MAXIMIZING TARGET COVERAGE OF UNMANNED AERIAL VEHICLE CARRIED ON MOBILE PLATFORM

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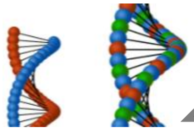
Supervisor : Asst. Prof. Murat Karakaya



- Current operational trends
- National acquisition projects
- Future projections

Promising Outlook for Navy's Unmanned Aviation

ANALYSIS

BY ANTOINE MARTIN

The U.S. Navy has ambitious plans to deploy new families of unmanned aircraft over the next decade.

Rear Adm. Dewolfe "Chip" Miller, director of intelligence, surveillance and reconnaissance (ISR) capabilities in the office of the deputy chief of naval operations for information dominance, called the Navy's unmanned aviation model a hybrid.

It partly follows the Air Force model of "ISR reach back," which means sending data collected by aircraft sensors back to network nodes for analysis. It also takes after the Army model of tactical ISR by bridging the information forward to the fighting unit.

Interoperability will be a significant challenge for the Navy, however. The Navy has not yet tightly integrated its unmanned air systems (UAS) within ship operations, and that is needed in order to effectively operate the UAS that will work in conjunction with manned aircraft, radars and weapon

2016, and 68

The Navy

resources w

Navy had to

the Air Force

An impor

sense-and-avoid payload h

technology that could be a

inventory.

There are still questions

Aviators have criticized th

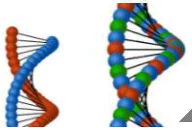
stress as the aircraft contin

orbit to a lower, closer orbi

than expected.

Going forward, BAMS

Mechanisms



Novel Problem:

- VRP route optimization
- Constraint of depot mobility
- Constraint of range capacity

PRACTICAL USE CASE:

