



Project 2 Kick-Off and Guest Lecture

IT3708 Bio-Inspired Artificial Intelligence
February 17th 2023

Anders Vandvik and Espen Grødem



Anders Vandvik
Indøk 2021
Master in optimization (metaheuristics)
1.5 years in Resolve



Espen Grødem
I&IKT 2022
Master in ICT & Operation Management
6 months in Resolve

Our involvement in IT3708

We are guest hosts of project 2. This involves...

- Providing the optimization case that you will solve in the project
- Hosting a competition that you can participate in during the project
- Hosting a kick-off and wrap-up of the project

Schedule

- Thursday, February 16th: Project description is available.
- Friday, February 17th (12:15 - 14:00): Kick-off with Visma Resolve @ F3.
- February 17th to March 20th: Work on the project.
- Tuesday, March 20th: Demo day.

Agenda

Introduction to Visma, Resolve, and our involvement in IT3708

Introduction to route planning in the home health care

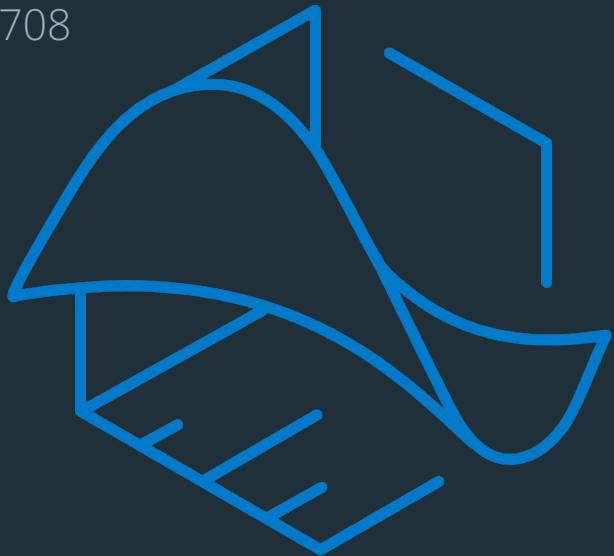
Deep dive into our Operational Route Planner (ORP)

15-minute break

Introduction to IT3708 project 2

Implementation tips & tricks

The competition web page



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Visma overview

14 000
Engaged employees

With more than **6 500**
developers



1 400 000
Customers

Running through Visma's
systems every month:

11 million payslips
22 million invoices

Revenue LTM
€ 1 995 million
EBITDA: € 580 million

In Visma there exists
200+ companies



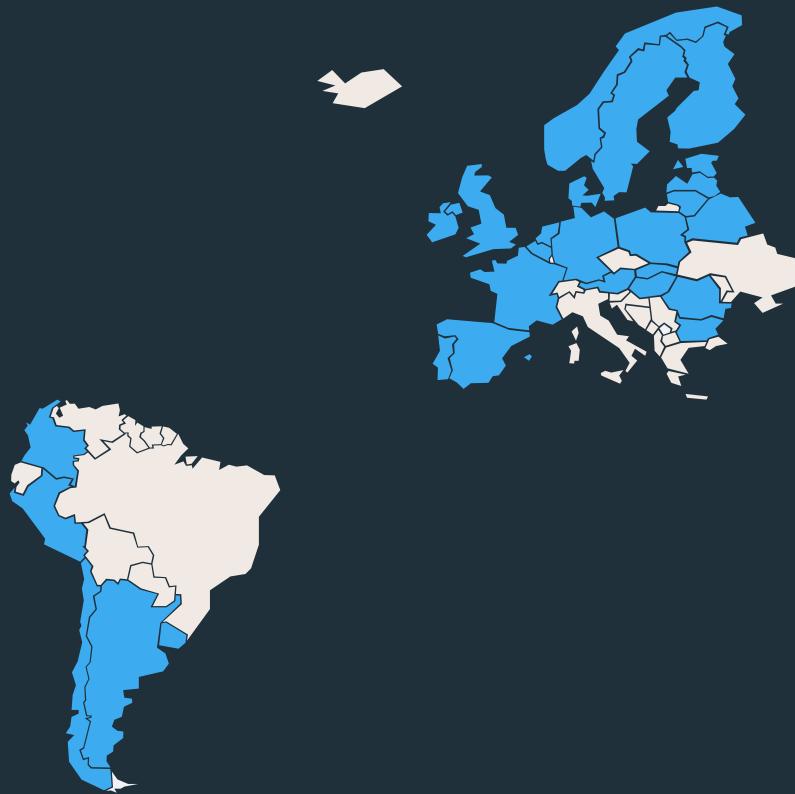
We are **where you are**
Strong local presence with
more than **250**
locations

Over 100 companies has joined Visma since 2020

...some selected acquisitions to illustrate our acquisition profile:

-2016	2017	2018	2019 (13)	2020 (37)	2021 (42)	2022 (42)
 tripletex	 Svensk E-IDENTITET	 W-websystemer	 inyett	 yuki	 sticos	 Bokio
 transPA	 COMENIUS	 raet	 saldeo SMART	 FramSikt	 helded	 hybel.no
 EasyCruit	 BLUEGARDEN	 Merit Tarkvara	 PROLØN	 ÅØ ARSREDOVISNING ONLINE	 therapieland	 mandü
 trimma	 mystore.no	 SmartDok	 PLUS PORT	 inFakt	 Kontek	 OutSmart
 VSWARE	 Admincontrol	 WE OPTIT	 PowerOffice Go	 Paybyway	 acubiz	 mySupply.dk
 MIND4iT	 MEGAFLEX	 Wikinggruppen	 roxit.	 Draftit	 bouwsoft	 inqom
 ValueFrame	 P P G	 SZÁMLÁZZ.HU	 meglerfront	 Nmbrs®	 oima	 appical
 dinero.	 OPTIVASYS	 idella	 ebpi	 smartbill	 ECARE	 HOUSE OF CONTROL
 MOVENIUM	 DAVILEX SMART BUSINESS SOFTWARE		 HR2day	 visionplanner	 webtop solutions	 festum
 e-economic				 COMPELLO	 temponizer	 nordeca
			 DomaCare	 blikk	 Teamleader	
			 Zetech	 keez	 DECLARANDO	
			 Jumis	 plandisc	 FLEX Applications	

Europe is our **core** market







Vision

Revolutionize decision-making

Purpose

Help people make better decisions, faster

→ Resolve



AI and software developers, infrastructure engineers and business development managers delivering **optimization and machine learning solutions** to significantly improve the operations of our customers

→ Resolve



Route optimization

Determining the best route for each worker



Kindergarten admission

Optimizing the admissions process for kindergartens



Automatic rostering

Creating fair and efficient workforce schedules



Timetabling

Automating the timetabling process for schools



Inventory optimization

Forecasting demand and providing optimal purchase order suggestions



Accounting advisory

Enabling accountants to give impactful and data-driven advices



Anomaly detection

Detecting irregularities to automate approval processes

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→ Resolve

Route Planning



Route Planning Domains and Markets

Home Nursing Care



Craftsmen



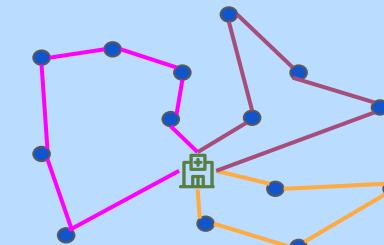
Home Health Care

Elderly people
need health
treatment



Lack of capacity to host
everyone in nursing
homes

Nurses give patients
health treatment in the
patients' homes



A need to for efficient
routes

Challenges in the Home Health Care

... for nurses



Stressful work



Routes are not efficient



Routes lack robustness

... for patients



Meets many different nurses



Unpredictable visiting times



Visits by nonpreferred nurses

Route Planning Problem

-  Competence
-  Workshifts
-  Synchronized tasks
-  Max number of heavy task per work shift
-  Balancing workload
-  Time windows
-  Employee visit history
-  Overqualification
-  Travel time & transport mode



Route Planning Problem



Competence



Workshifts



Synchronized tasks



Max number of heavy task per work shift



Balancing workload



Time windows



Employee visit history



Overqualification



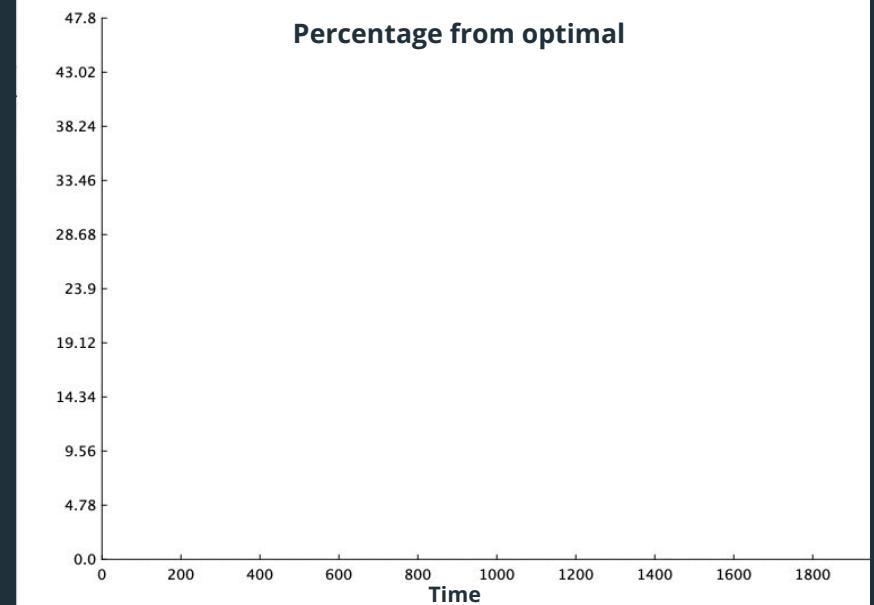
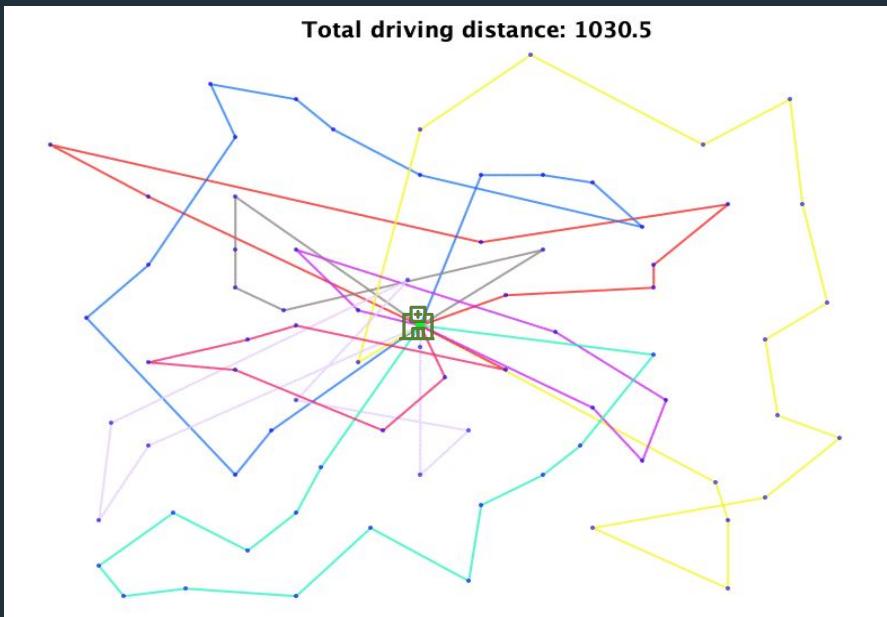
Travel time & transport mode

Constraints

Objectives



Meta heuristic finding close to optimal



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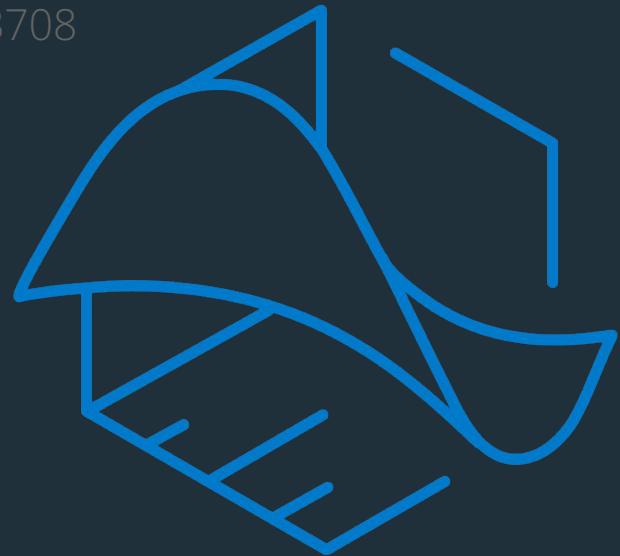
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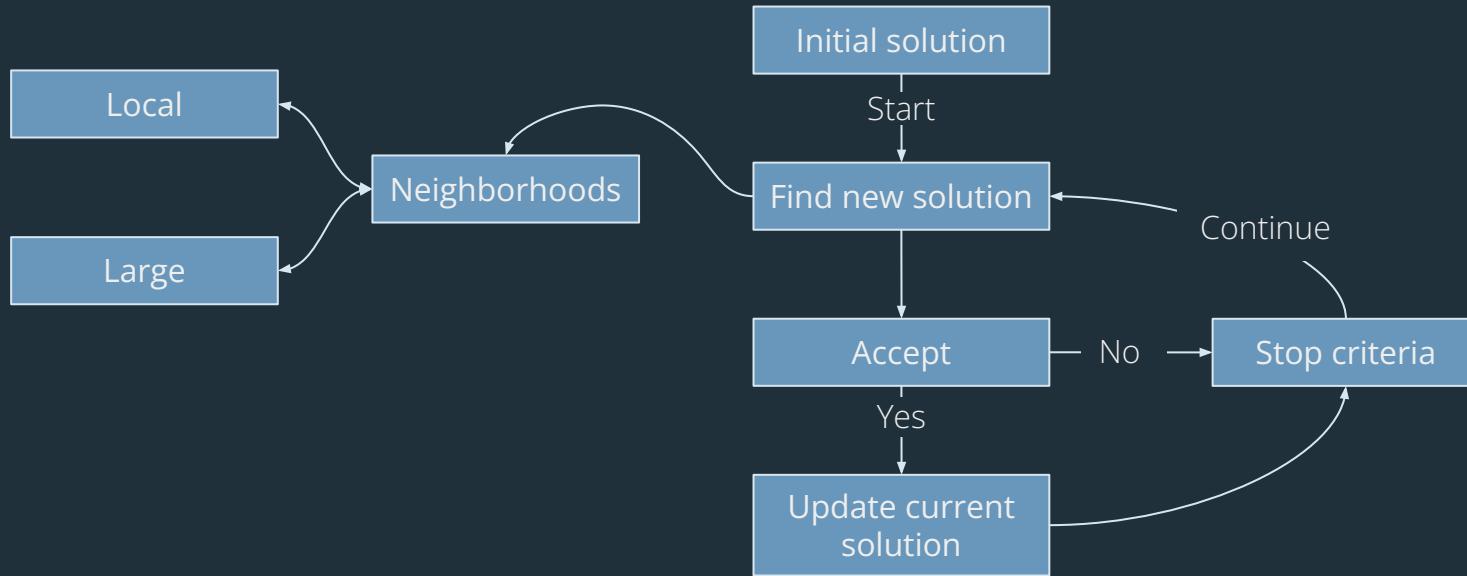
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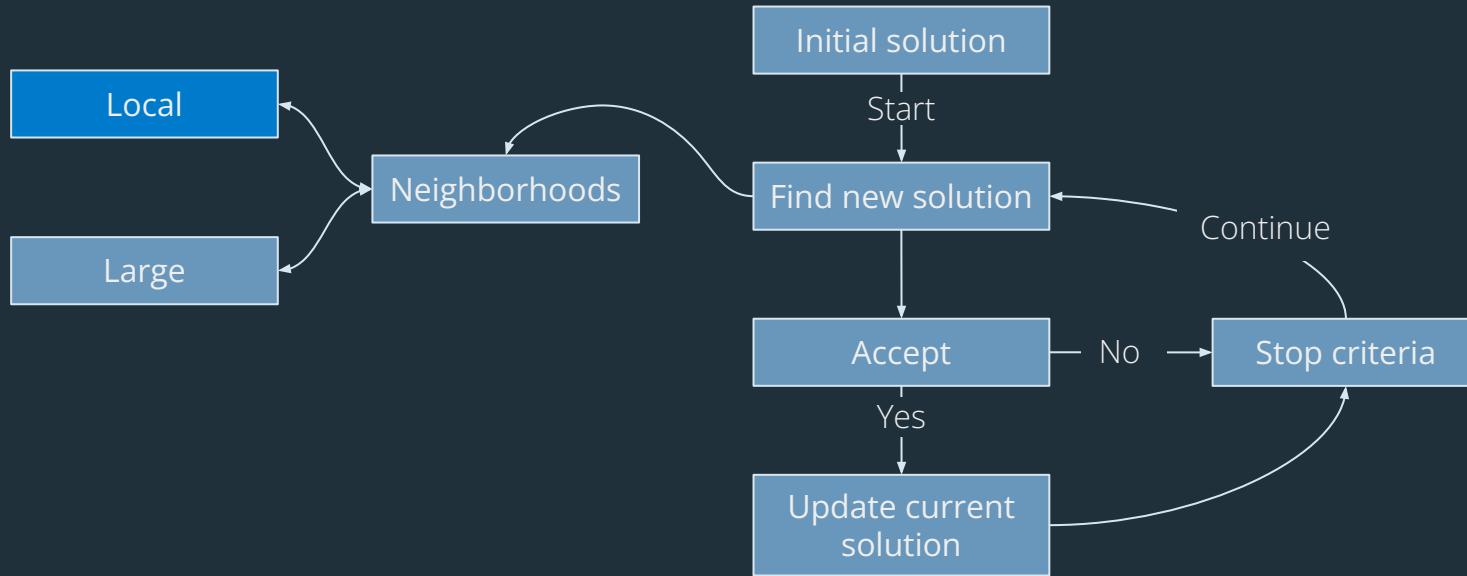


