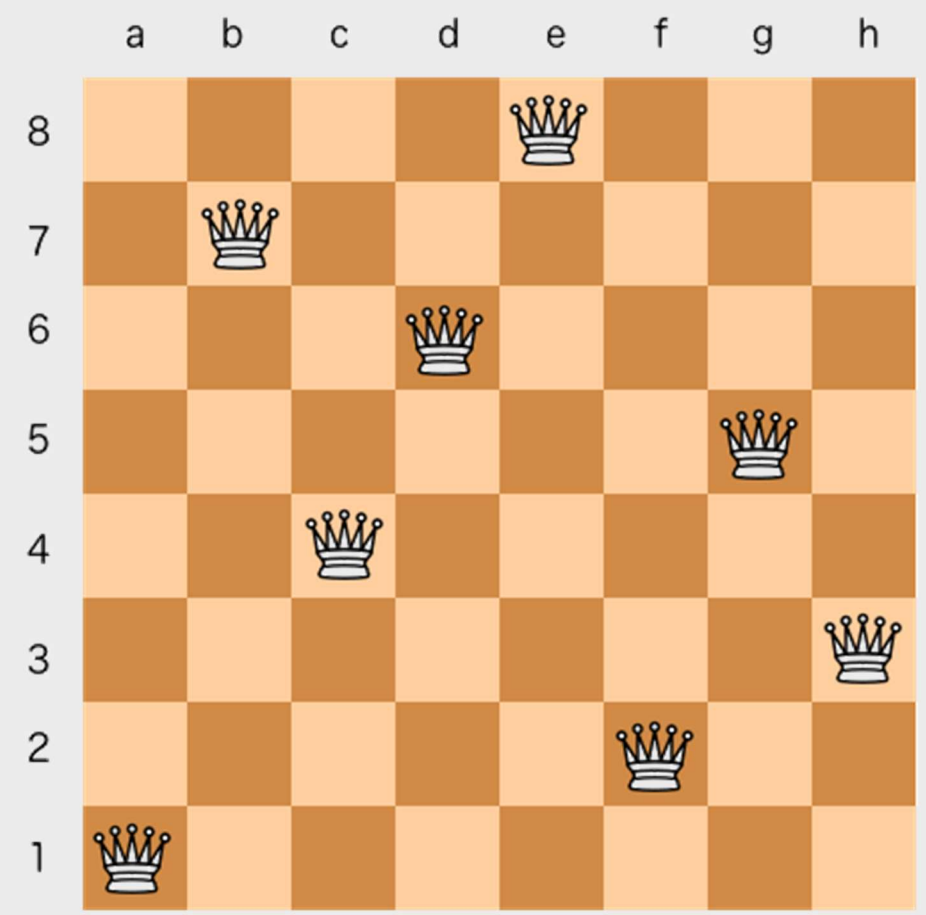
	a	b	c	d	e	f	g	h
8	0	0	0	0	1	0	0	0
7	0	1	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0
5	0	0	0	0	0	0	1	0
4	0	0	1	0	0	0	0	0
3	0	0	0	0	0	0	0	1
2	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0