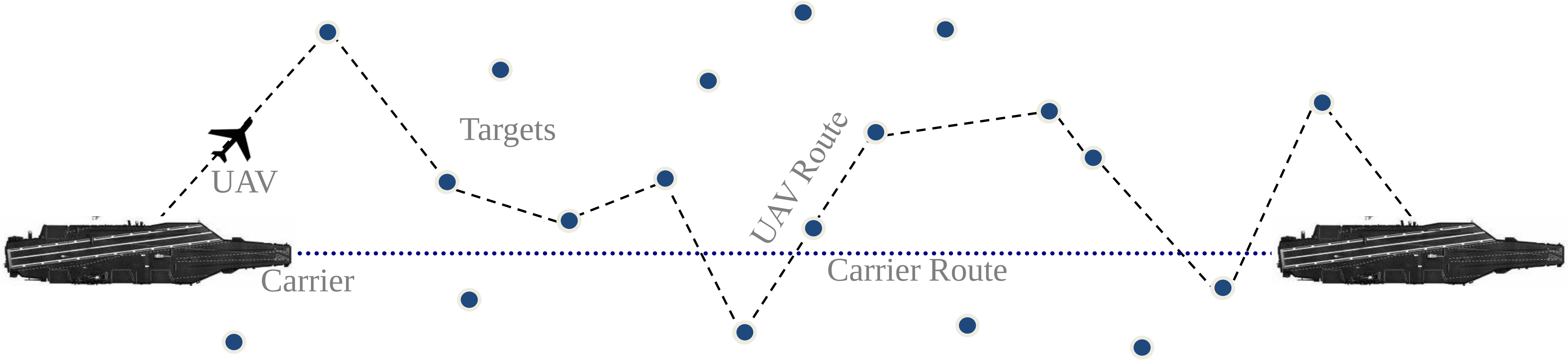
Carrier Launched UAV

UAV → **Vehicle**

Carrier → **Depot**

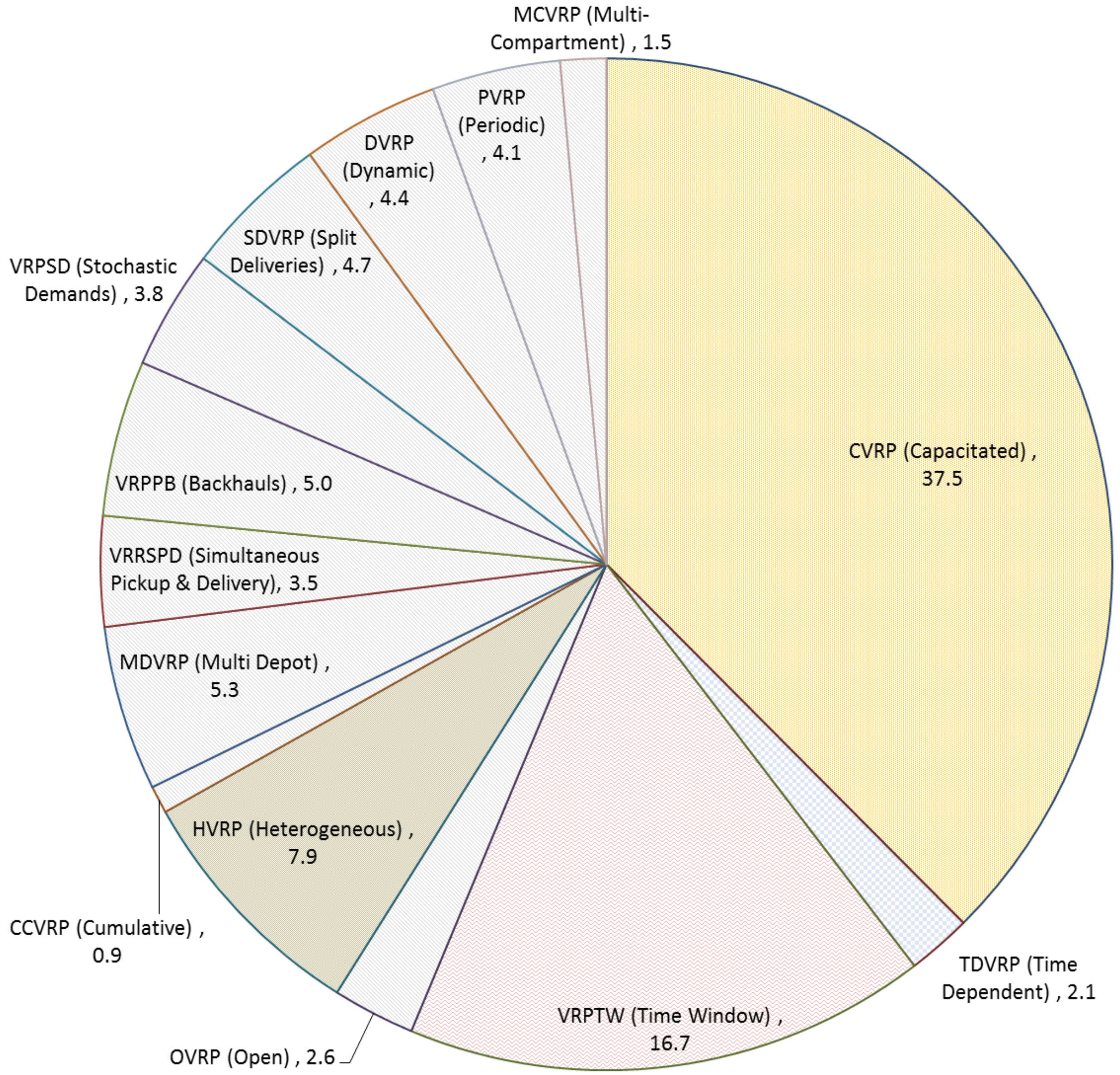
Targets → **Customers**

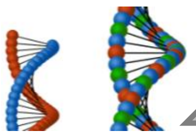
(Mapping)



Some VRP Variants:

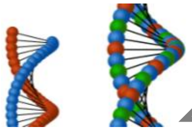
- mVRP
- MDVRP
- VRP-TW
- CVRP
- DVRP
- HVRP
- TTRP