Genetic Algorithm **vs** Large Neighborhood Search

Large Neighborhood Search (LNS)



Large Neighborhood Search (LNS)



Local neighborhood

Intra move: Move one patient visit in one employee's route

Nurse 1



Nurse 1



Local neighborhood

Intra swap: Swap two patient visits for one employee

Nurse 1

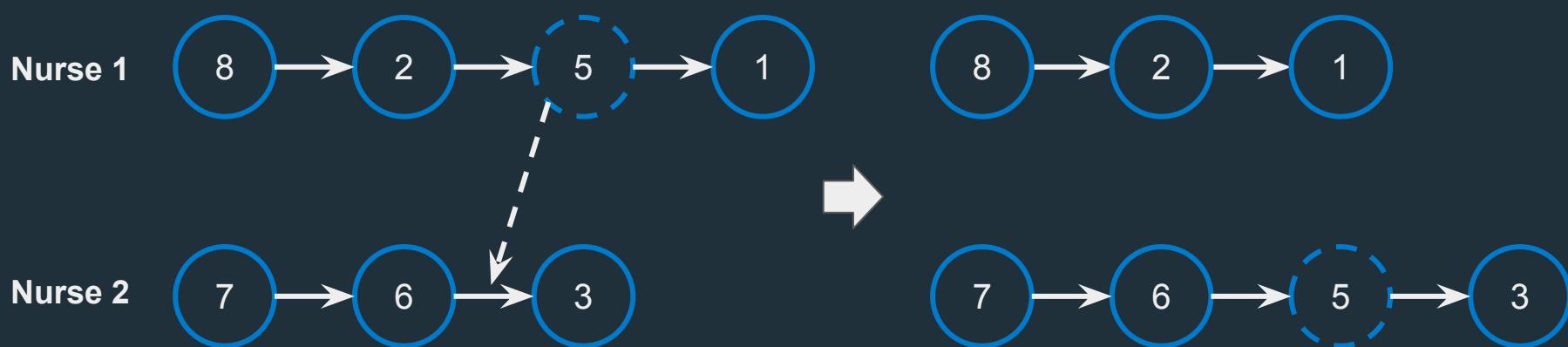


Nurse 1



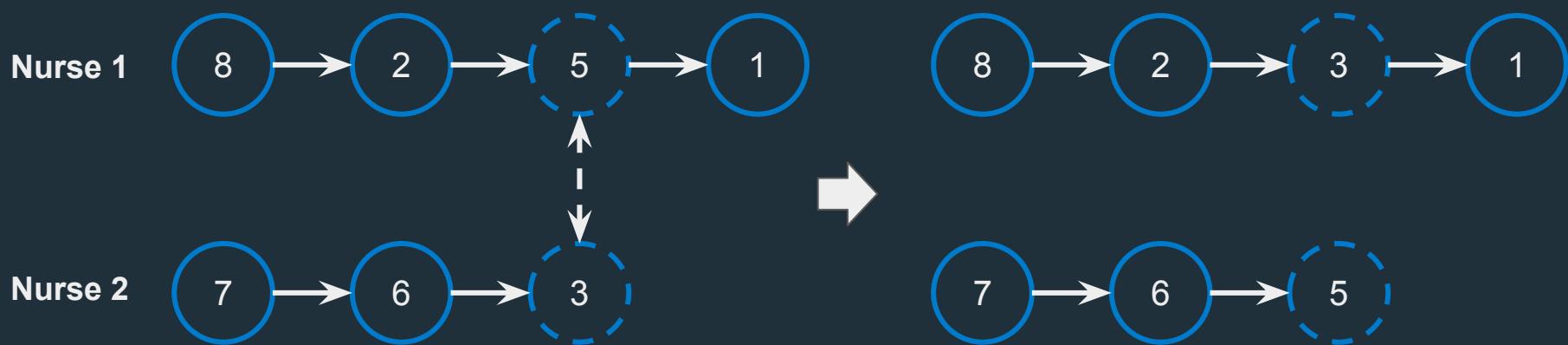
Local neighborhood

Inter move: Move one patient visit from one employee to another

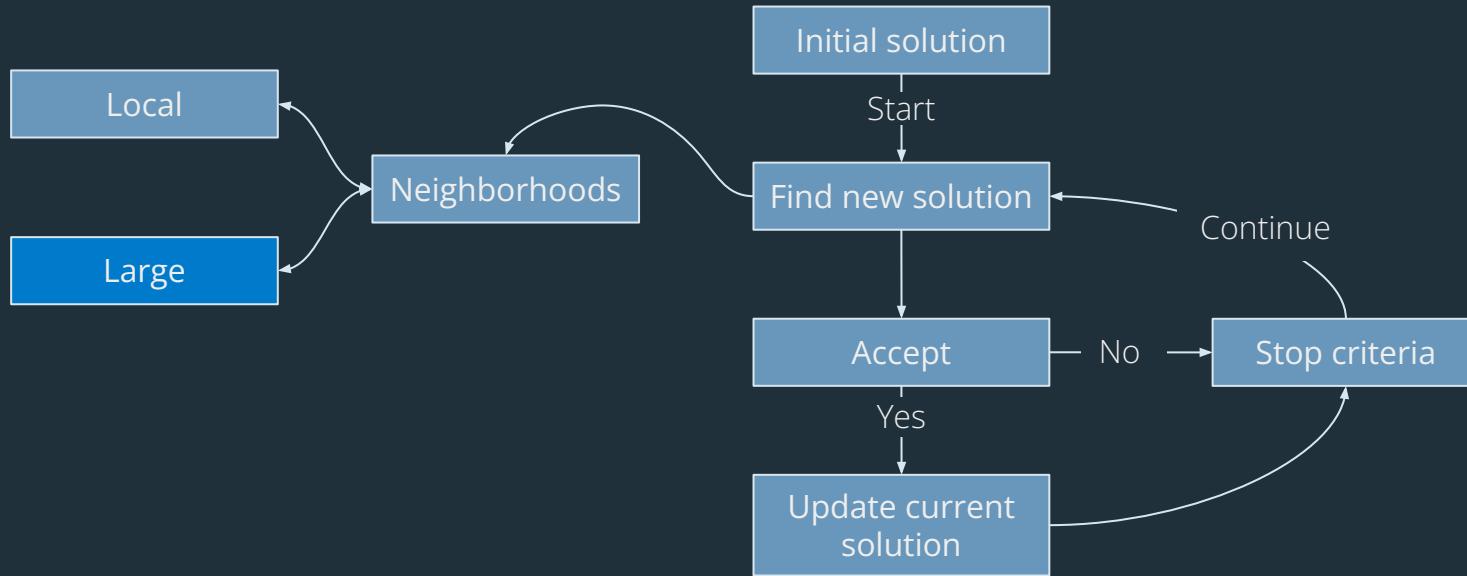


Local neighborhood

Inter swap: Swap two patient visits between employees



Large Neighborhood Search (LNS)



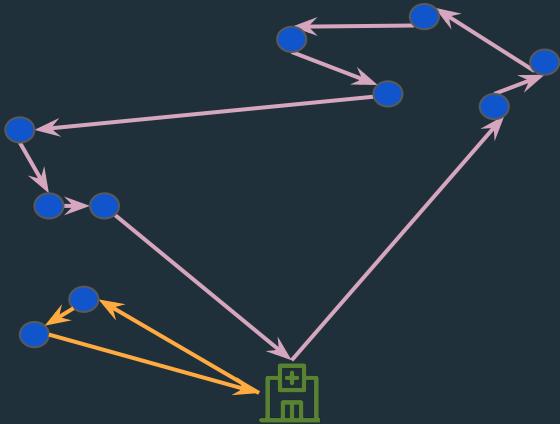
Large neighborhood

- Ruin and Recreate approach
 - Select a destroy and repair operator and apply them to get a new solution
- Set of destroy operators
 - Random removal
 - Greedy removal
 - Cluster removal
- Set of repair operators
 - Random insert
 - Greedy insert
 - Optimal insert

Large neighborhood

Remove clusters: Identify clusters of worsening visits.

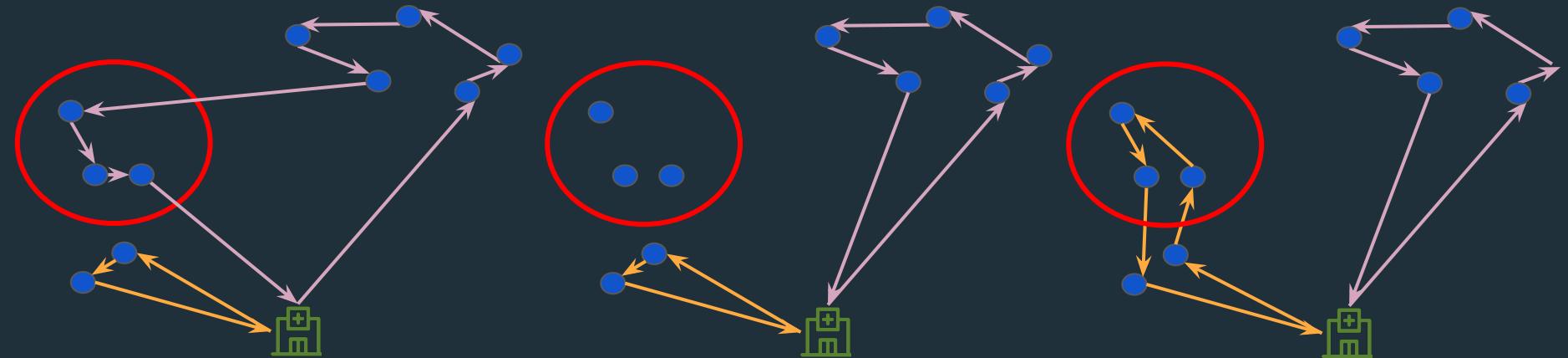
Example: longest travel not connected with office



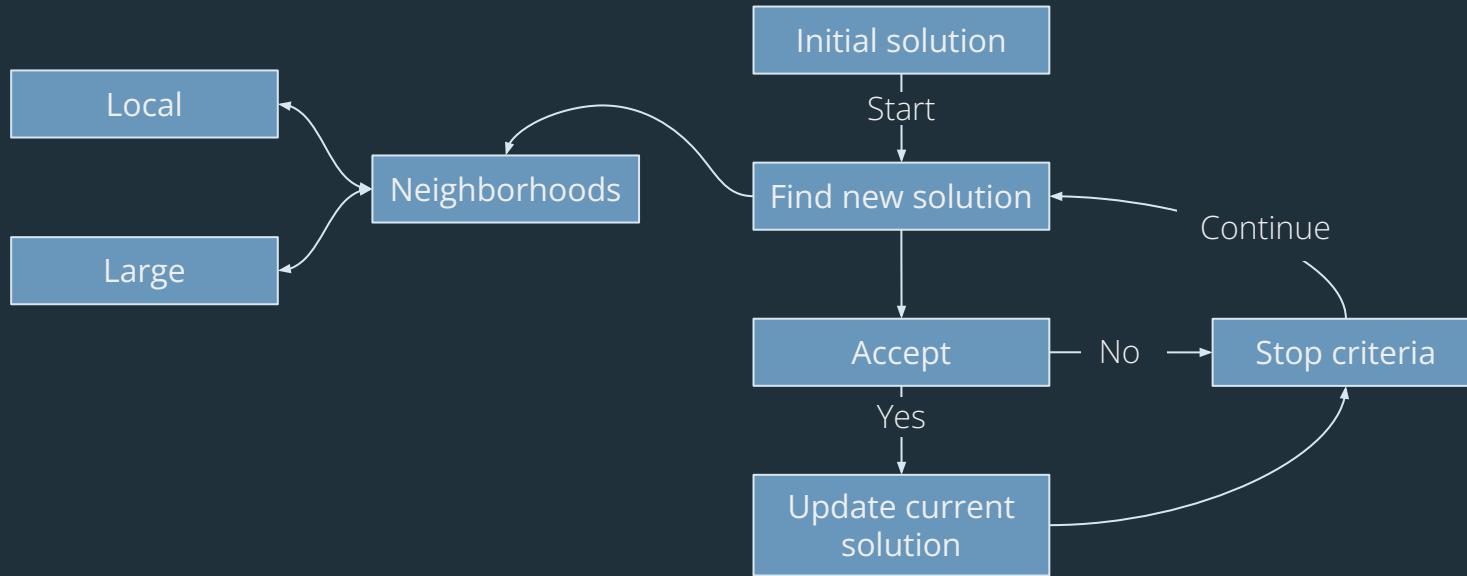
Large neighborhood

Remove clusters: Identify clusters of worsening visits.

Example: longest travel not connected with office



Large Neighborhood Search (LNS)



Customer value of the Route Planner

💰 Better **resource allocation** and competence matching

❤️ **Face-to-face** time with patients **increased with 14%**

⌚ **Time saved** for planning routes



→ Resolve

Demo



Usage dashboard

https://dub01.online.tableau.com/#/site/visma/views/Fl_ytRoutePlanner/UsageOverview?:iid=1

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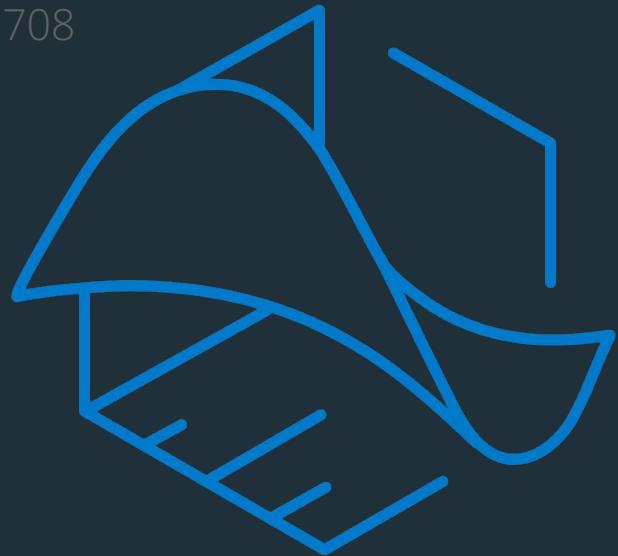
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2. Assisting with a solution validator you can use when you implement the problem
3. Hosting a competition that you can participate in during the project

The case: Solving the simplified home health care optimization problem

Nurses



Patients



Depot → patients → depot

Capacity (homogeneous)

Finish care within time window, wait if early

Be back within the return time

Visited by exactly one nurse

Demand/strain (heterogeneous)

Time window and care time

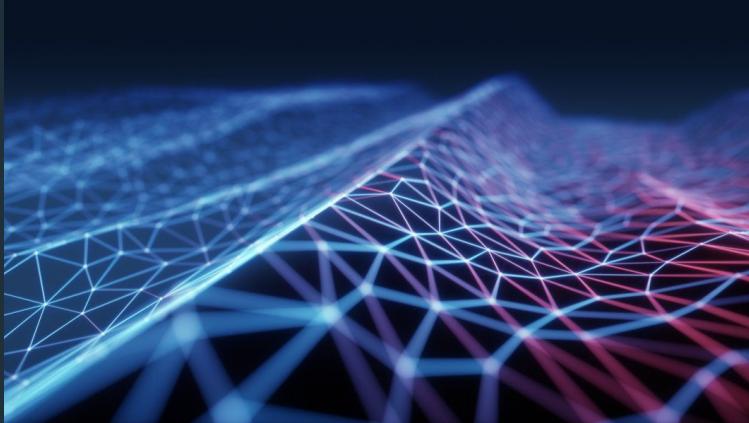
The constraints

1. Each route starts at the depot on time 0.
2. Each route ends at the depot and must arrive before the given depot return time.
3. The total demand on a route must be less than or equal to the nurse's capacity.
4. Each patient visit on a route must be within the respective time windows.
5. Each patient is visited on exactly one route.