Solution Representation

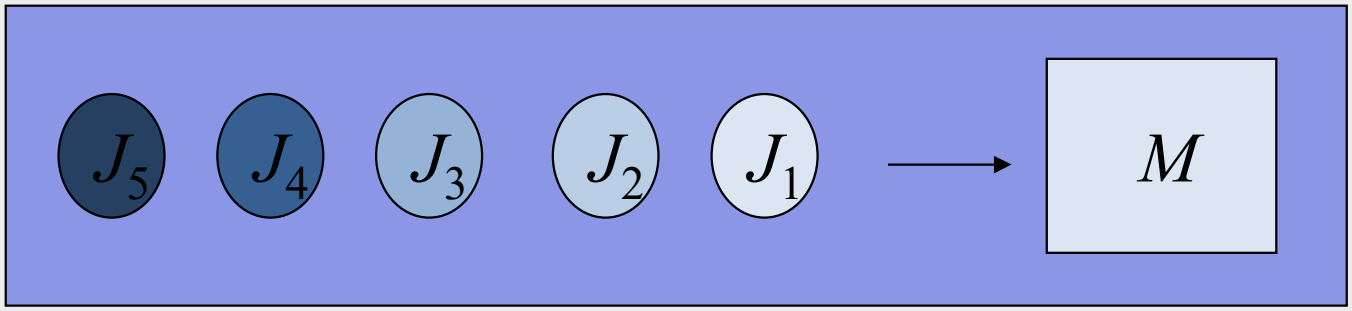
N queens

a	b	c	d	e	f	g	h
1	7	4	6	8	2	5	3

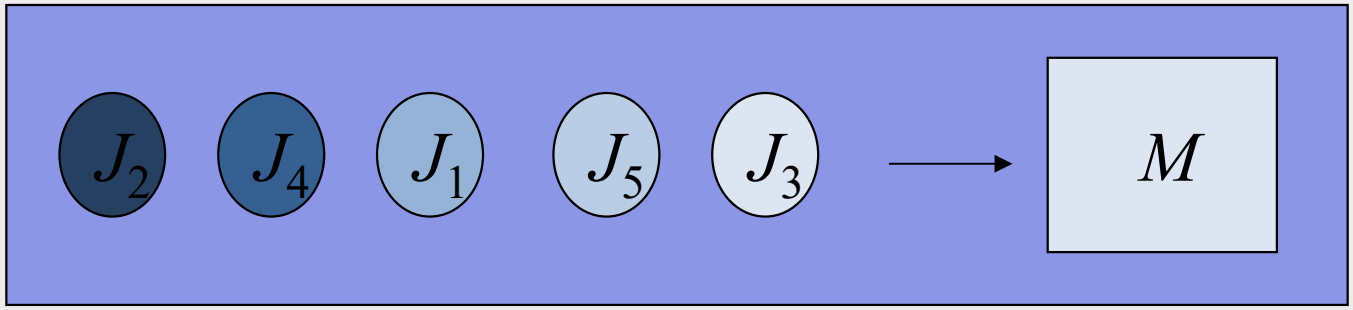


Single Machine

- ATM queue
- Small shops with one cashier



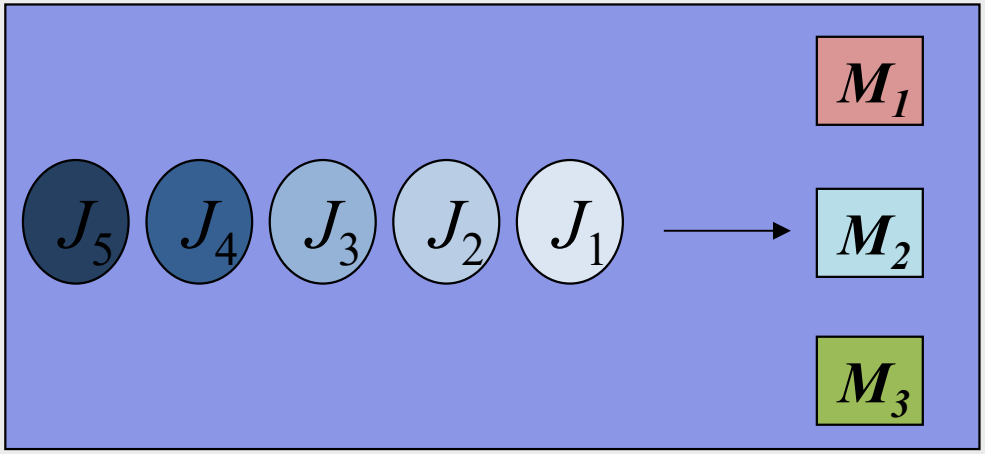
Single machine



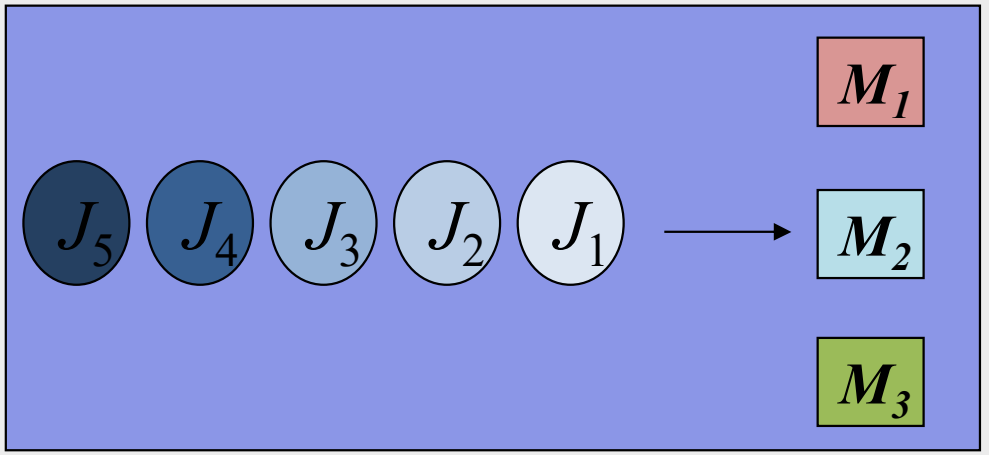
2	4	1	5	3

Parallel Machines

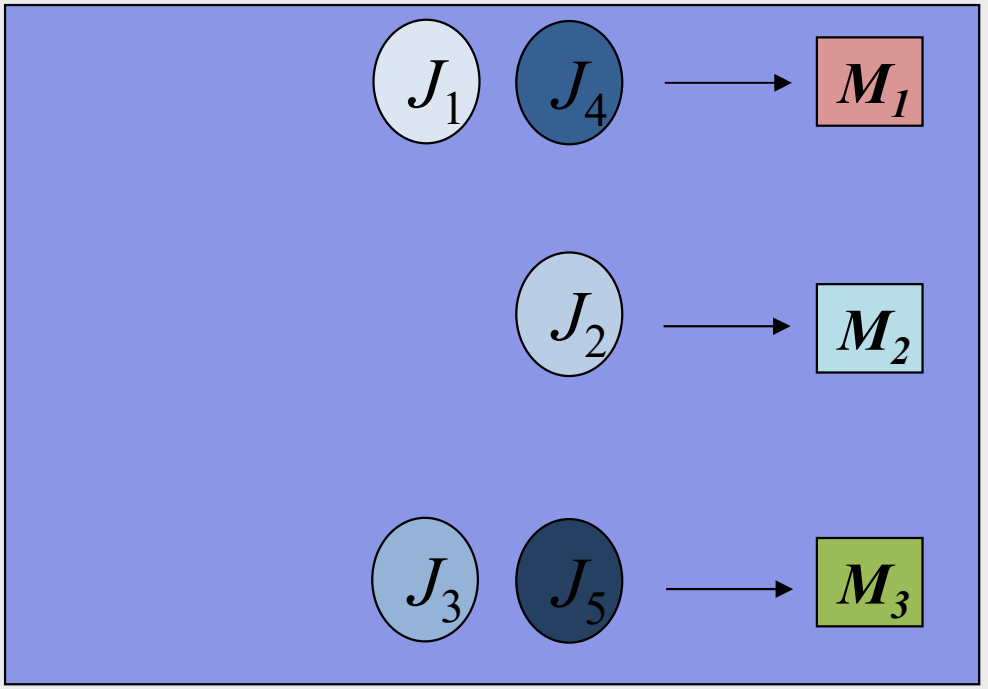
- Machines in parallel
  - There are several machines in parallel.
  - Shops with multiple cashier
  - Check-in at airport
  - Bank services