- The UAV has to takeoff from and land on a moving carrier
- The UAV has a limited flight range
- The goal is to maximize the targets the UAV can visit

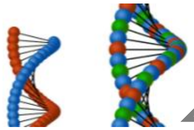
C-MoDVRP



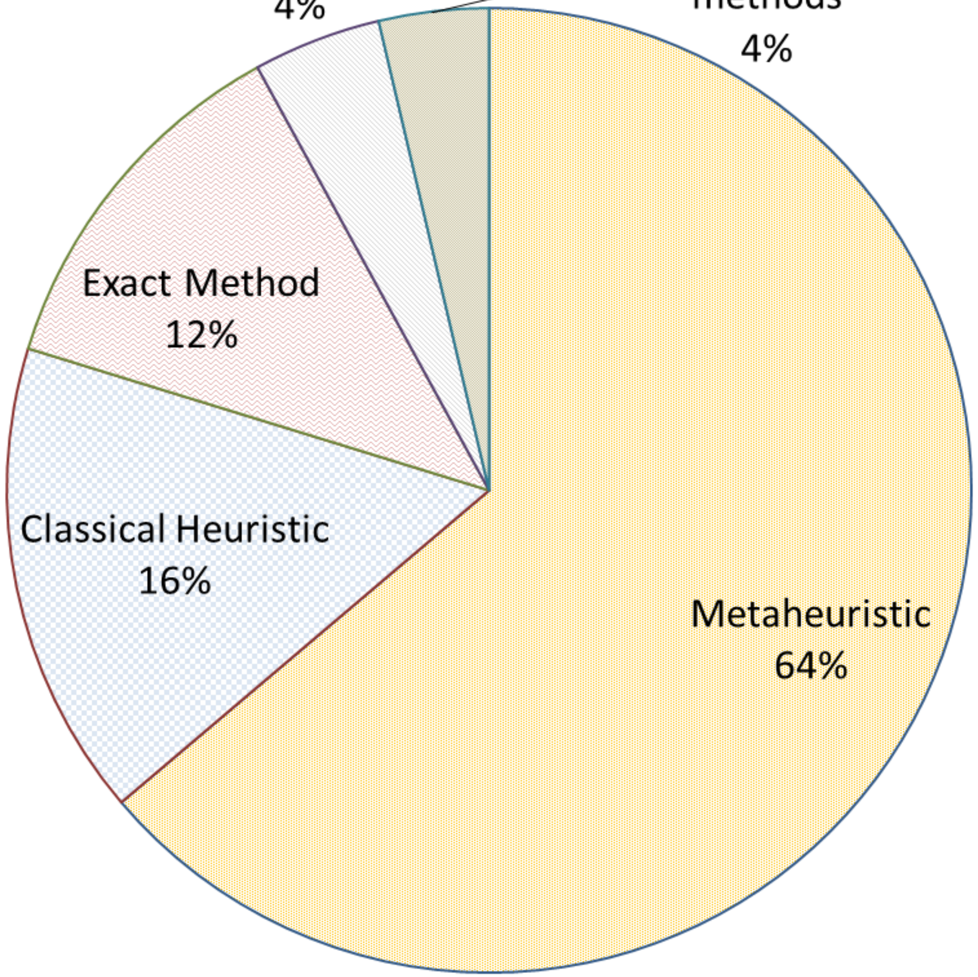
A solution should:

- Choose a takeoff point
- Design a route between the targets
- Take into account the future landing distance