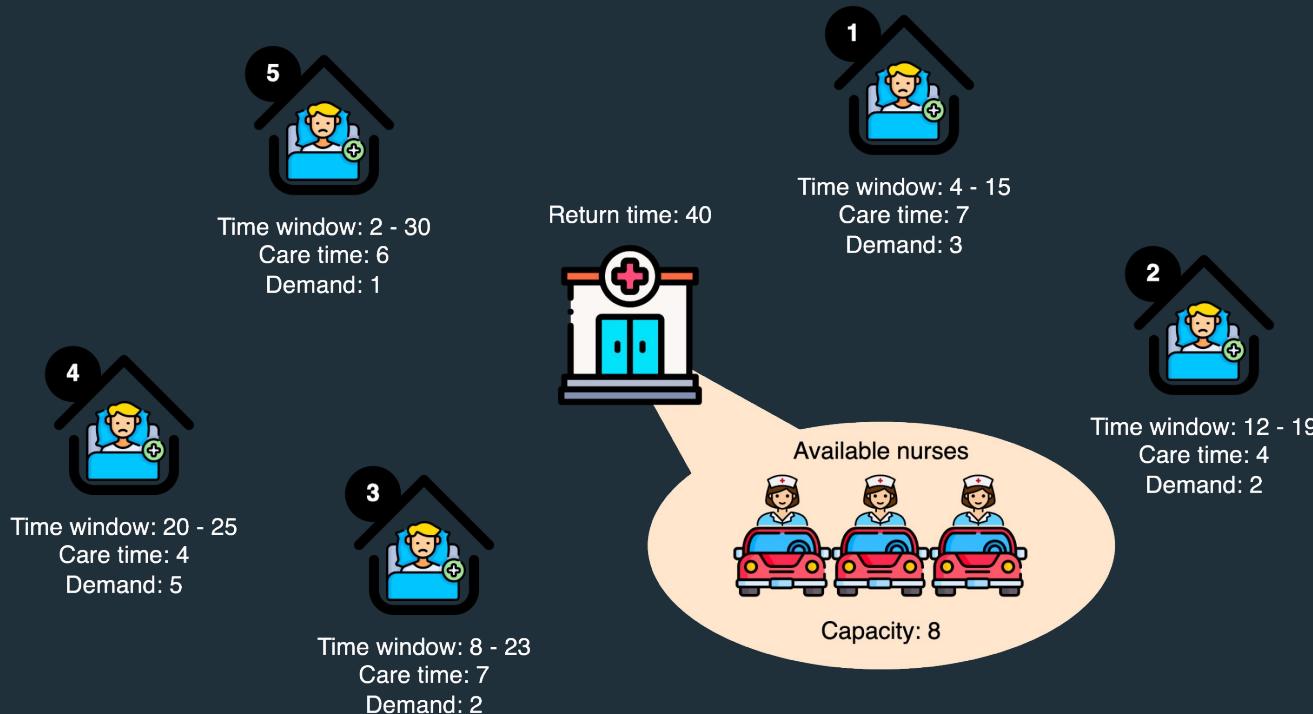
The objective

*Make routes that satisfy the constraints and...
minimize the total travel time, i.e., the sum of the travel time of all routes.*

Note that the travel time does not include the care time or the potential waiting time!



Example of a problem instance



Your task

Implement a genetic algorithm (GA) solving the simplified home health care optimization problem.



The instances

Instance	Benchmark	5%	10%	20%	30%
train_0	828	870	911	994	1077
train_1	590	620	649	708	767
train_2	1258	1321	1384	1510	1636
train_3	1133	1190	1247	1360	1473
train_4	1262	1326	1389	1515	1641
train_5	1093	1148	1203	1312	1421
train_6	924	971	1017	1109	1202
train_7	871	915	959	1046	1133
train_8	732	769	806	879	952
train_9	855	898	941	1026	1112

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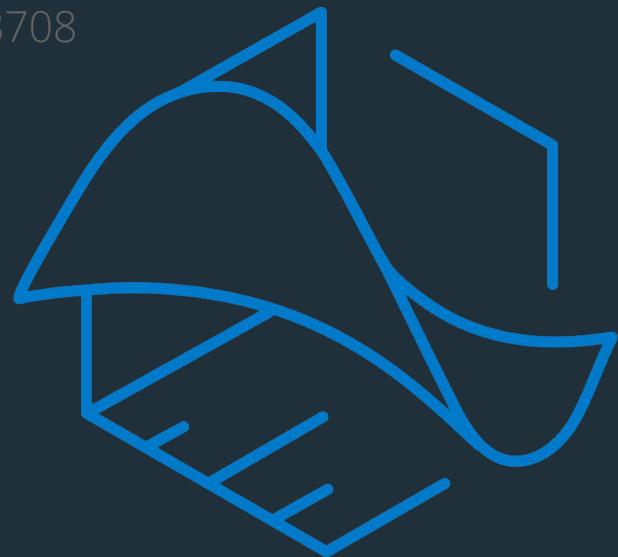
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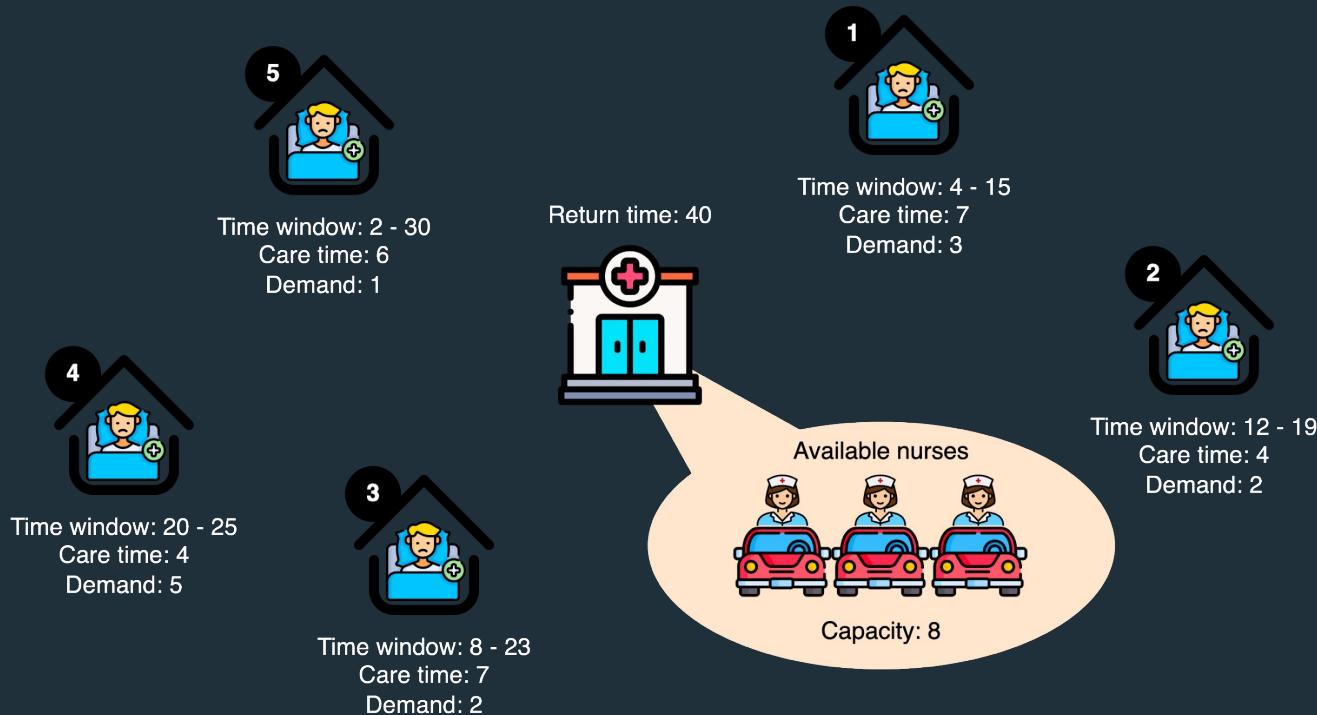
Implementation tips & tricks

The competition web page

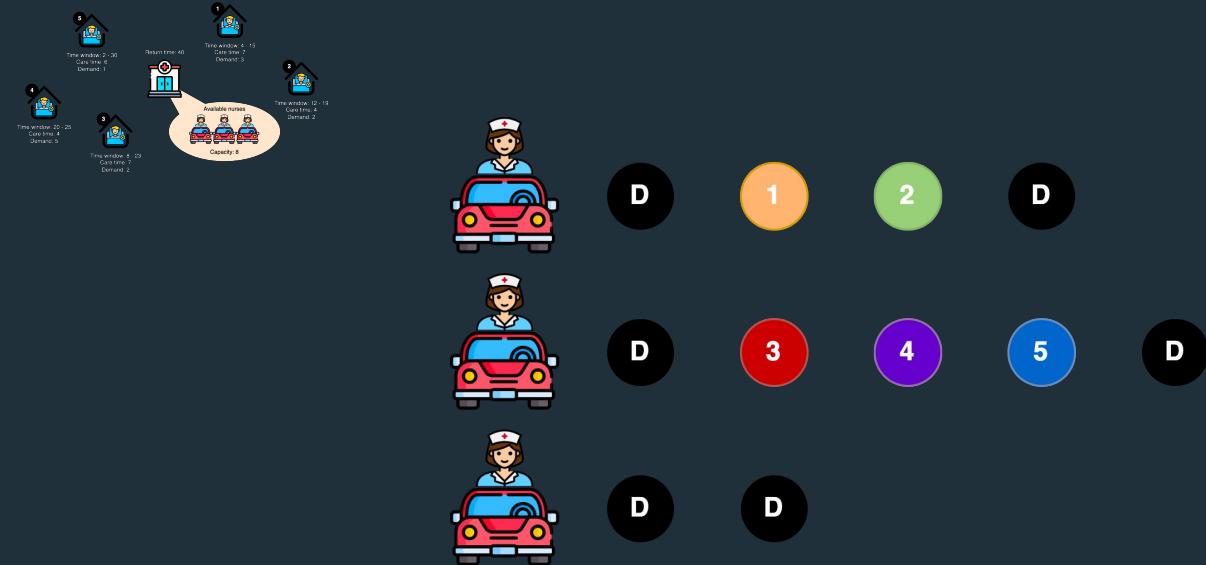


Part 1: Implementing **solutions**, **constraints**, and **objective**

Example of a problem instance



Example of a solution



Example of a solution representation



$$\begin{bmatrix} 1 & 2 \\ 3 & 4 & 5 \\ \end{bmatrix}$$

The case: Solving the simplified home health care optimization problem

Nurses



Depot → patients → depot

Capacity (homogeneous)

Finish care within time window

Be back within the return time

Patients



Visited by exactly one nurse

Demand (heterogeneous)

Time window and care time

The case: Solving the simplified home health care optimization problem

Nurses



Depot → patients → depot

Capacity (homogeneous)

Finish care within time window

Be back within the return time

Patients



Visited by exactly one nurse

Demand (heterogeneous)