Parallel machines

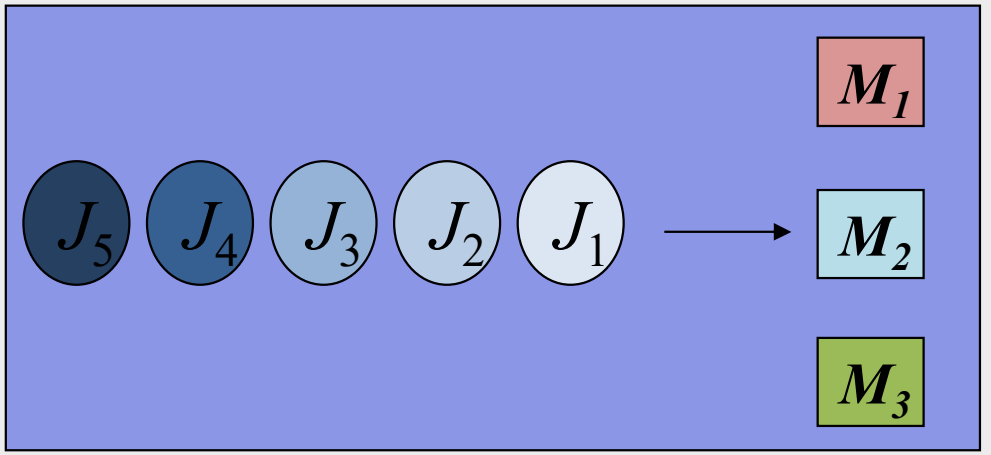


5	4	3	2	1
–	–	–	1	4
–	–	–	–	2
–	–	–	3	5

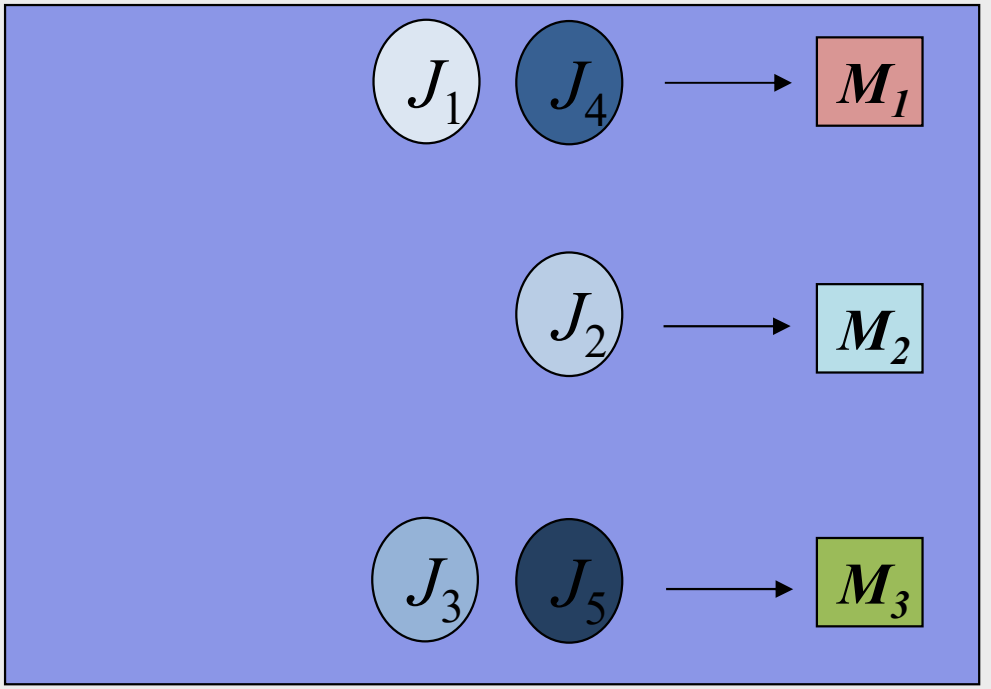