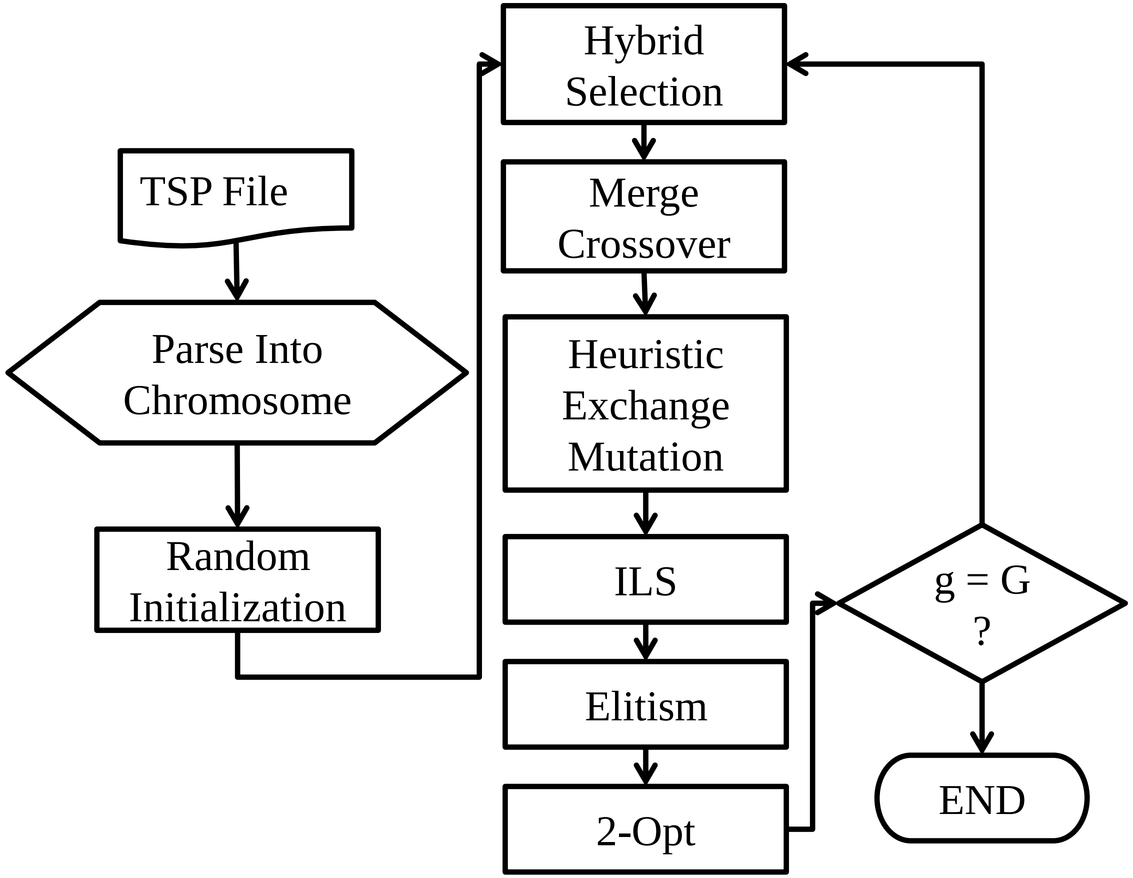
GA-CMoD

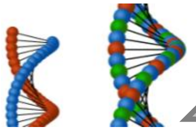


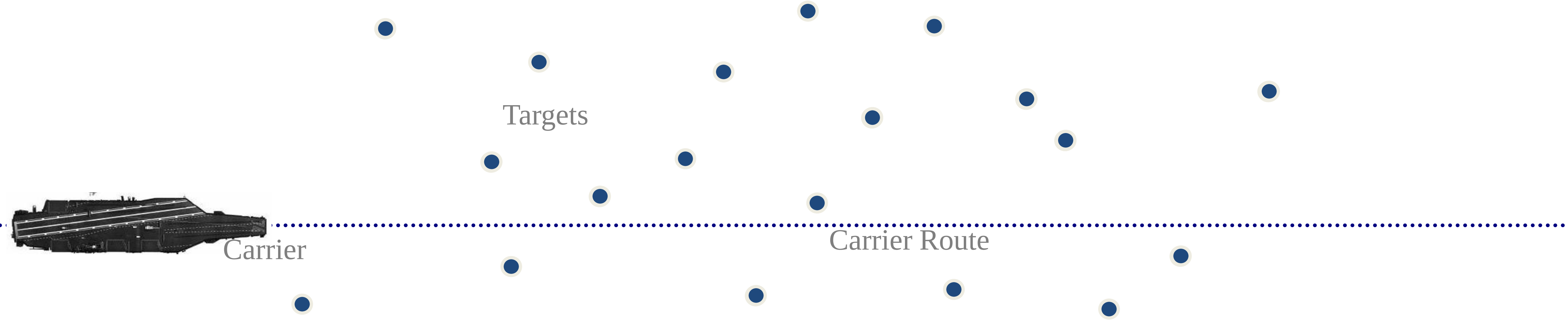
C-MoDVRP – NP Complete