Time window and care time

Route visit times and duration

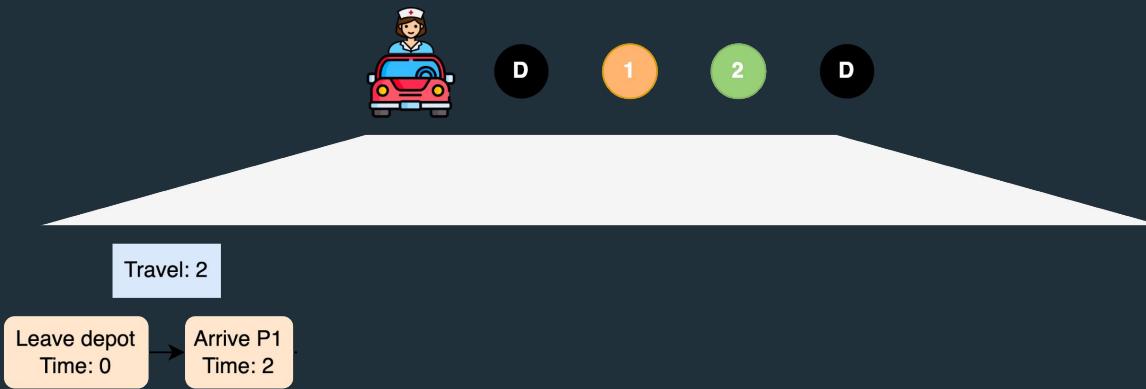


Route visit times and duration

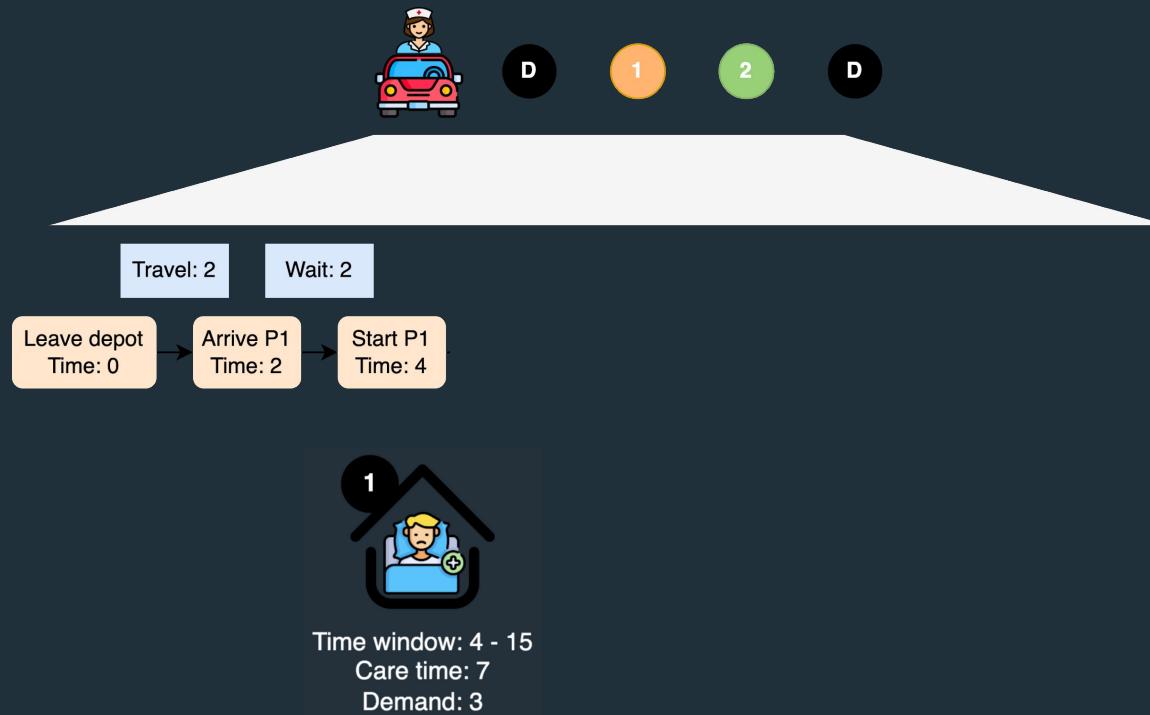


Leave depot
Time: 0

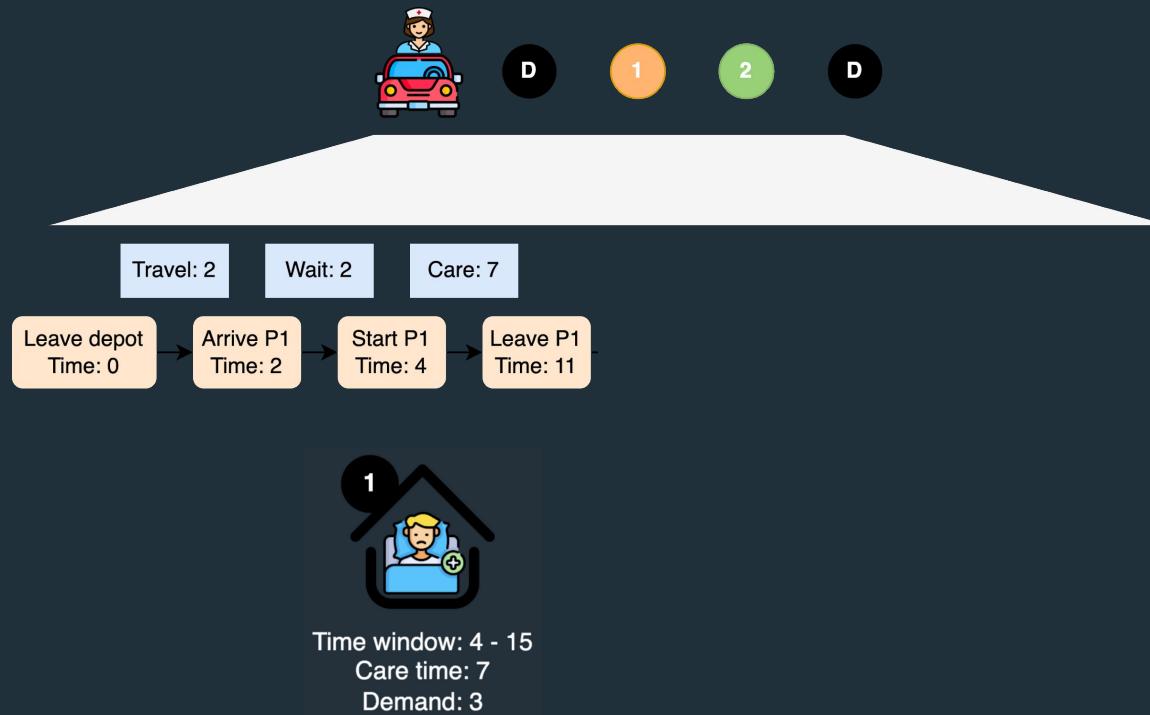
Route visit times and duration



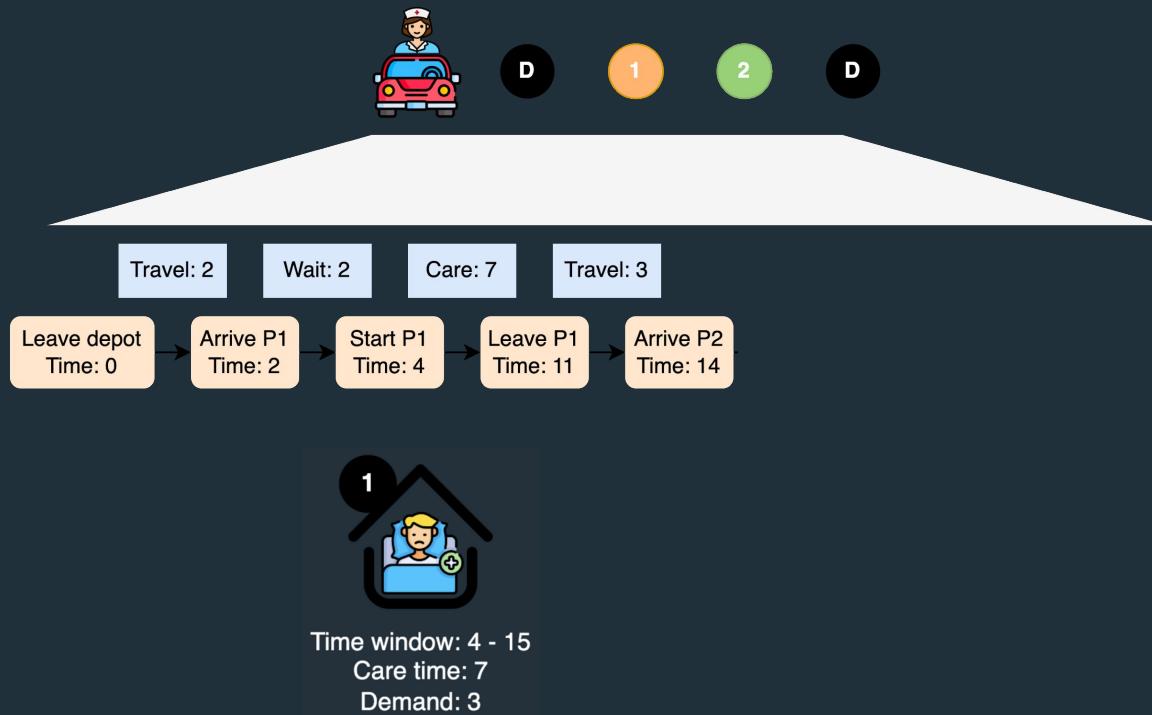
Route visit times and duration



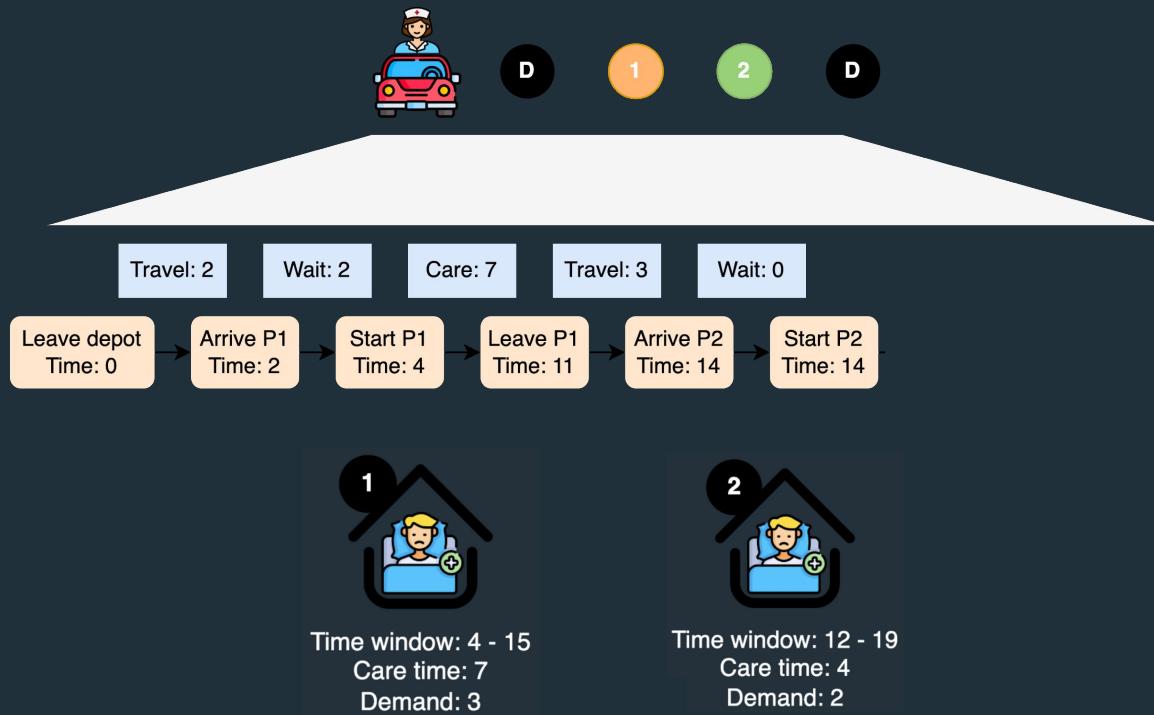
Route visit times and duration



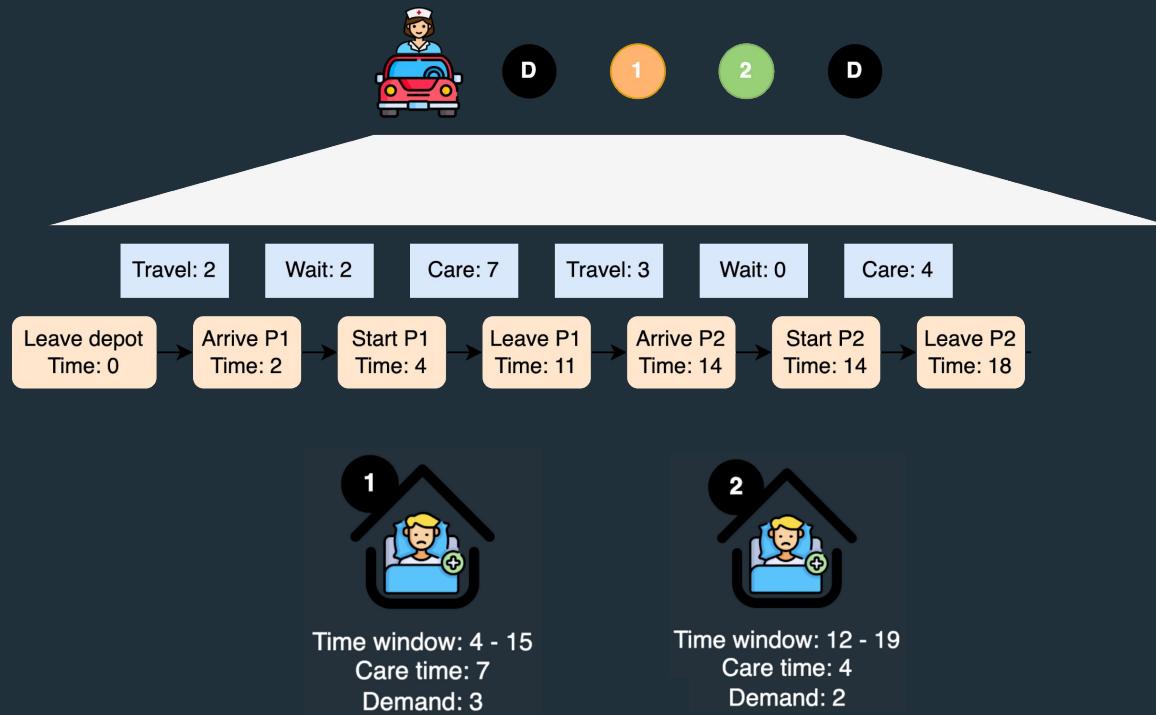
Route visit times and duration



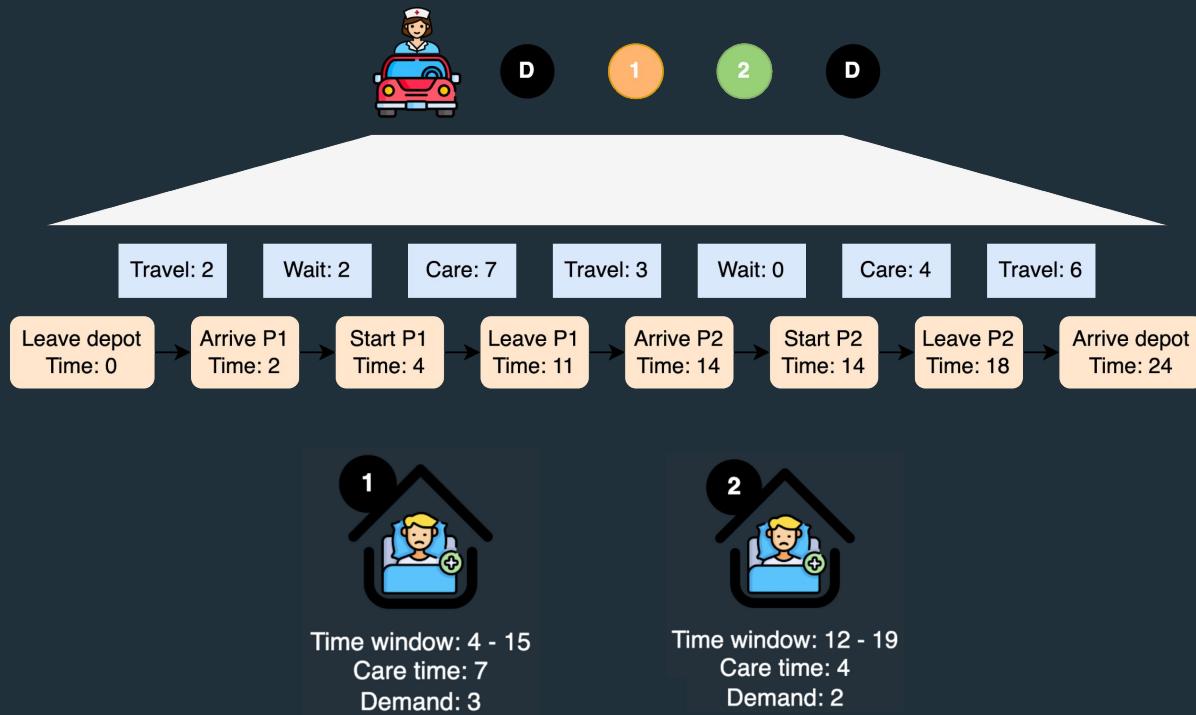
Route visit times and duration



Route visit times and duration



Route visit times and duration



Accessing travel times

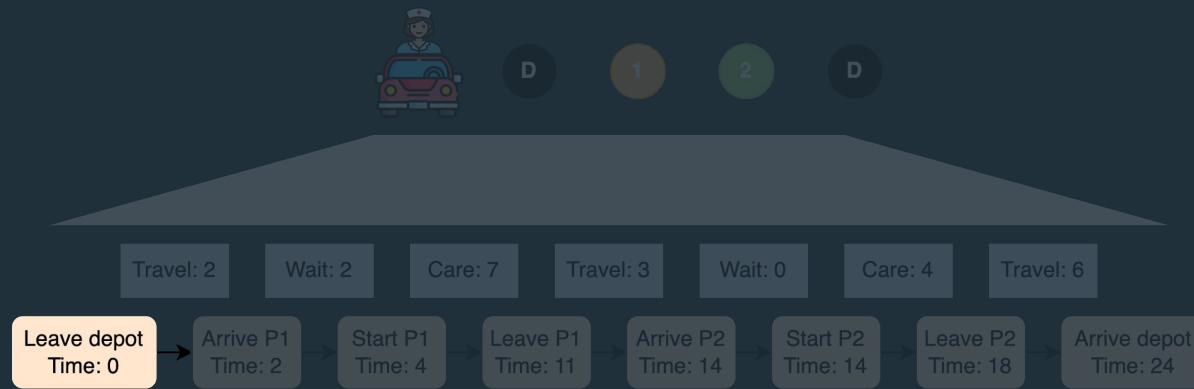
	Depot	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Depot	0	2	6	2	7	1
Patient 1	2	0	3	9	2	3
Patient 2	6	3	0	1	5	2
Patient 3	2	9	1	0	7	3
Patient 4	7	2	5	7	0	4
Patient 5	1	3	2	3	4	0

Revisit the constraints

$$\left[\begin{array}{c} \left[\begin{array}{cc} 1 & 2 \end{array} \right] \\ \left[\begin{array}{ccc} 3 & 4 & 5 \end{array} \right] \\ \left[\begin{array}{c} \end{array} \right] \end{array} \right]$$