Solution Representation

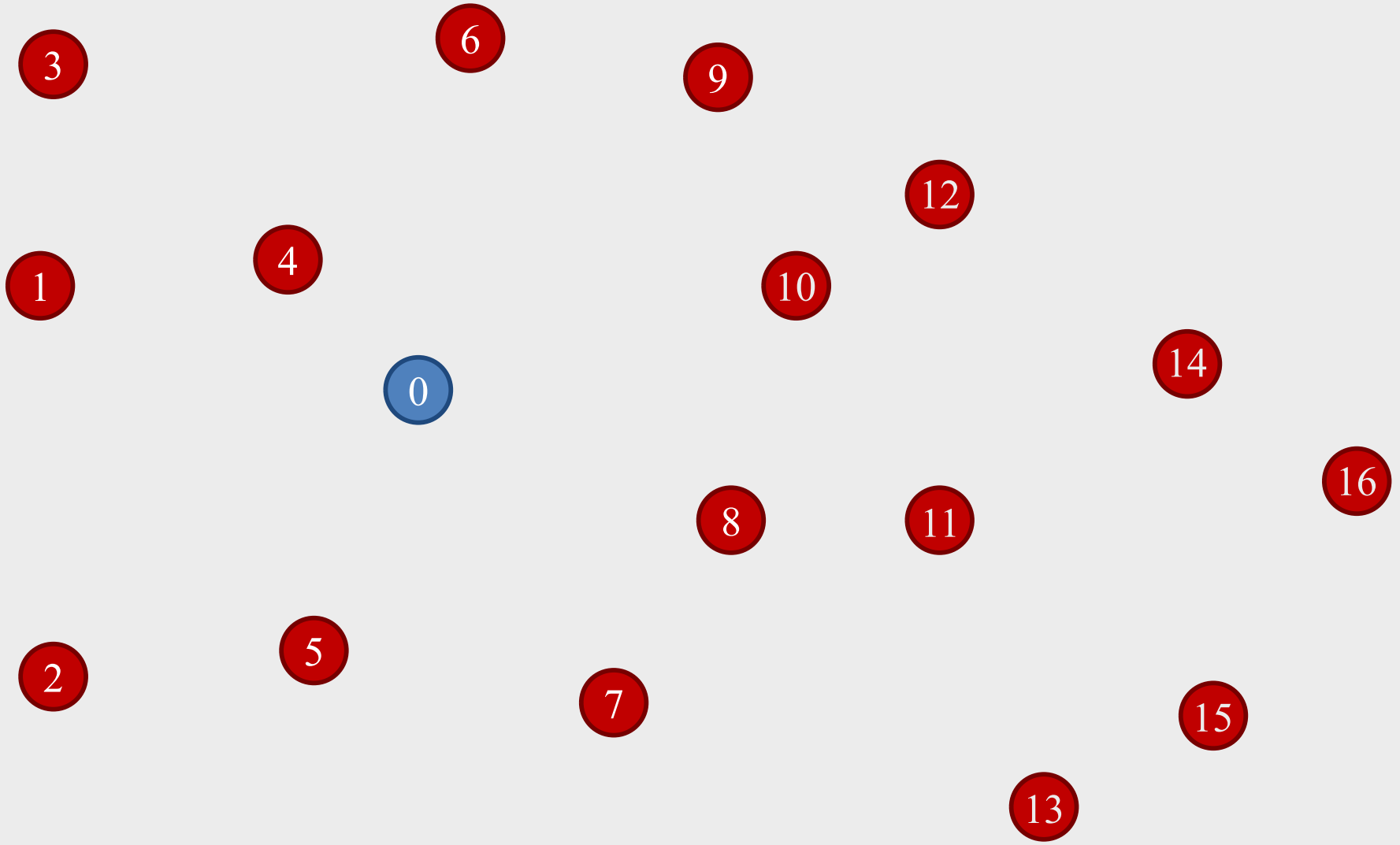
Parallel machines



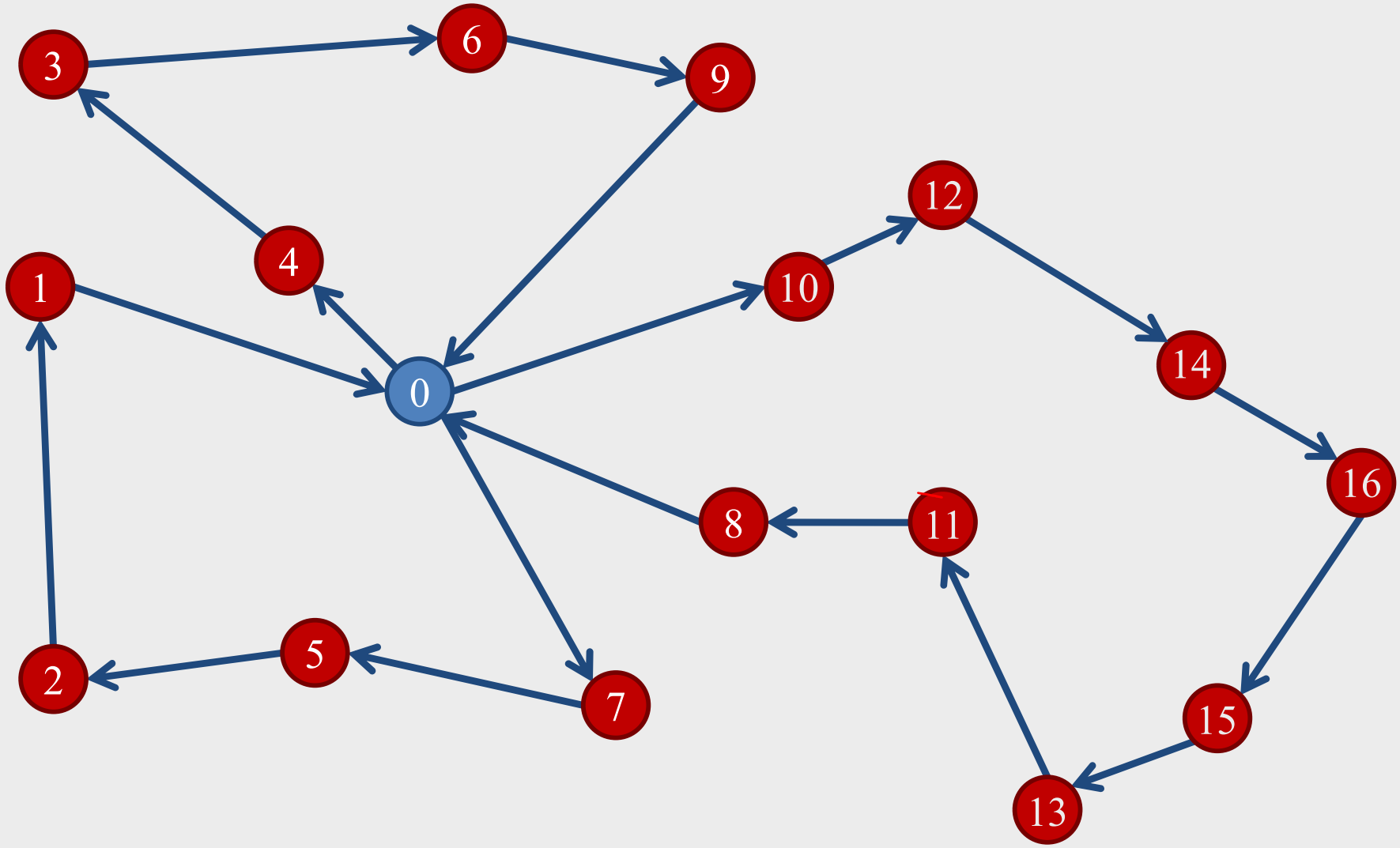
1	4	0	2	0	3	5



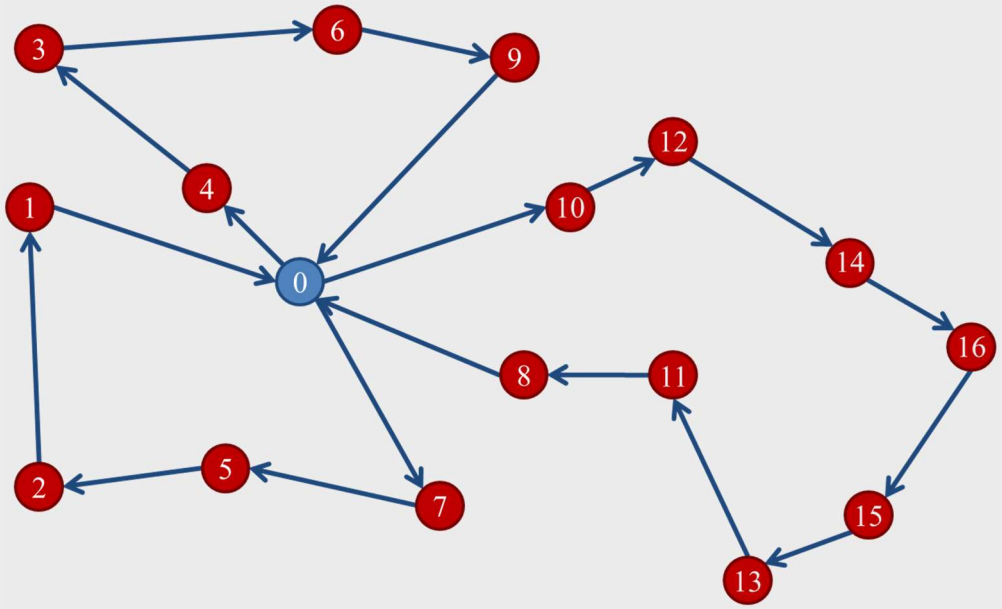