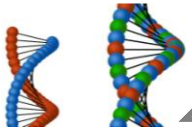


GA-CMoD



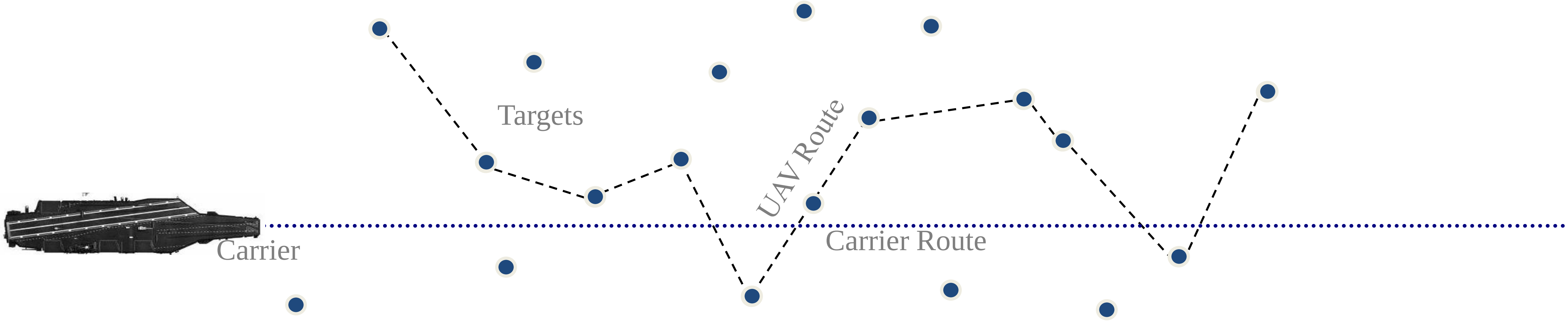


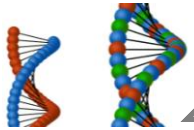

Targets
Carrier
Carrier Route