1. Each route starts at the depot on time 0.

Start route at time 0 at depot

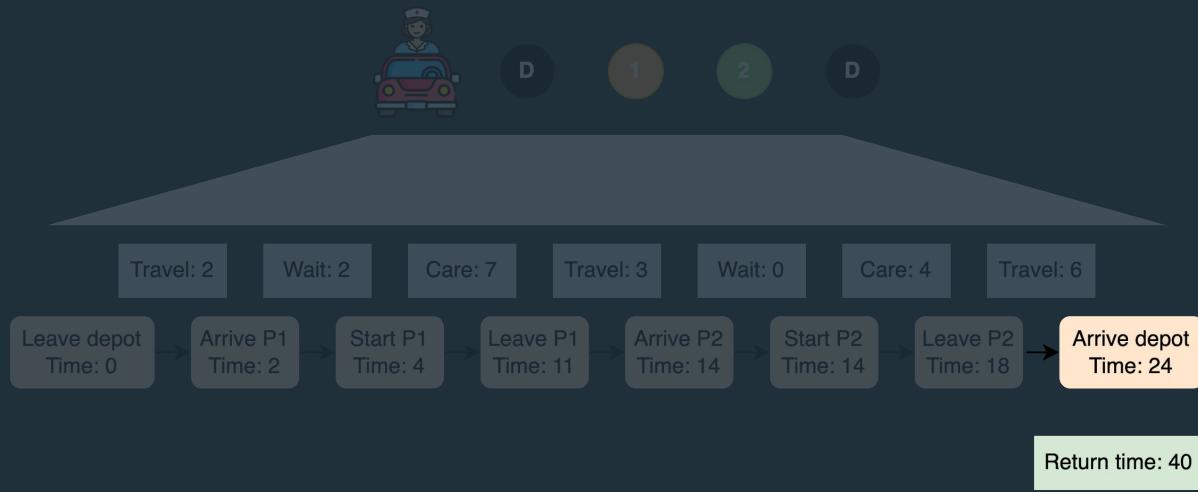


Revisit the constraints

$$\left[\begin{array}{cc} 1 & 2 \\ 3 & 4 & 5 \\ \vdots & & \end{array} \right]$$

2. Each route ends at the depot and must arrive before the given depot return time.

End route at depot before return time

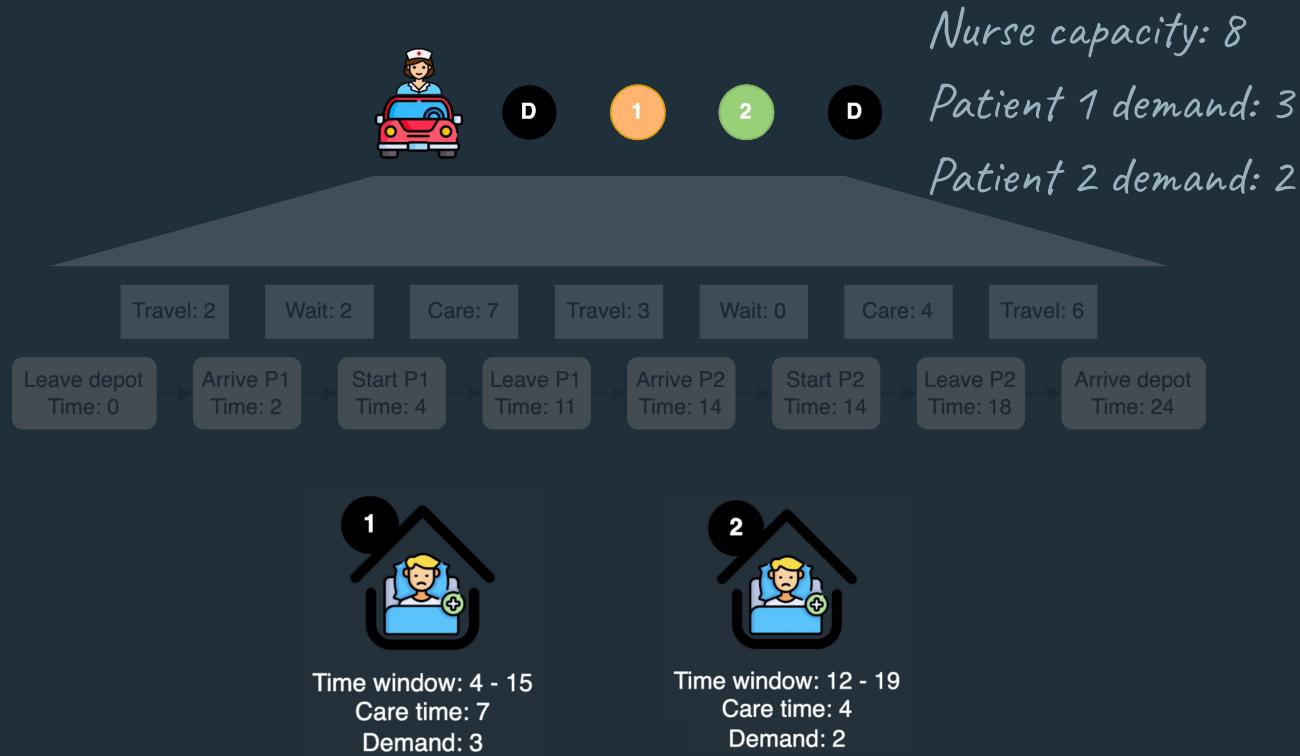


Revisit the constraints

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 & 5 \\ \vdots & & \end{bmatrix}$$

3. The total demand on a route must be less than or equal to the nurse's capacity.

Route demand less than capacity

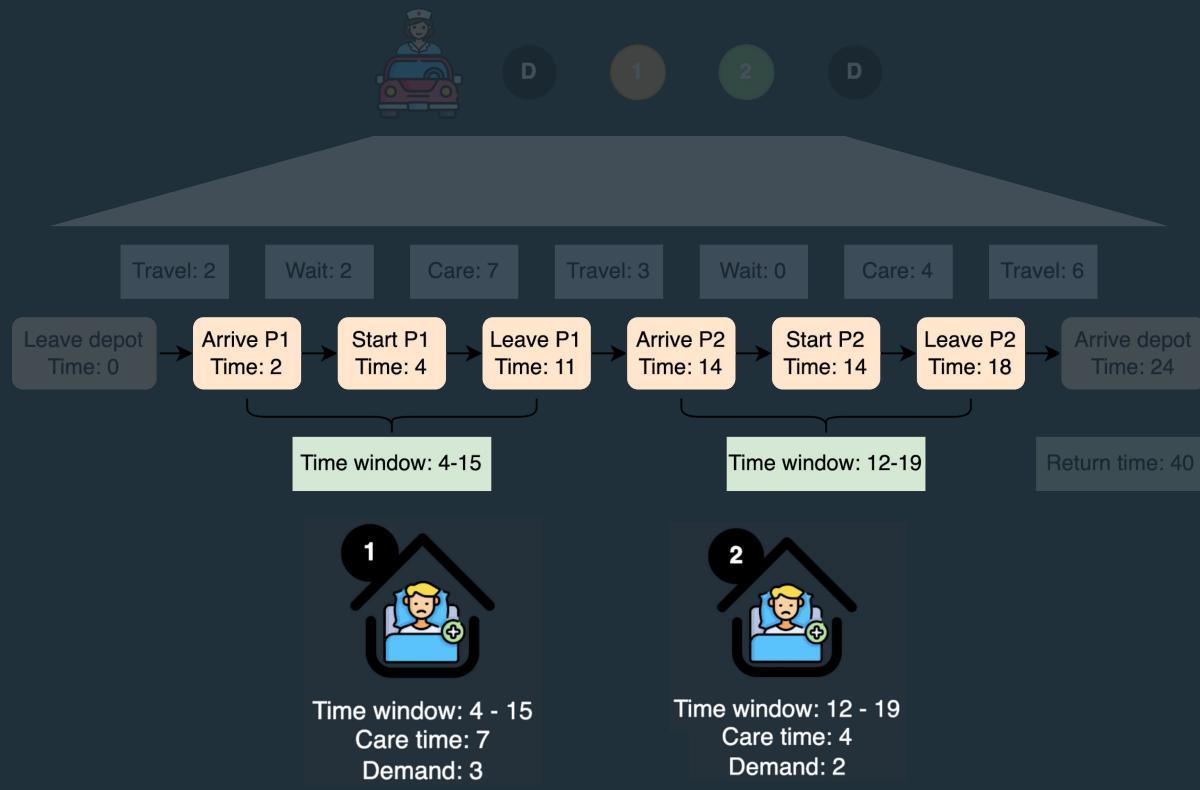


Revisit the constraints

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 & 5 \\ \vdots & \vdots \end{bmatrix}$$

4. Each patient visit on a route must be within the respective time windows.

Patient visits within time windows



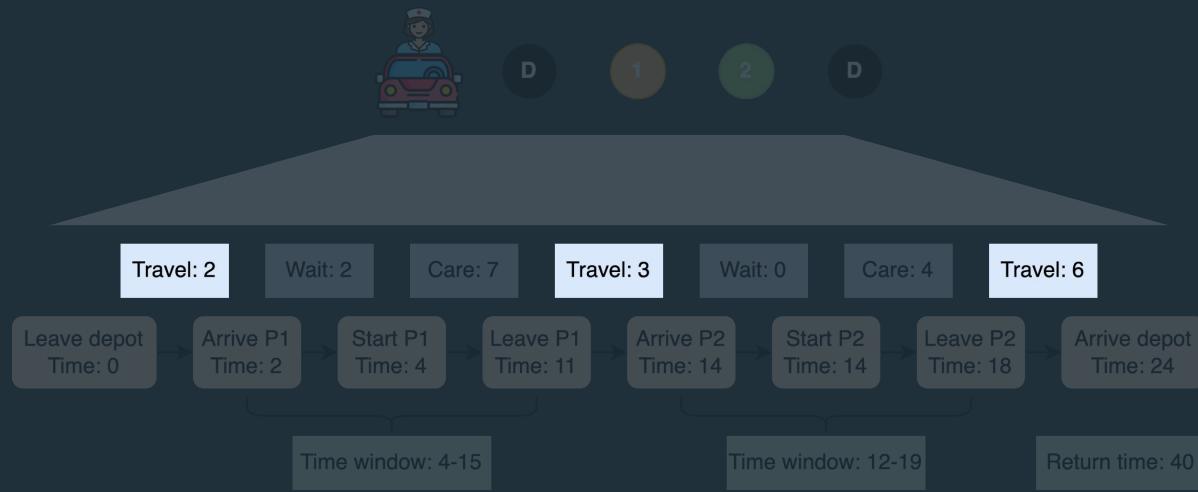
Revisit the constraints

$$\left[\begin{array}{cc} 1 & 2 \\ 3 & 4 & 5 \\ \end{array} \right]$$

5. Each patient is visited on exactly one route.

Visit each patient exactly once

Calculating the objective



... do this for the other routes as well and sum all route travel times

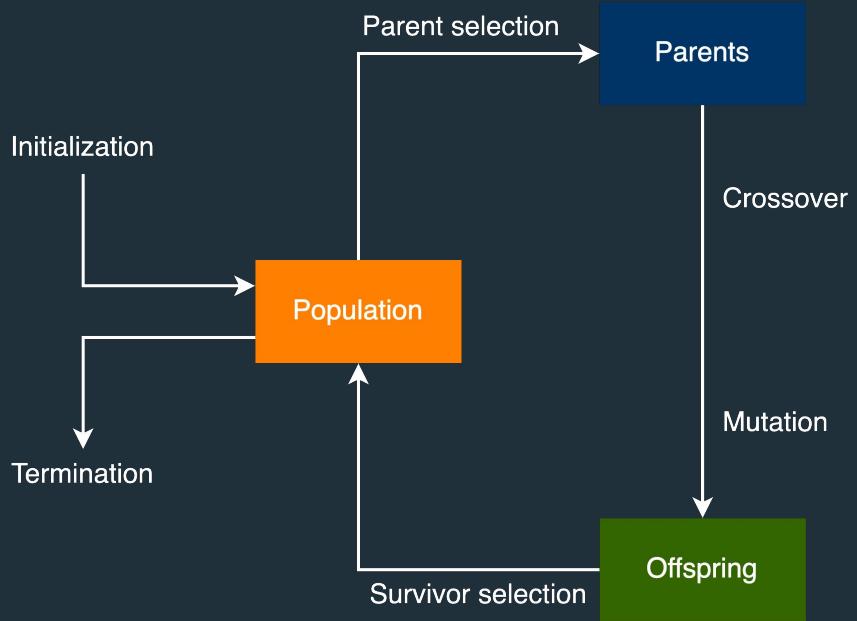
Recap

We have been through...

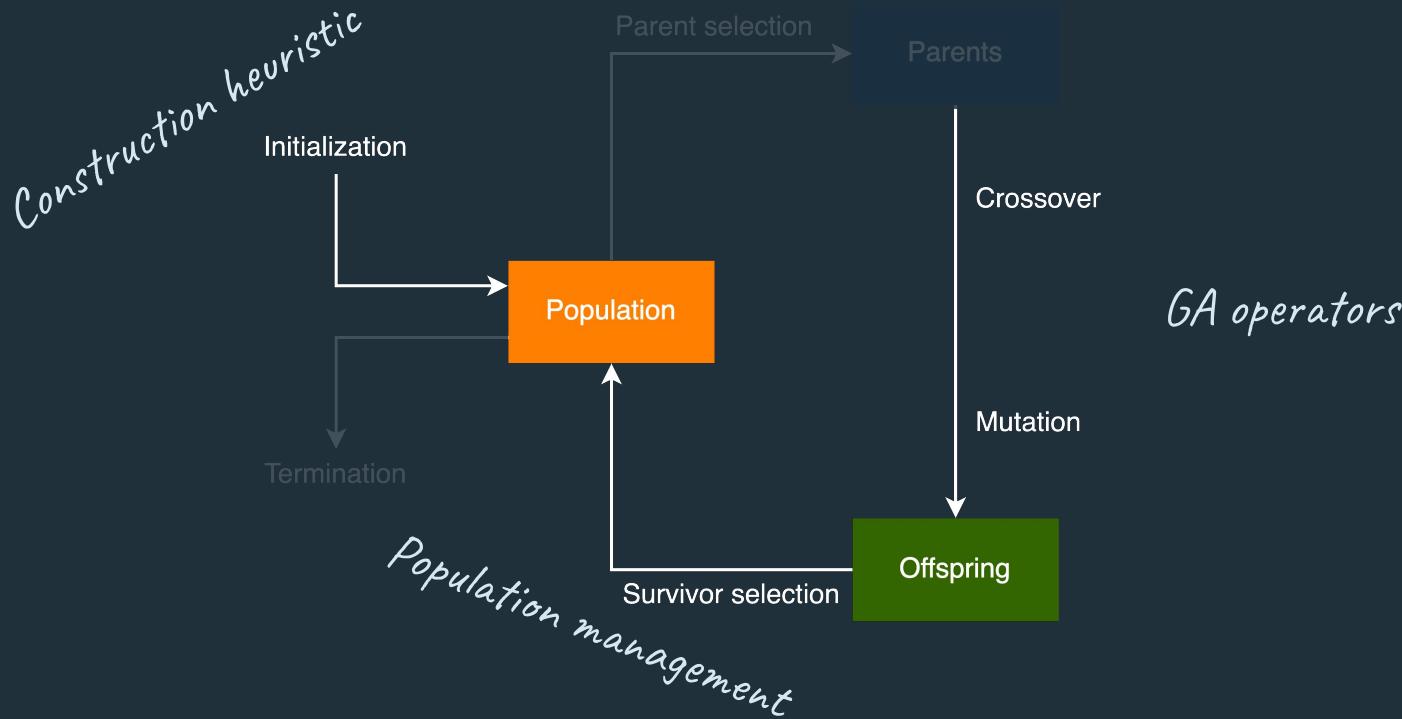
1. How a solution to the problem looks and how it can be represented
2. Making this solution adhere to the problem's constraints
3. Calculating the objective value of a solution