Vehicle Routing Problem (VRP)



Vehicle Routing Problem (VRP)

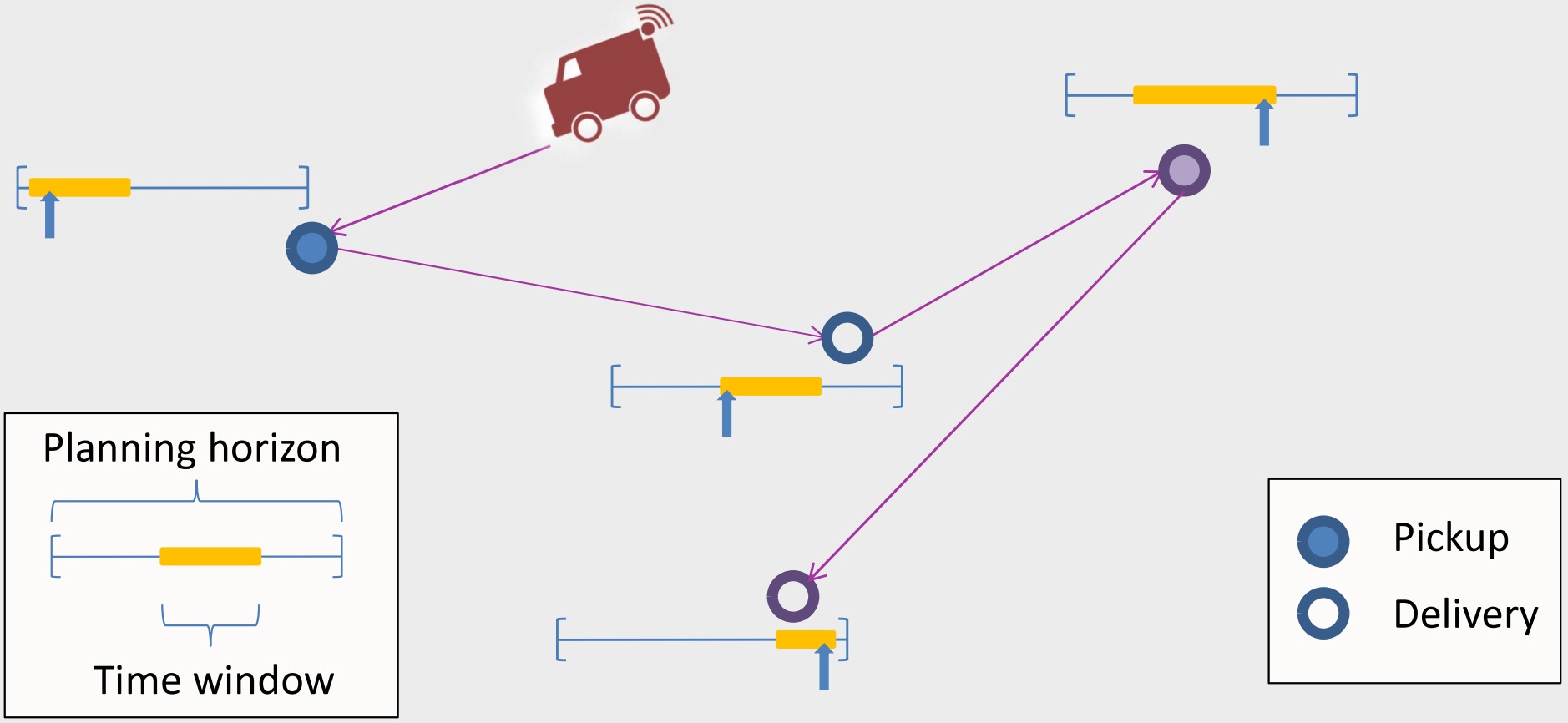


Vehicle Routing Problem (VRP)