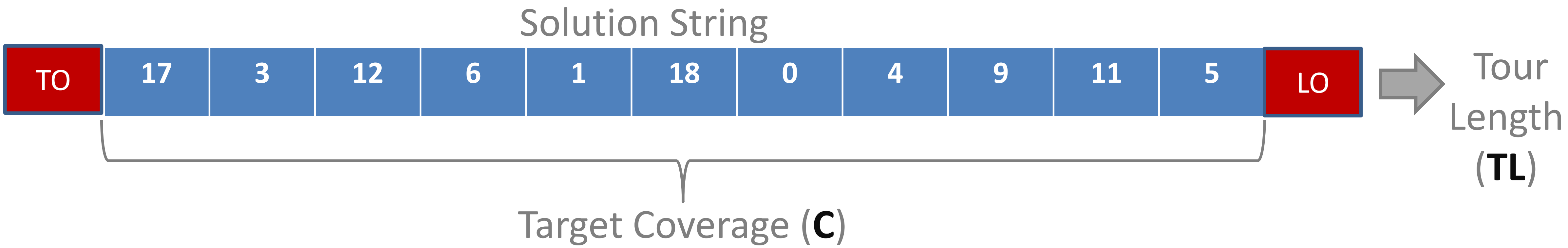


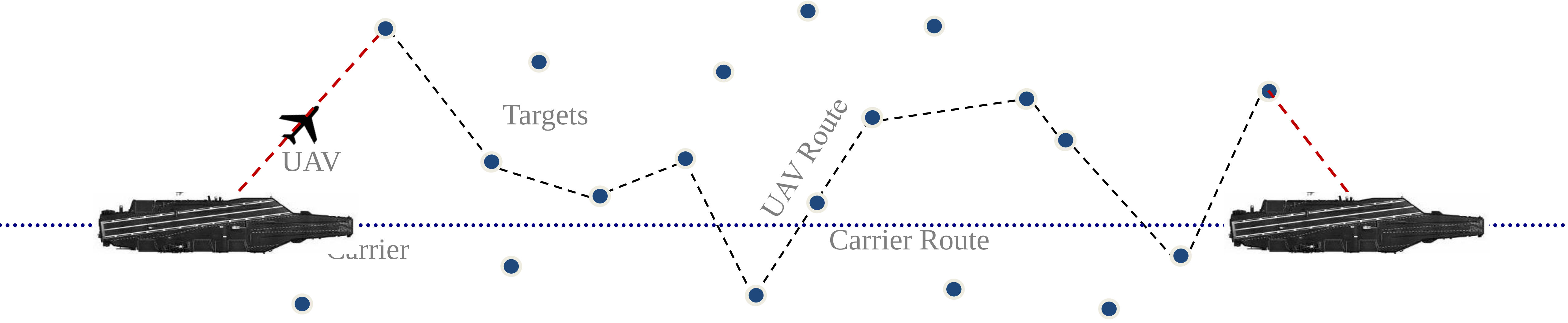
Solution String

17	**3**	**12**	**6**	**1**	**18**	**0**	**4**	**9**	**11**	**5**