Part 2: Boosting GA performance

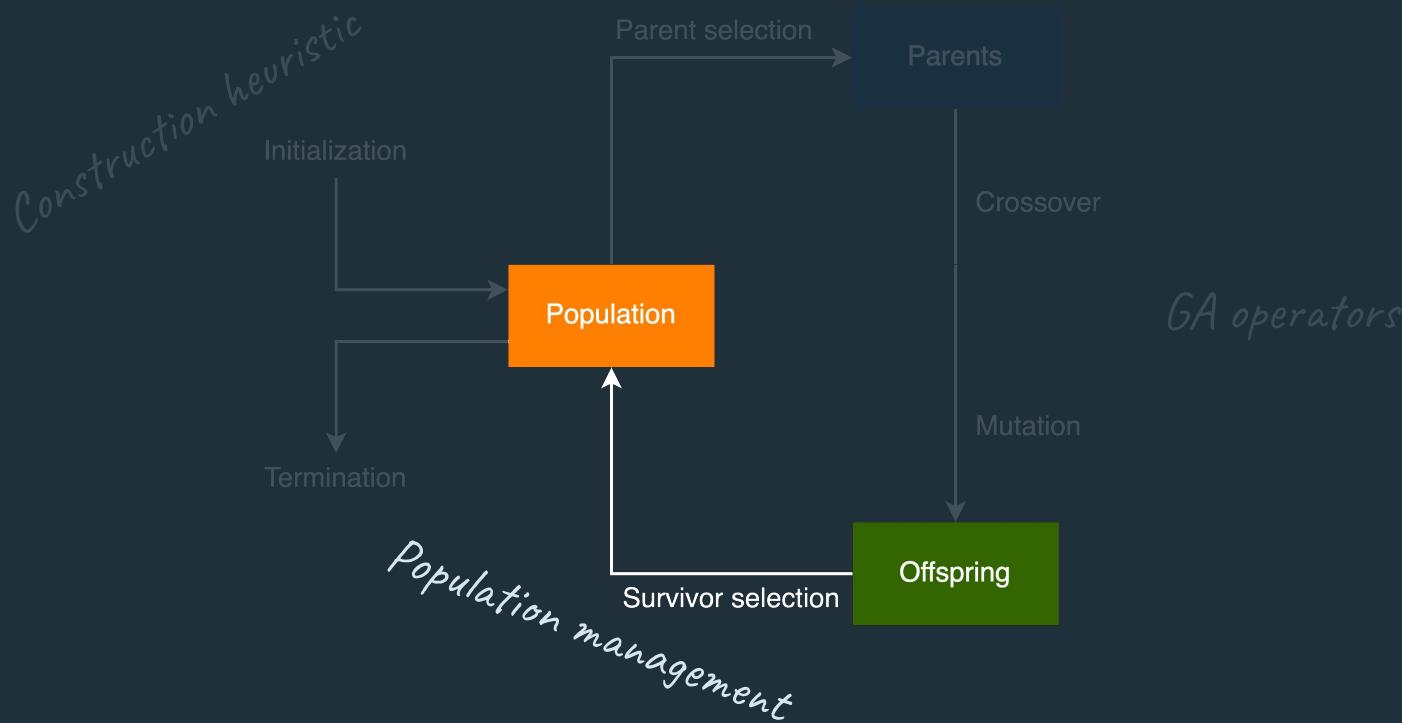
Genetic algorithm recap



Performance improvement areas



Performance improvement areas



Improving population management

Elitism



Infeasible / feasible population

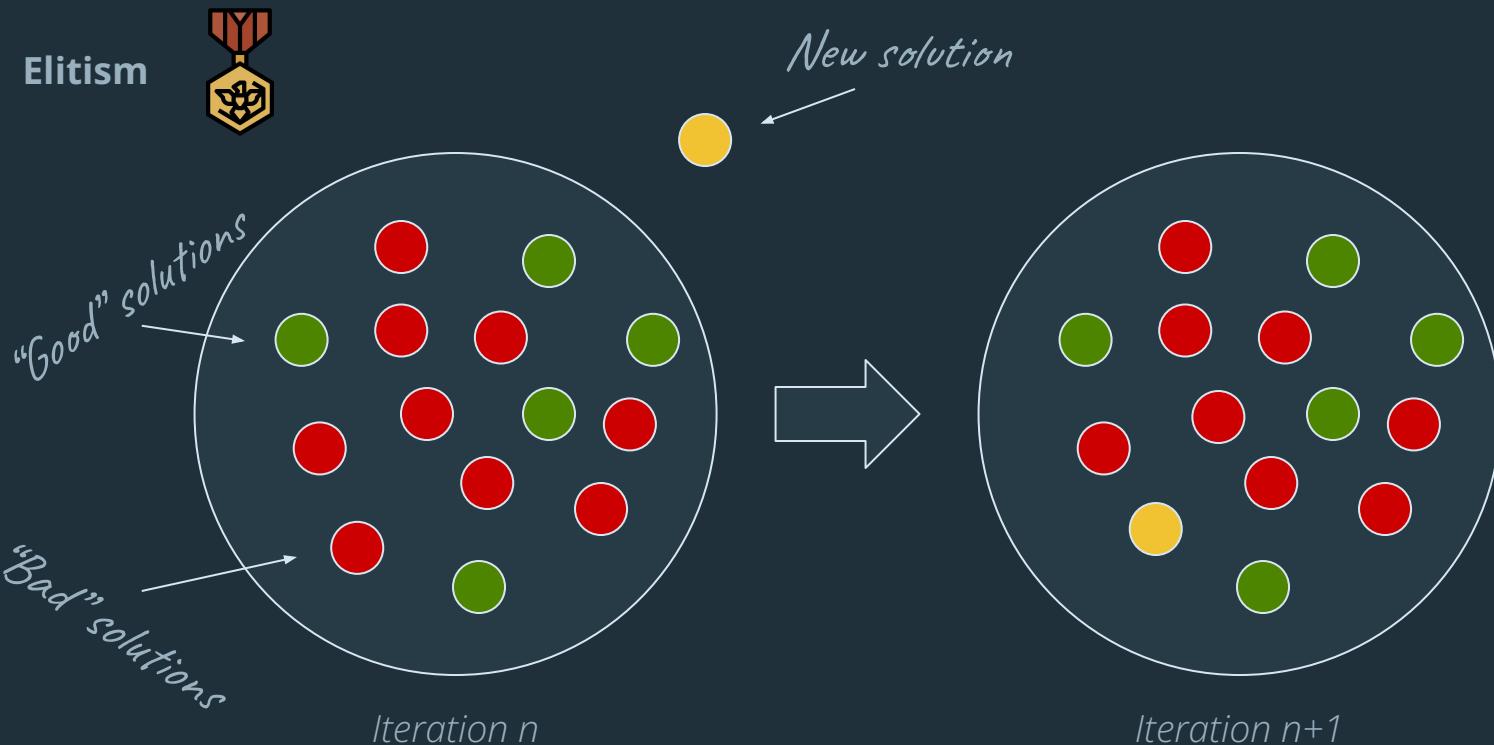


Diversify population during search



... and many more. Do research and be creative!

Improving population management



Improving population management

Infeasible / feasible population



Select parents from...

Feasible
individuals

Infeasible
individuals

Improving population management

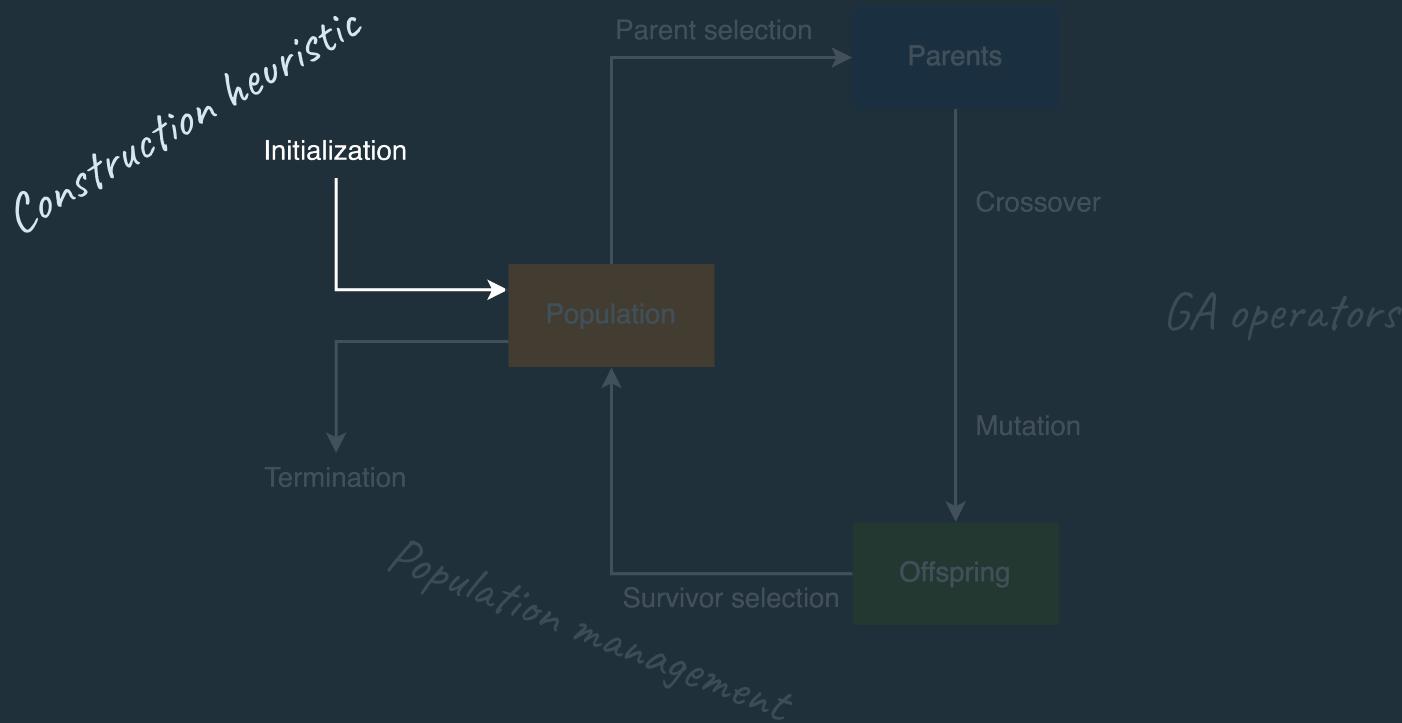
Diversify population during search



No improving solution for the previous Y iterations?

Keep the X best solutions, run a (random) construction heuristic to create brand new individuals

Performance improvement areas



Construction heuristic ideas

Place patients in nurse routes randomly (will yield both feasible and infeasible solutions)

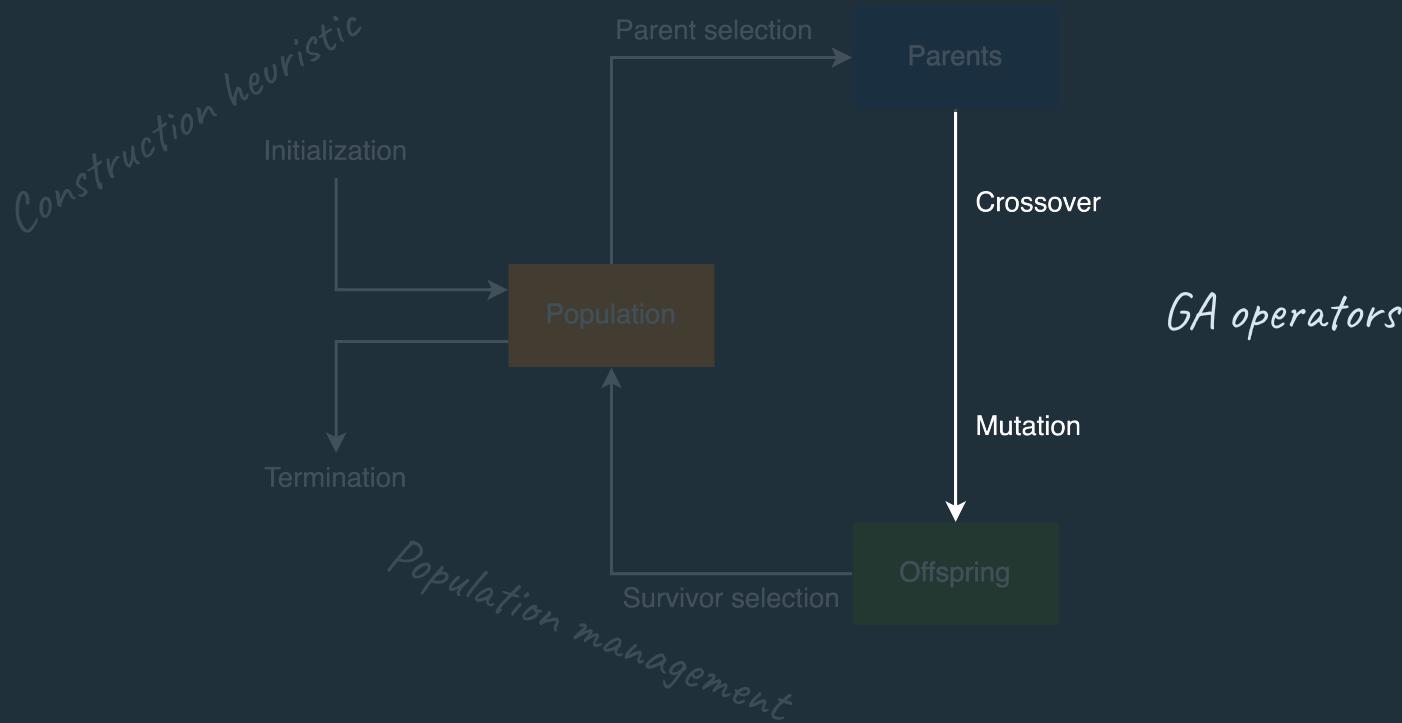
Greedy heuristic (assign the patient to the nurse route where the travel time increase is smallest)

Identify clusters and assign nurses to clusters

If you implement local search, use operators from this to "educate" the individuals

... and many more. Do research and be creative!

Performance improvement areas



Improving GA operators

Local search (education)



Parallel computations



Choosing efficient data structures



... and many more. Do research and be creative!

Improving GA operators

Local search (education)



Marginally alter a solution (individual) and investigate the neighborhood of the solution.

Many different local search operators can be implemented, but some are:

Move a patient to another spot in the route

Move a patient to another route

Swap two patients within a route

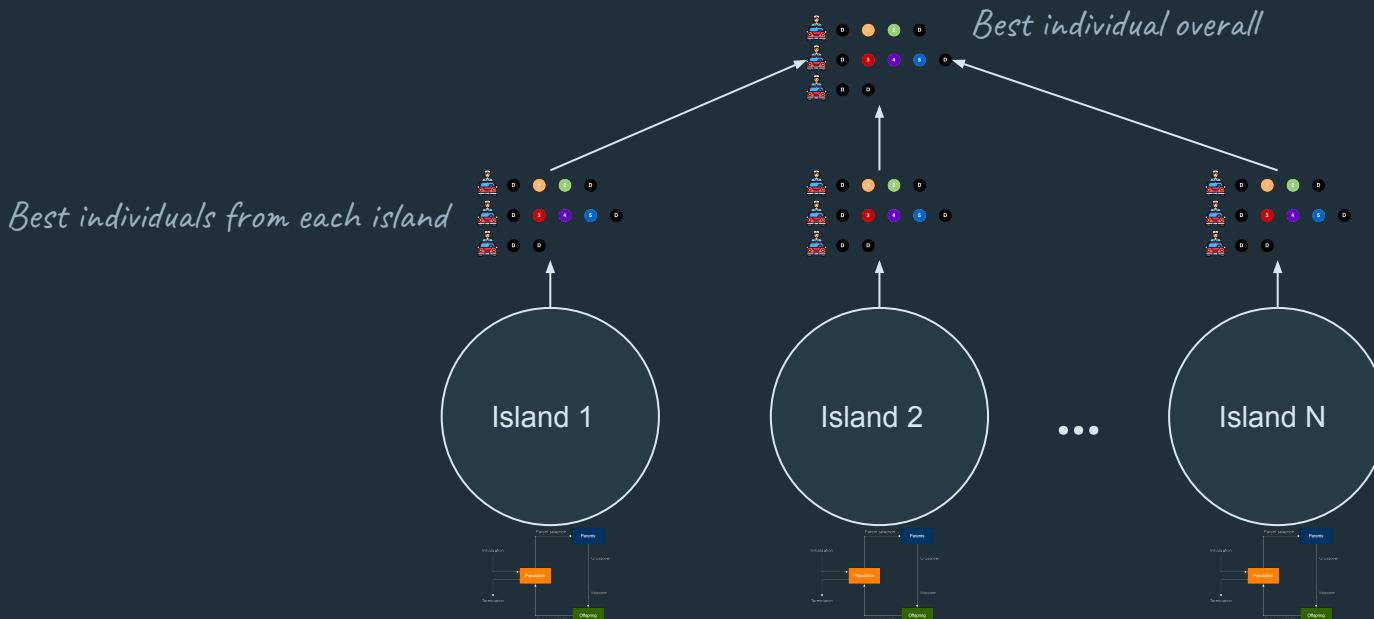
Swap two patients in different routes

...