4	3	6	9	0	7	5	2	1	0	10	12	14	16	15	13	11	8

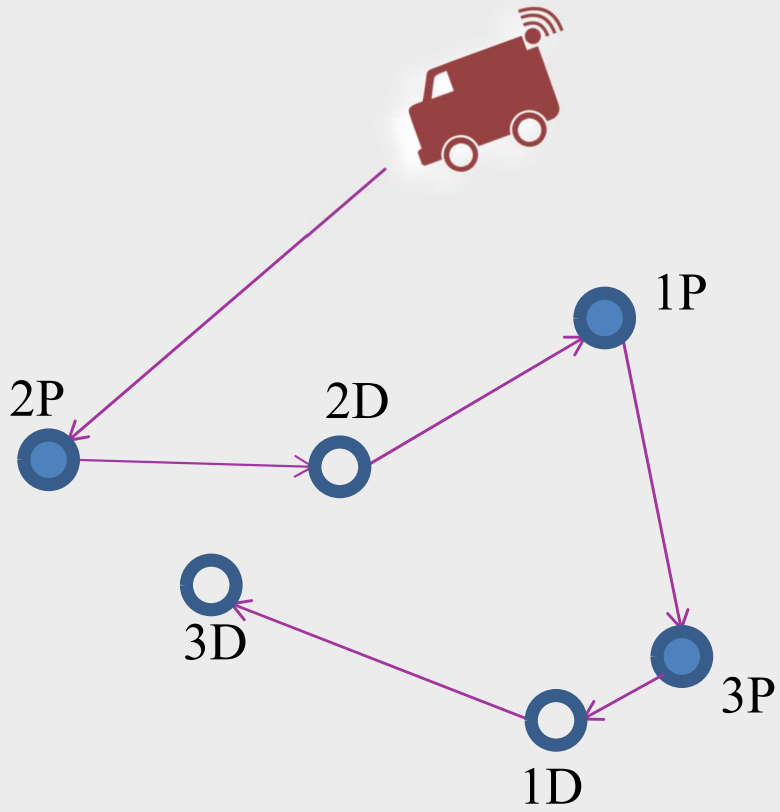
Pickup and delivery



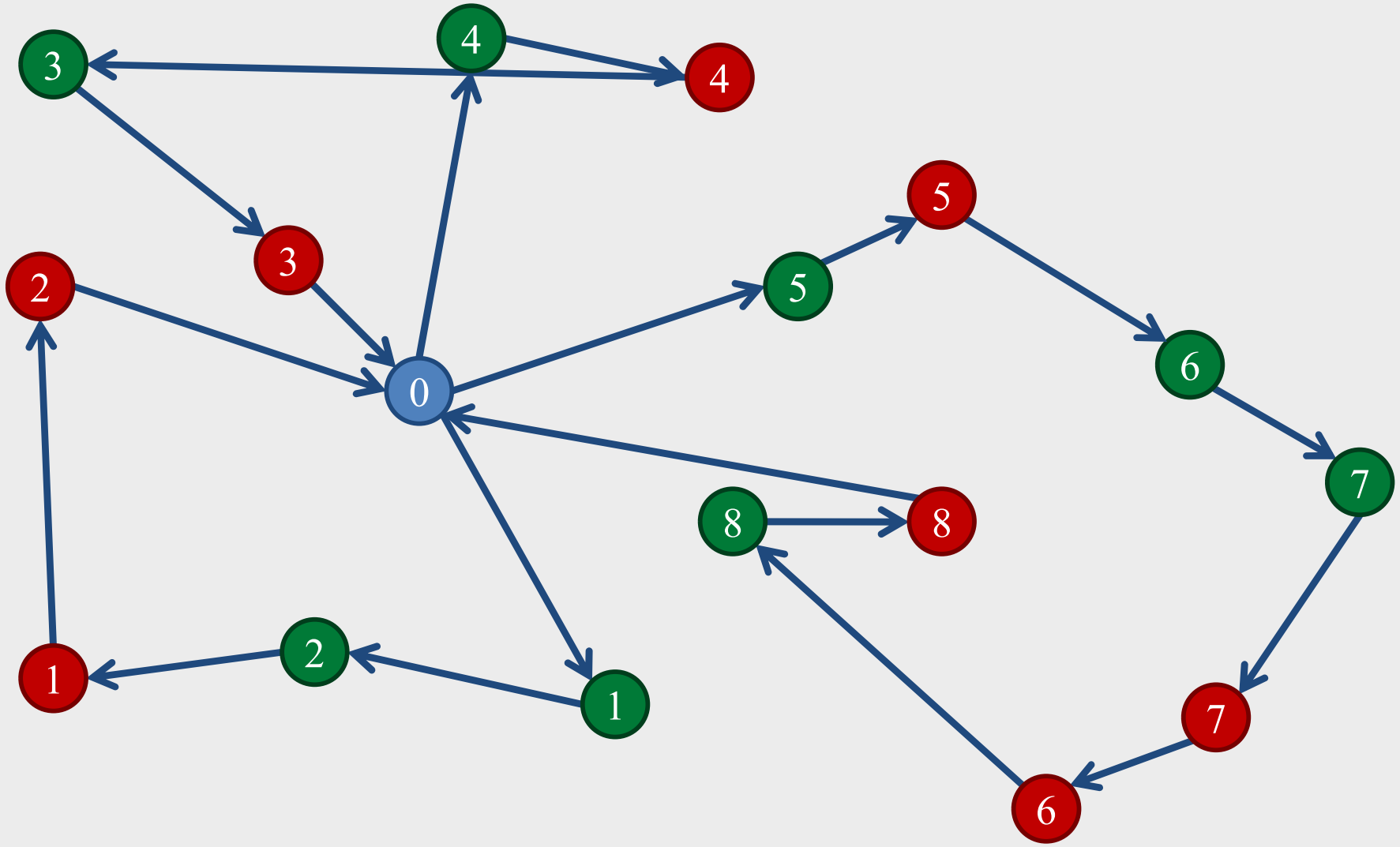
Request: Origin, Destination, Size, Time windows at origin and destination