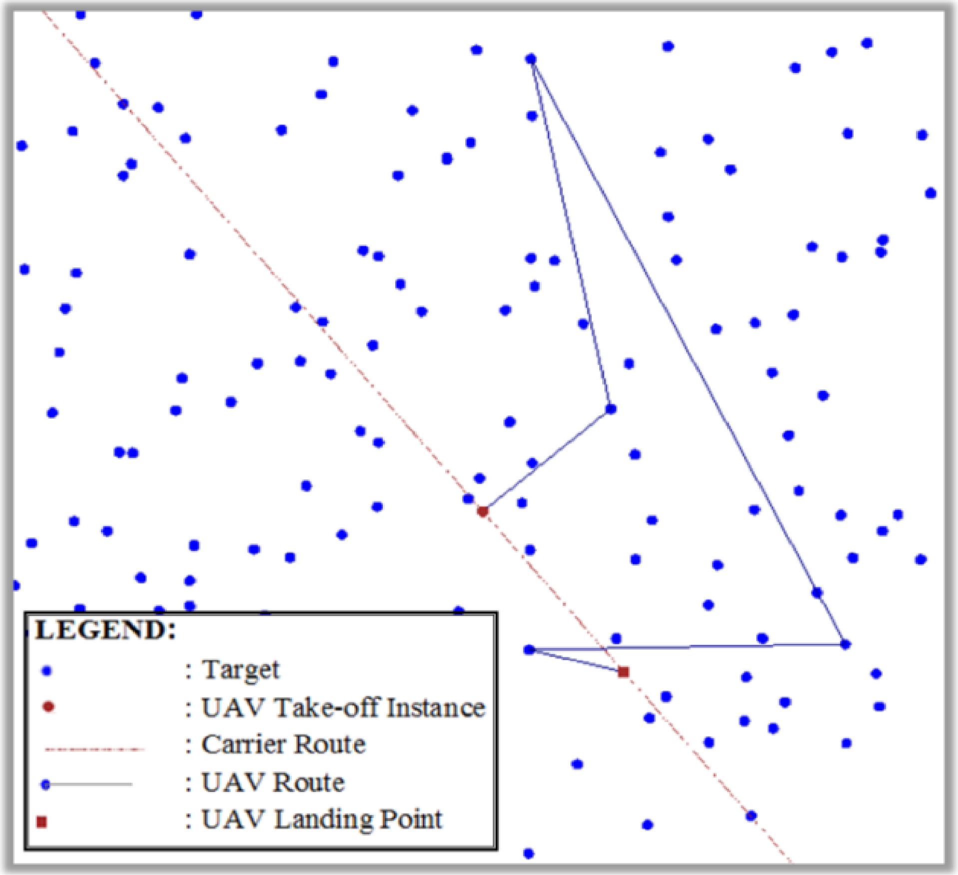




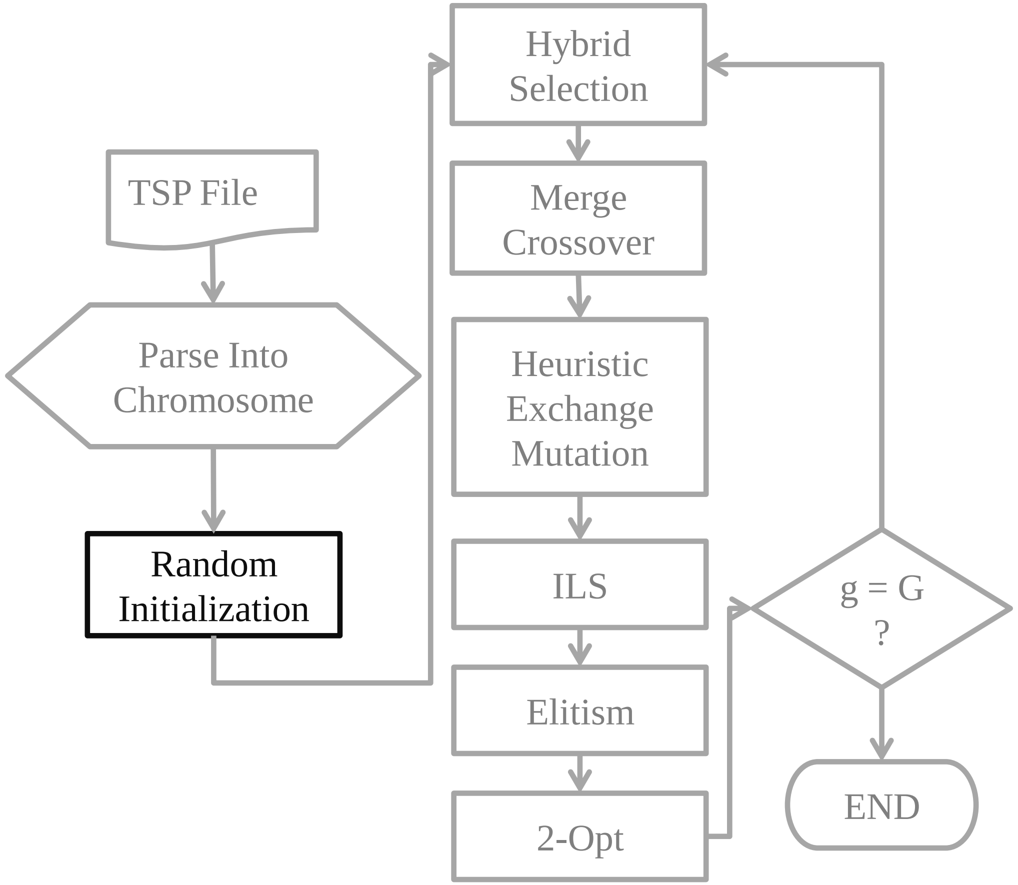

Solution String
TO
17
3
12
6
1
18
0
4
9
11
5
LO
Tour Length (TL)
Target Coverage (C)