Improving GA operators

Parallel computations {

Option 1: Parallel Genetic Algorithm with "Islands"



Improving GA operators

Parallel computations



Option 2: Parallelizing the local search

Pick X solutions (individuals) to run the local search (education) on, and do so in parallel

Improving GA operators

Choosing efficient data structures



Think about what operations you will be doing on your solutions and choose an efficient data structure

Google x |

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About 47,100,000 results (0.56 seconds)

Summary

Operation	LinkedList time complexity	ArrayList time complexity
Insert at last index	$O(1)$	$O(1)$ (If array copy operation is Considered then $O(N)$)
Insert at given index	$O(N)$	$O(N)$
Search by value	$O(N)$	$O(N)$
Get by index	$O(N)$	$O(1)$

2 more rows • Aug 16, 2019

<https://dzone.com> • Performance Zone

Performance Analysis of ArrayList and LinkedList in Java

Other tips

Place time window constraint in the objective with a **large** penalty parameter

$$objective = \sum_{n=1}^{N^{\text{Number of nurses}}} travel_time_n$$

Other tips

Place time window constraint in the objective with a **large** penalty parameter

$$objective = \sum_{n=1}^{N_{\text{nurses}}} travel_time_n + penalty * \sum_{p=1}^{P_{\text{patients}}} time_window_violation_p$$

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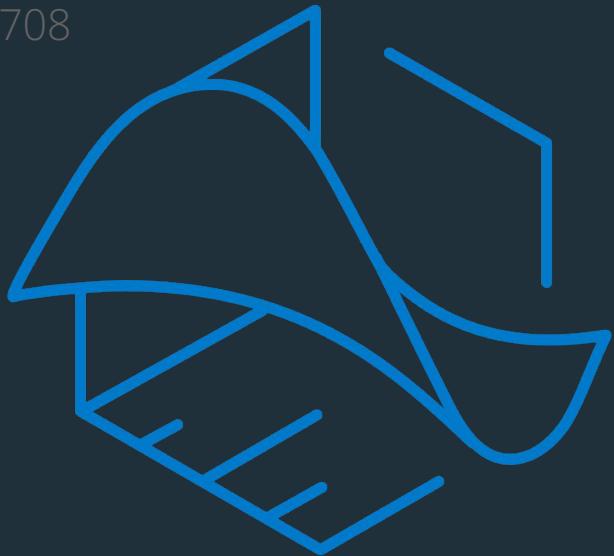
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Basic info about the competition

Completely **optional** and nothing to do with your score in the project or course.

Run your algorithm locally on a specified instance, upload it and get a score.

High score list.

Best score at 12:00 on March 1st: gift card for komplet.no worth 1000 NOK

Best score at 12.00 on March 20th: gift card for komplet.no worth 2000 NOK

Competition web page

<https://it3708.resolve.visma.com>



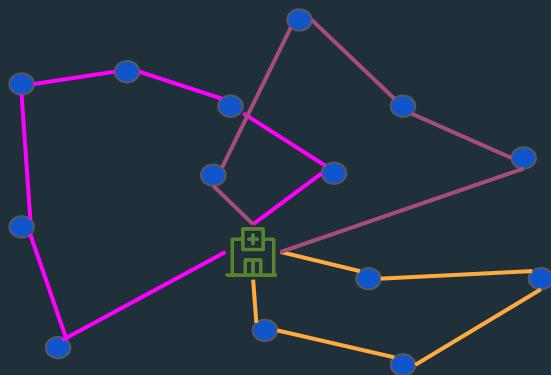
**Entrepreneurial
Responsible
Dedicated
Inclusive**

Make progress happen

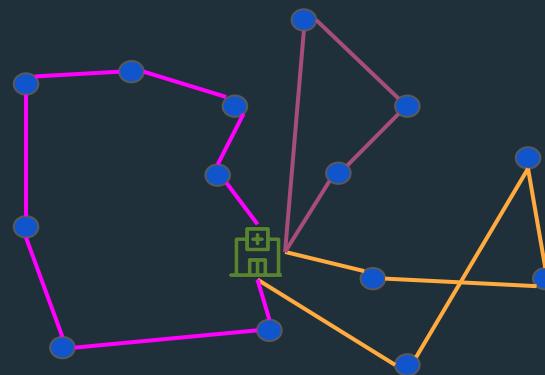


Appendix: Crossover

Individual 1



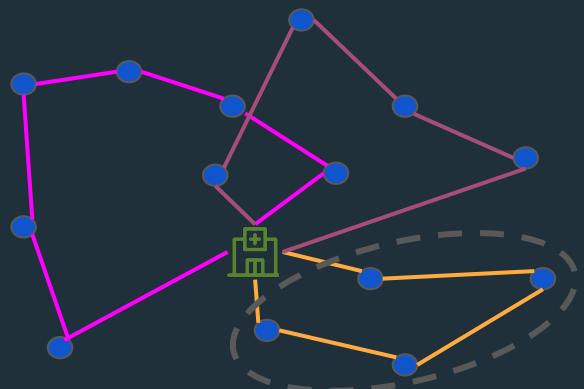
Individual 4



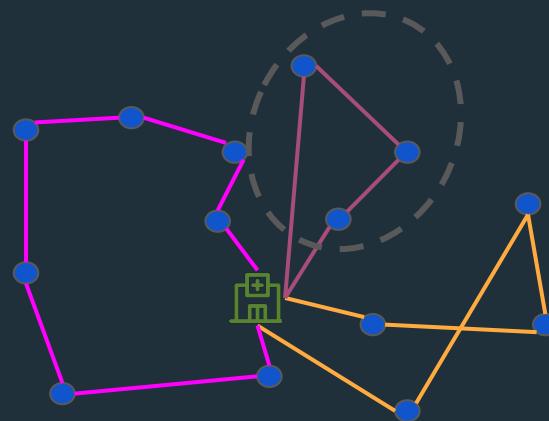
How can we **combine features** from the two individuals to create two **new offsprings**?

Appendix: Crossover

Individual 1



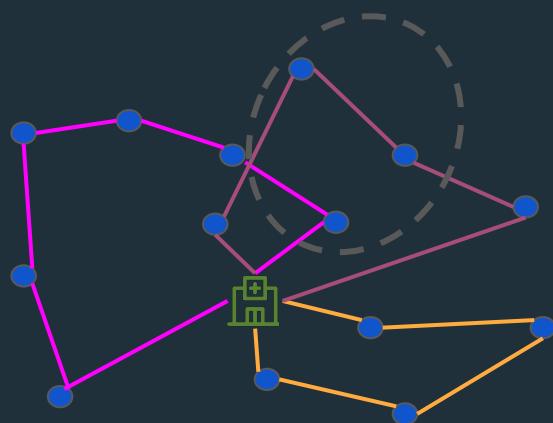
Individual 4



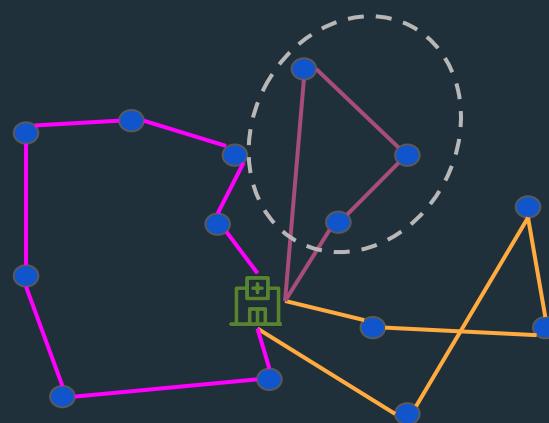
Select two random nurses' routes

Appendix: Crossover

Individual 1



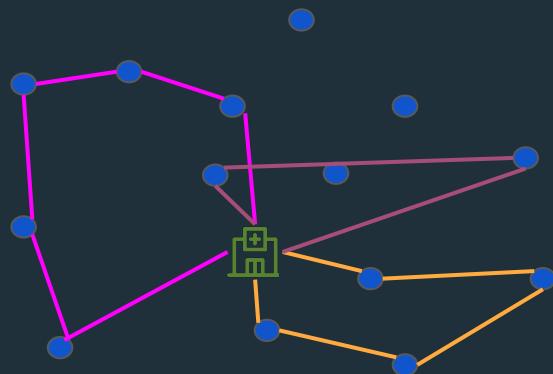
Individual 4



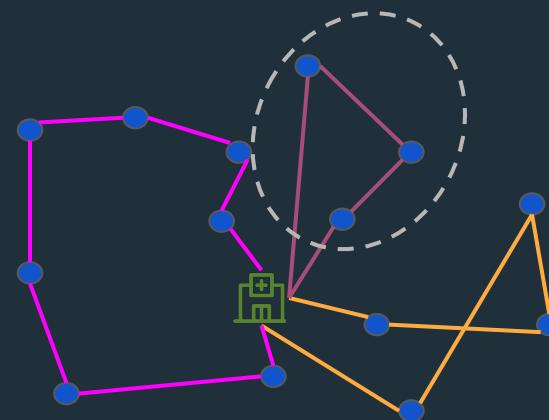
Identify the patients selected from Individual 4 in Individual 1

Appendix: Crossover

Individual 1



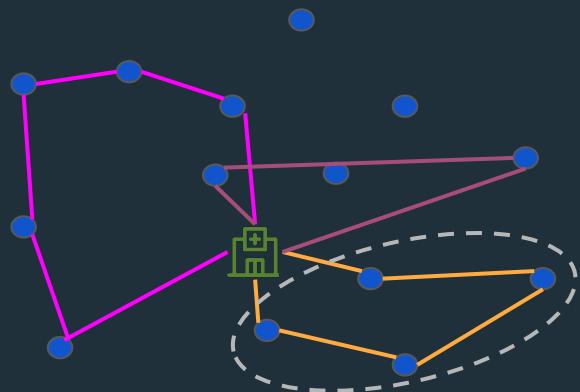
Individual 4



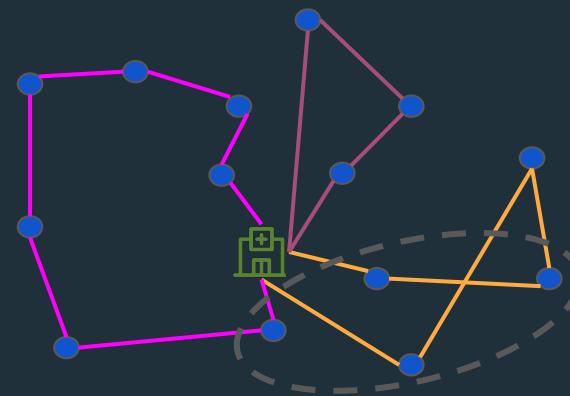
Remove the patients from Individual 1

Appendix: Crossover

Individual 1



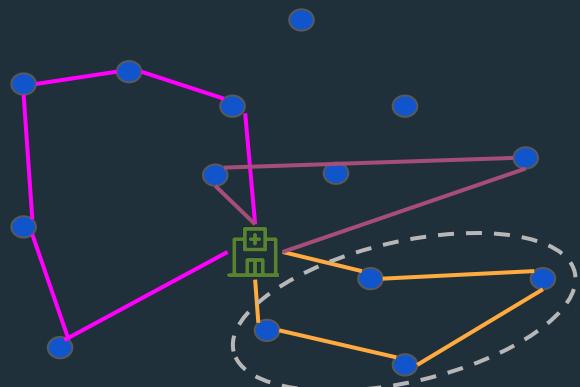
Individual 4



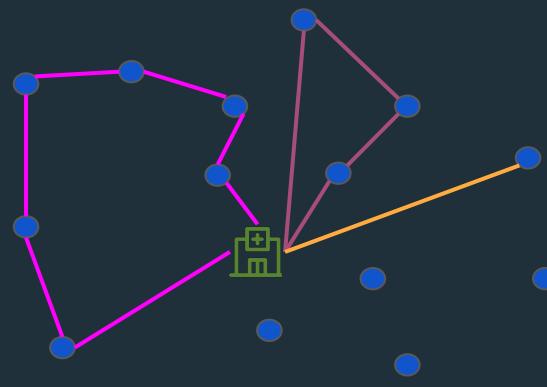
Identify the patients selected from Individual 1 in Individual 4

Appendix: Crossover

Individual 1



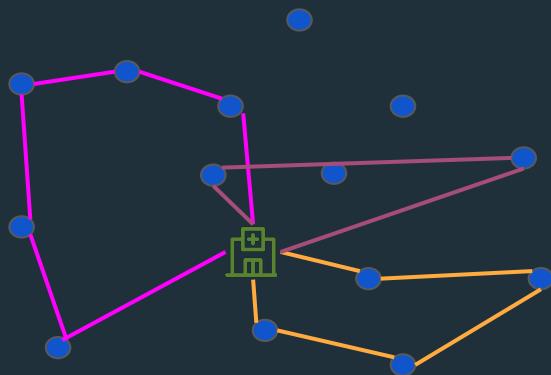
Individual 4



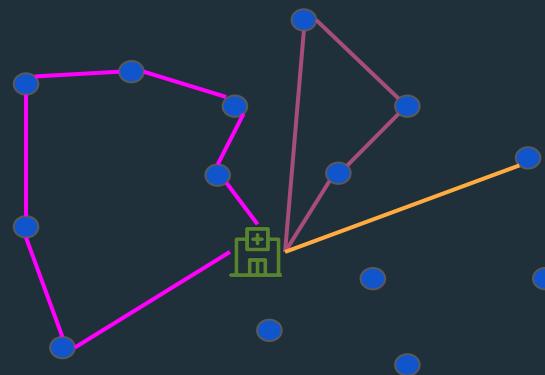
Remove the patients from Individual 4

Appendix: Crossover

Individual 1



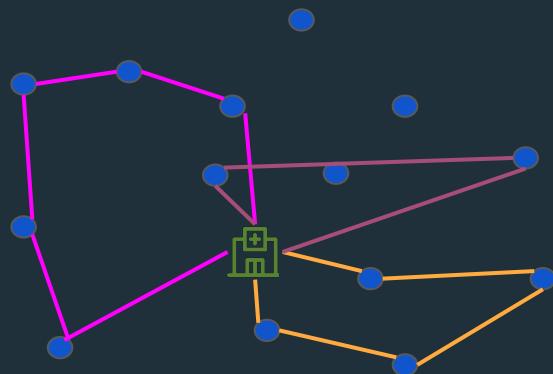
Individual 4



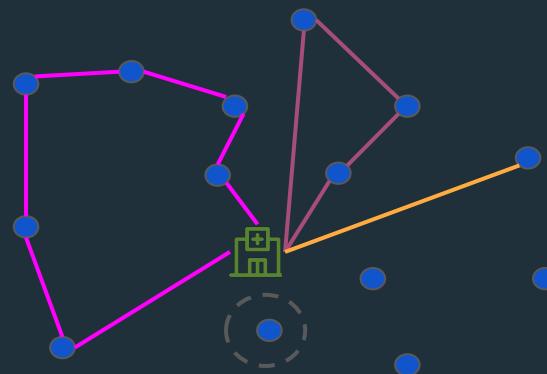
Result after removing patients in crossover

Appendix: Crossover

Individual 1



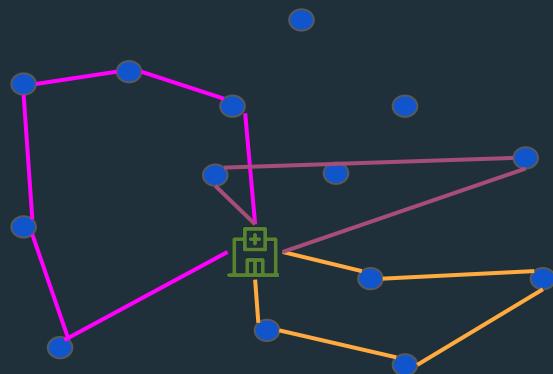
Individual 4



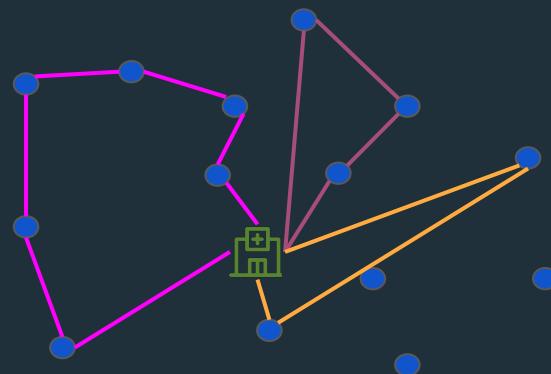
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