Pickup and delivery

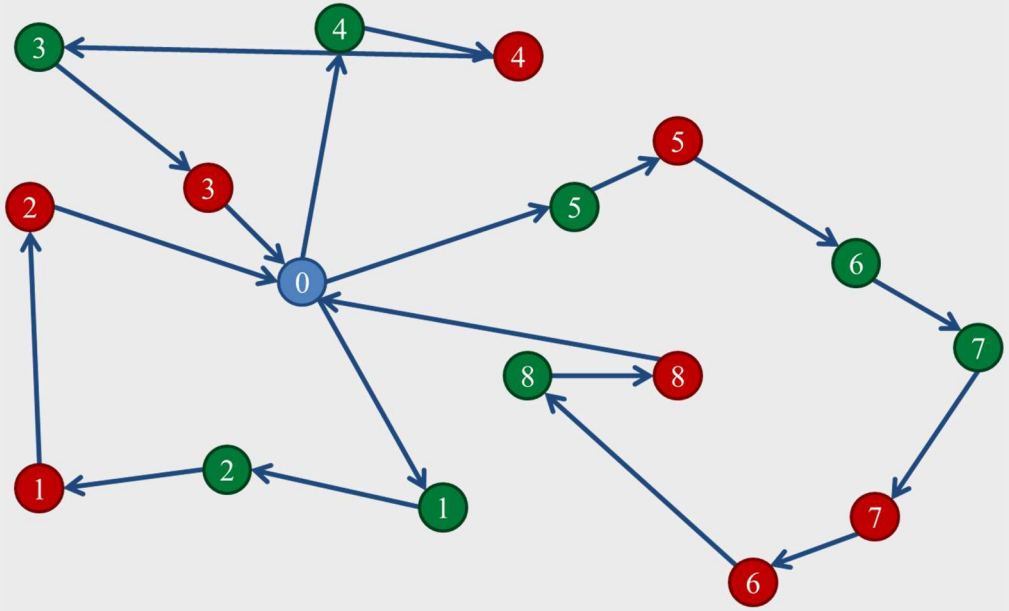
2	2	1	3	1	3



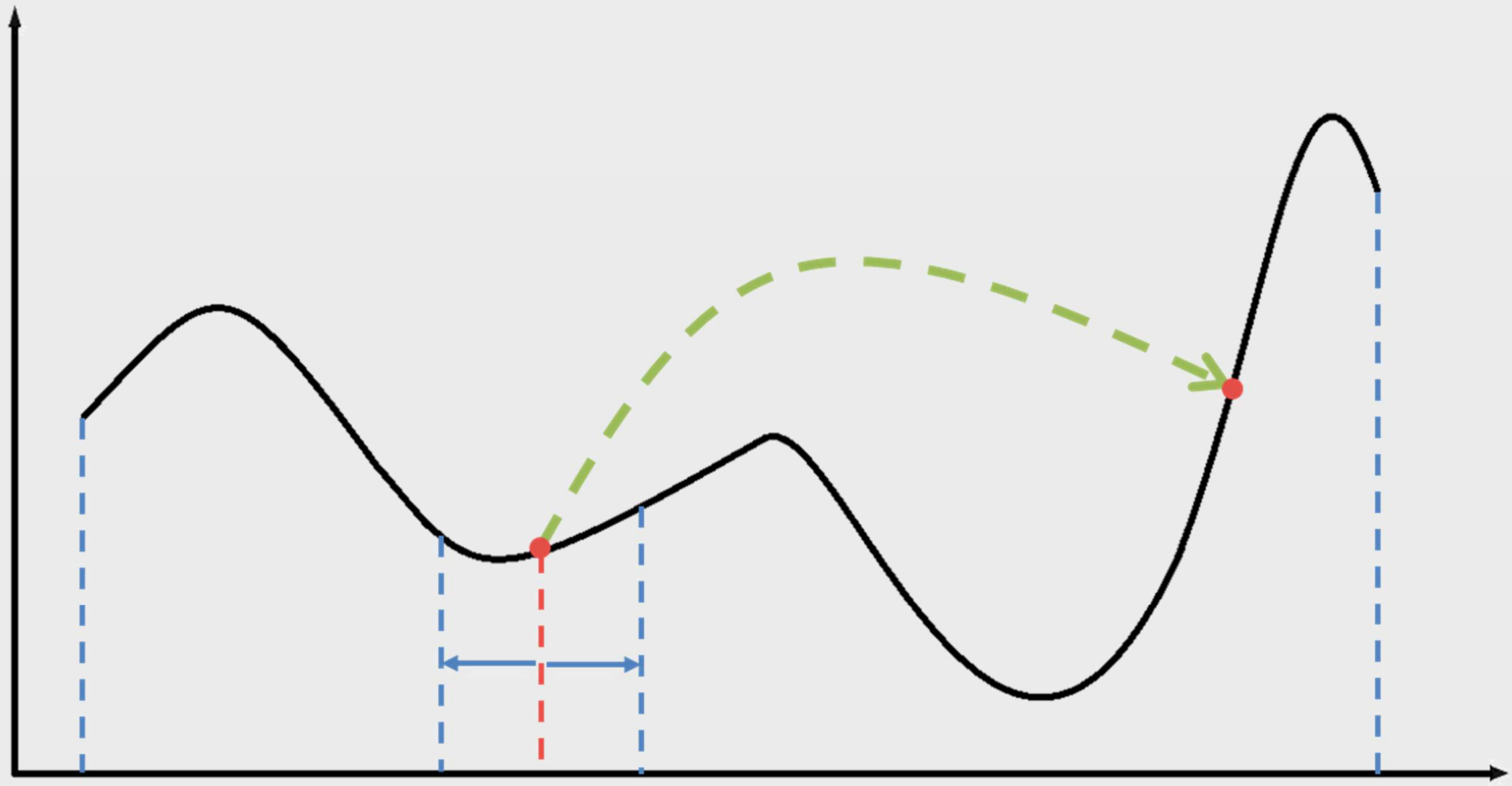
Pickup and delivery



Pickup and delivery



4	4	3	3	0	1	2	1	2	0	5	5	6	7	7	6	8	8



Initial Solution

- Random solution
- Construction algorithms
- Most of the time a good feasible solution helps
- Sometimes we get into trouble at the beginning
  - Hard to find a feasible solution
  - Premature convergence

