Class 8 - Problem Focus

Guiding Genetic Algorithms with Language Models for Combinatorial Optimization

MISE Research Program - July 2025

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Capacitated Autonomous Robot Routing

Capacitated Autonomous Robot Routing (CARR)

A charging depot dispatches an identical fleet of **K** autonomous mobile robots to perform **N** spatially-distributed tasks (e.g. sensor swap-outs, collecting packages, etc).

There are **N + 1** locations, numbered from **0** to **N**, where location **0** corresponds to an initial location where all the robots start from, and each of the other locations correspond to one task to be performed

Robots must start and finish at the initial location

Robots can move from location ***i*** to location ***j*** and they can perform a task once they are at a location, at a cost of $\mathbf{C_{ij}}$

Each task has to be performed at least once and each location can't be visited more than once (except the starting location)

Because of battery limits and payload constraints, each robot may perform at most **L** tasks before returning to recharge.

CARR Parameters

- **N** - number of task locations (indexed **1** … **N**)
- **K** - number of identical autonomous robots
- **L** - maximum tasks a single robot may handle
- C_{ij} - travel cost to move from location **i** to **j**

You can assume that:

- **K < N** (more tasks than robots, otherwise the problem is trivial)
- C_{ij} **>= 0** (cost is nonnegative)
- $C_{ij} = C_{ji}$ (cost is symmetric)
- **K * L >= N** (enough robots to complete all tasks)

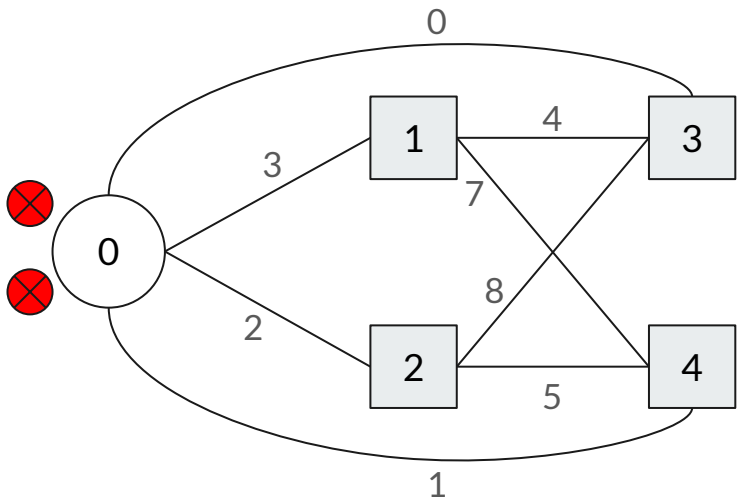
CARR Constraints

- **Start/End rule**: every robot starts and ends at location 0
- **Capacity**: each robot's route contains ≤ **L** task locations
- **Task coverage**: every task location (1…**N**) is visited at least once
- **No revisits**: except for the start location, no location is visited more than once

CARR Objective

Find a path for each robot that satisfies all the constraints and minimizes the total travel cost across all robots

CARR Example



N = 4, K = 2, L = 2

$C_{01} = 3$

$C_{02} = 2$

$C_{03} = 0$

$C_{04} = 1$

$C_{13} = 4$

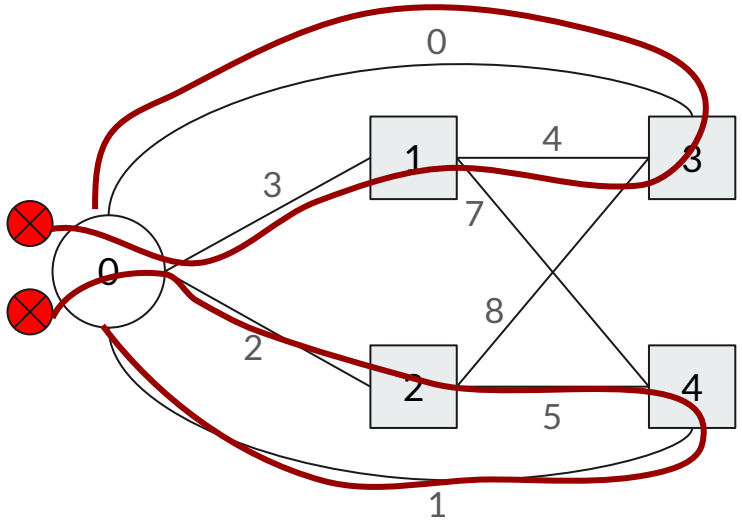
$C_{14} = 7$

$C_{23} = 8$

$C_{24} = 5$

All other C_{ij} are ∞

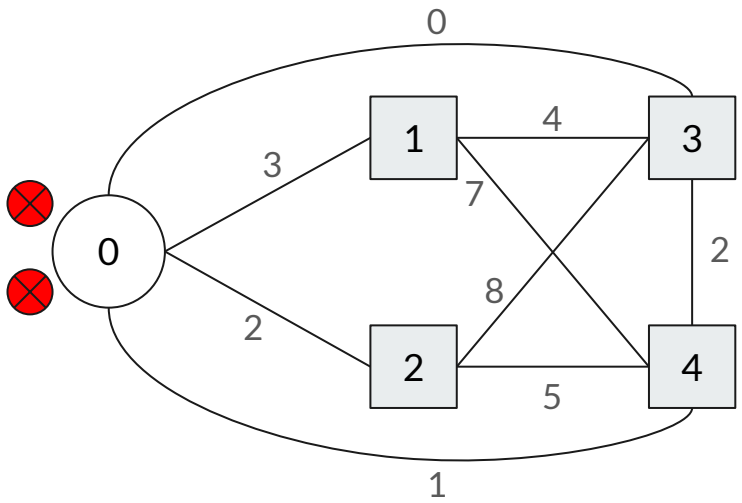
CARR Example - Solution



Robot 1: 0 -> 1 -> 3 -> 0
Robot 2: 0 -> 2 -> 4 -> 0

N = 4, K = 2, L = 2
$C_{01} = 3$
$C_{02} = 2$
$C_{03} = 0$
$C_{04} = 1$
$C_{13} = 4$
$C_{14} = 7$
$C_{23} = 8$
$C_{24} = 5$
All other C_{ij} are ∞

CARR Example 2



N = 4, K = 2, L = 3

$C_{01} = 3$

$C_{02} = 2$

$C_{03} = 0$

$C_{04} = 1$

$C_{13} = 4$

$C_{14} = 7$

$C_{23} = 8$

$C_{24} = 5$

$C_{34} = 2$

All other C_{ij} are ∞

What's next?

Next class Monday (3pm)

Assignment Sheet to be added to the website soon

Class 9: Combining LLMs and GAs