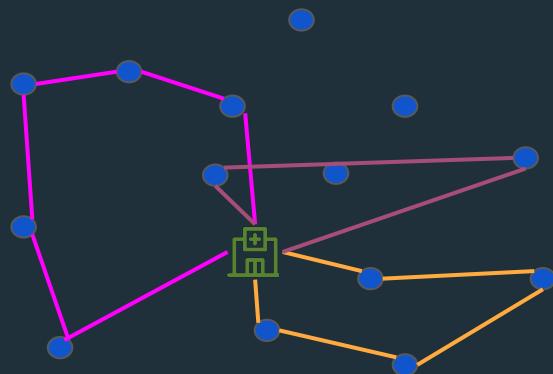
Individual 4



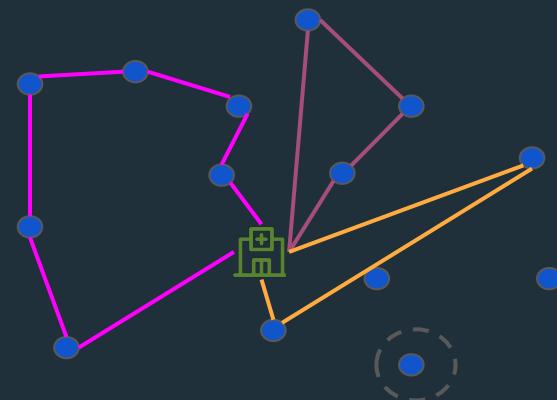
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



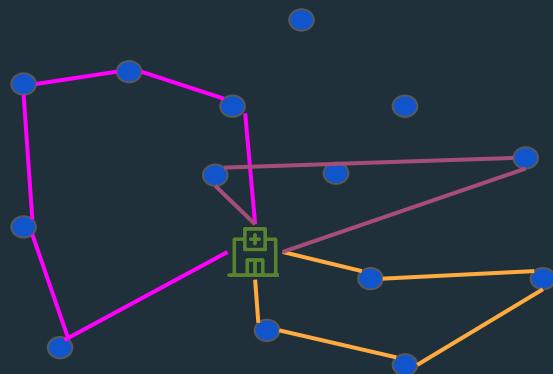
Individual 4



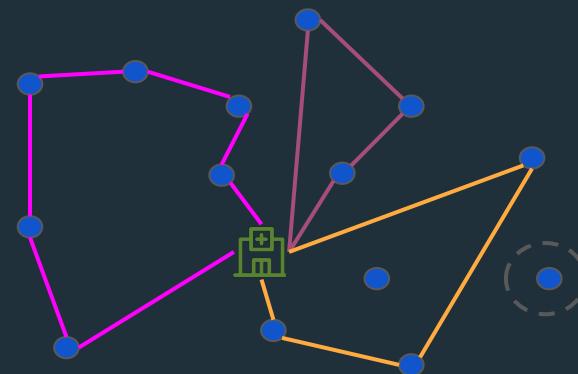
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



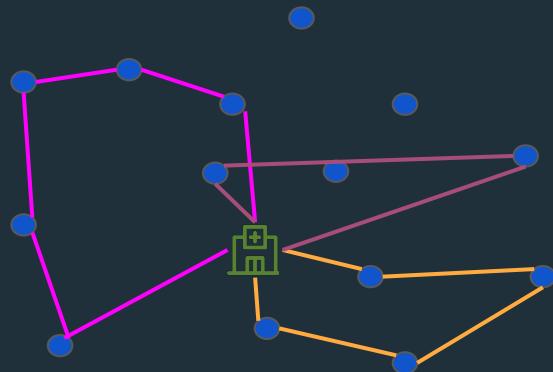
Individual 4



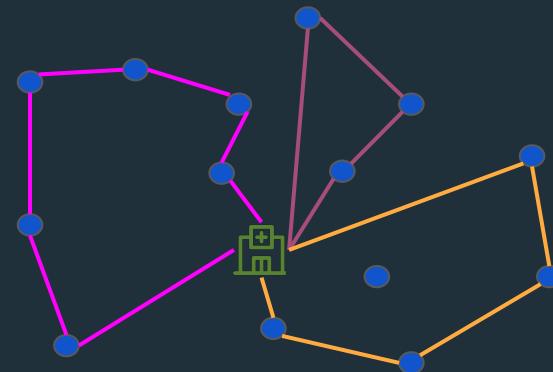
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



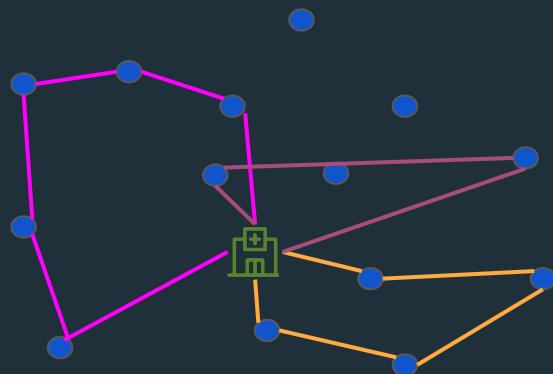
Individual 4



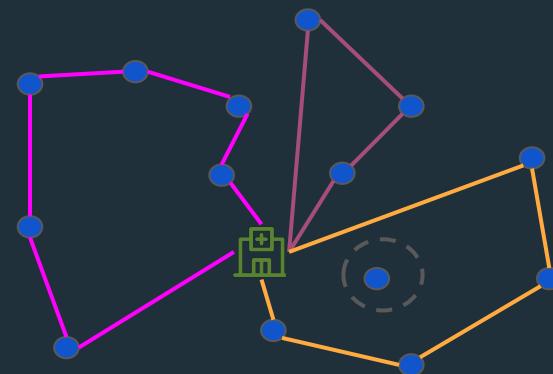
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



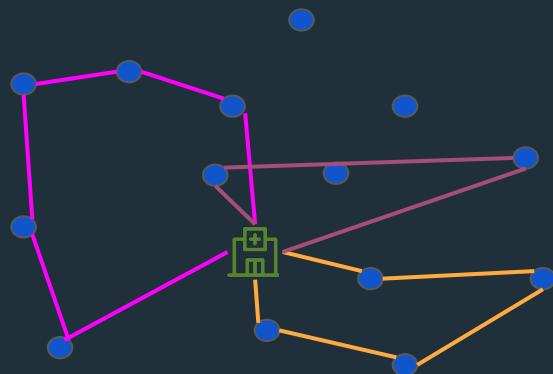
Individual 4



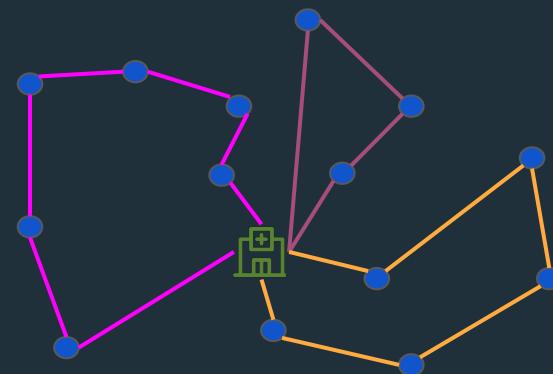
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



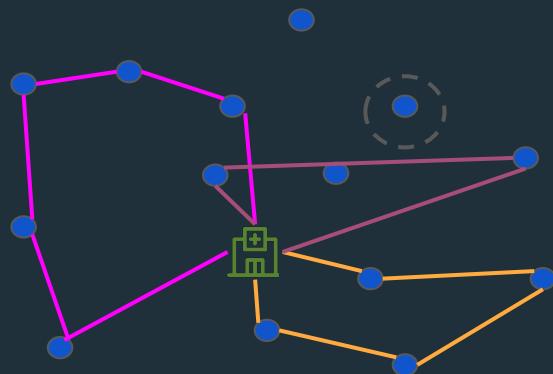
Individual 4



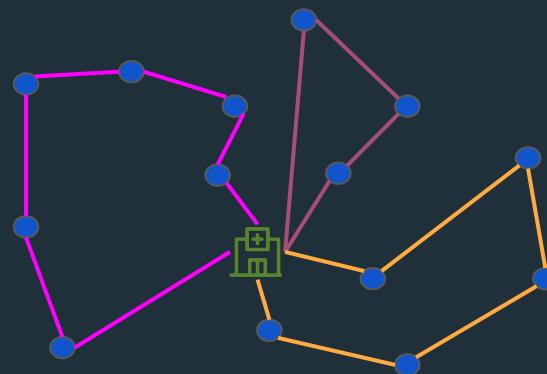
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



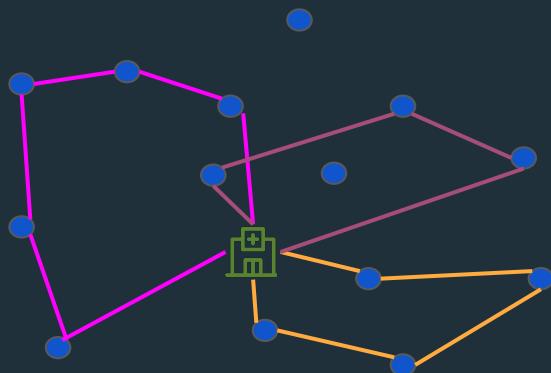
Individual 4



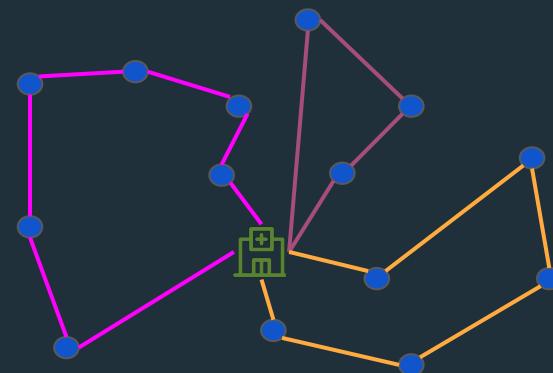
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



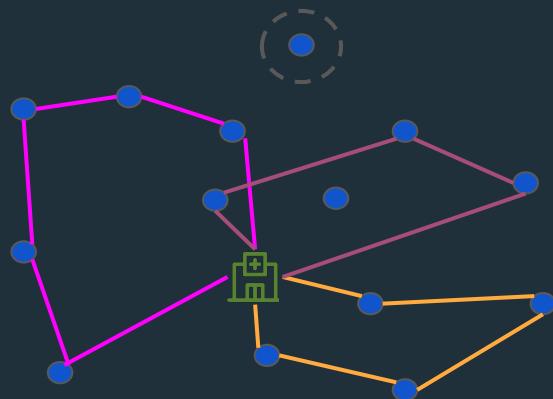
Individual 4



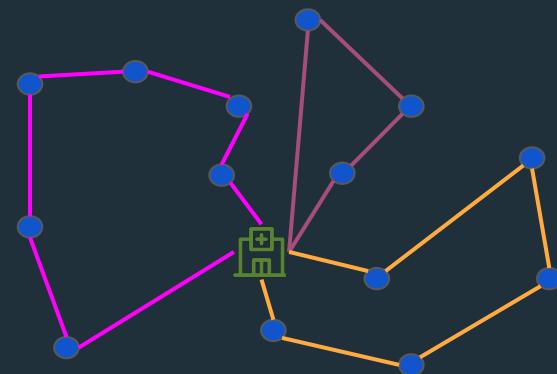
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



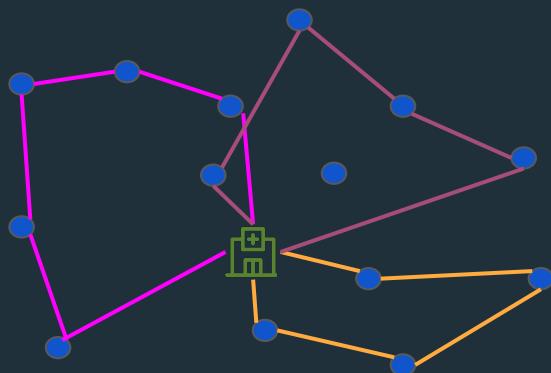
Individual 4



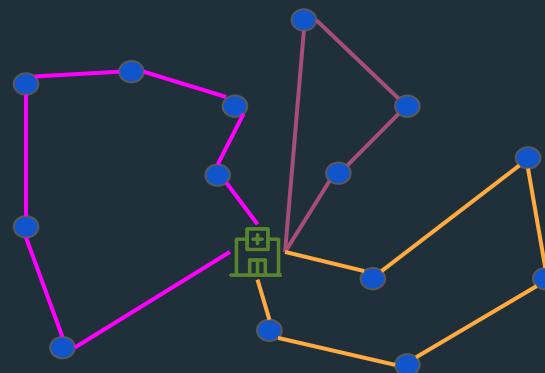
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



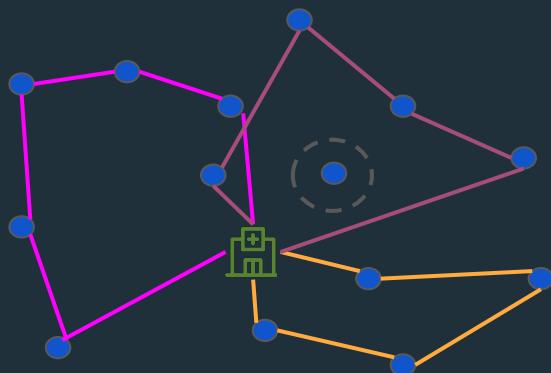
Individual 4



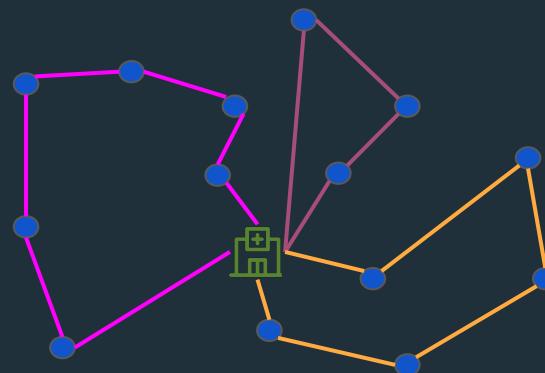
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



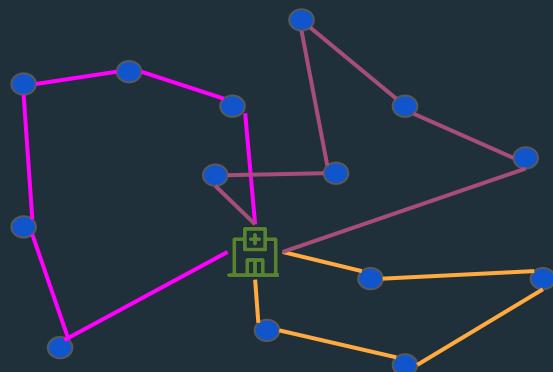
Individual 4



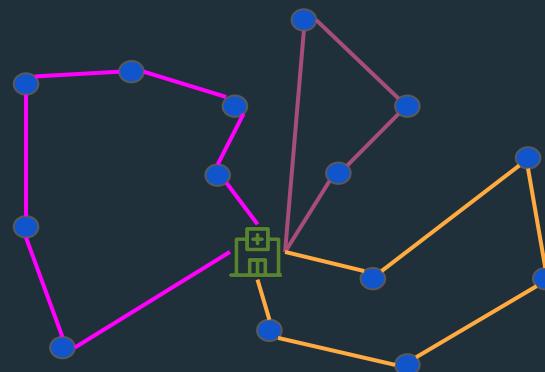
For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



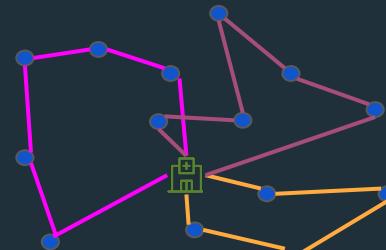
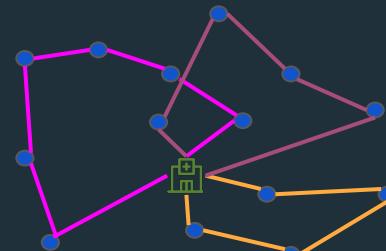
Individual 4



For each patient without a visitor, find the best insertion

Appendix: Crossover

Individual 1



Individual 4