Diversification and Intensification

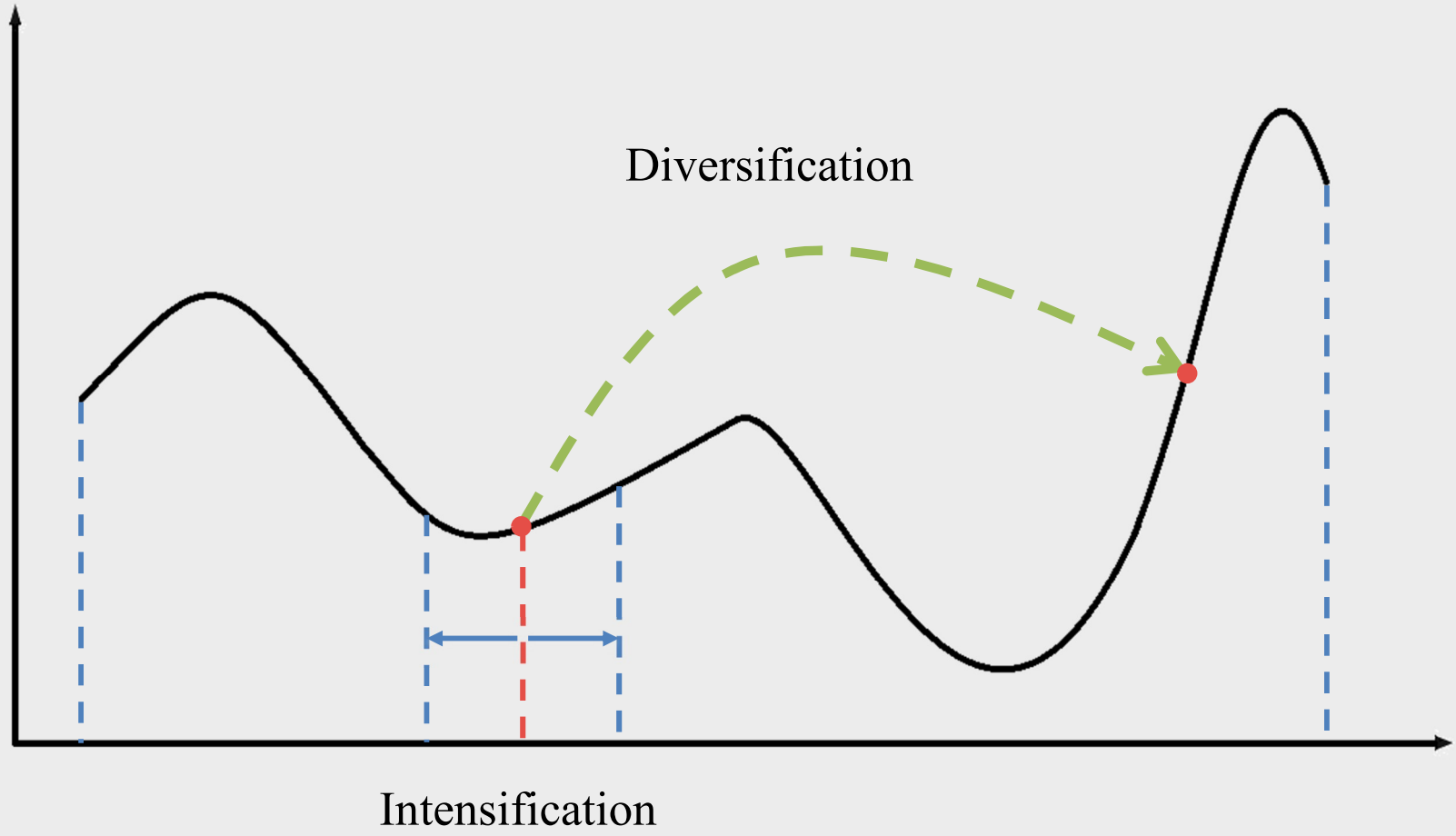
In principle, for a metaheuristic algorithm to be efficient, it has to have some special capabilities:

- Be able to generate new solutions that can usually be more likely to improve the previous/existing solutions
- Be able to cover most important search areas where the global optimum may lie.
- Be able to escape any local optimum

Diversification and Intensification

- Two major components of any metaheuristic algorithms are: intensification and diversification, or exploitation and exploration
- Diversification means to generate diverse solutions so as to explore the search space on a global scale
- Intensification means to focus the search in a local region knowing that a current good solution is found in this region.
- A good balance between intensification and diversification will usually ensure that global optimality is achievable.
- The selection of the best (~intensification) ensures that solutions will converge to the optimum, while diversification via randomization allows the search to escape from local optima and, at the same time, increases the diversity of solutions.

Diversification and Intensification



Diversification vs. Intensification

- The fine balance between these two components is very important to the overall efficiency and performance of an algorithm.
  - Too little exploration and too much exploitation could cause the system to be trapped in local optima, which makes it very difficult or even impossible to find the global optimum. → Local search
  - Too much exploration but too little exploitation, it may be difficult for the system to converge and thus slows down the overall search performance → Blind random search
  - Too much exploration and too much exploitation → Full search, time consuming
  - Too little exploration and too little exploitation → Algorithm is lazy!

Termination

The algorithm ends when it satisfies the stopping criteria

- Fixed number of iterations reached
- Allocated budget (computation time/money) reached
- After some non-improving iterations
- Manual inspection
- …
- Combinations of the above

LECTURE #4:

INTRODUCING SOME COPS