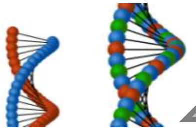

Targets
UAV
UAV Route
Carrier Route

Sampling the search space by randomly generated chromosomes



GA-CMoD



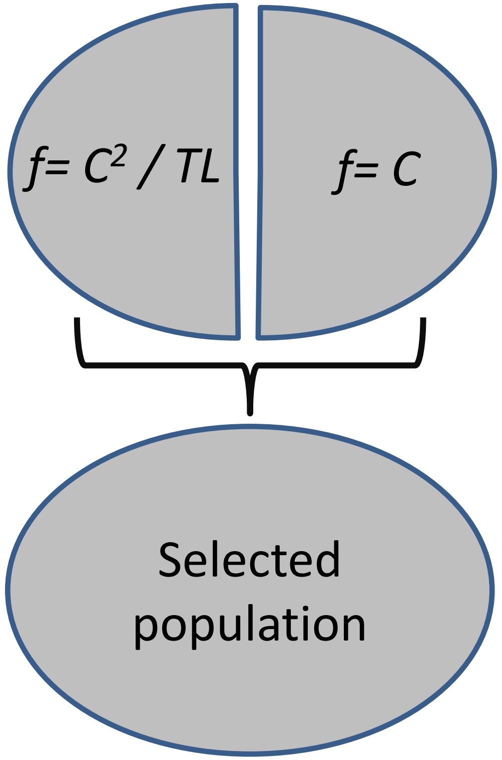


$$TL = \sum_{i=0}^{l-1} \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2}$$

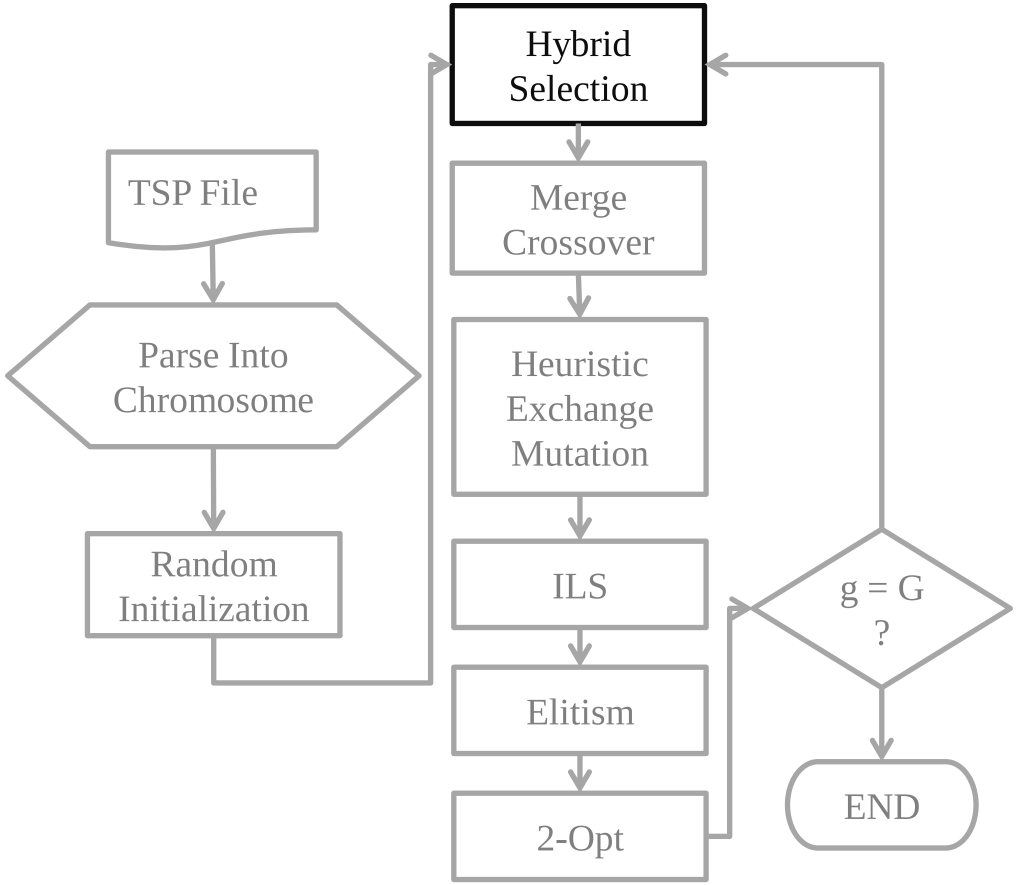
i = 0 -> Take-off instance

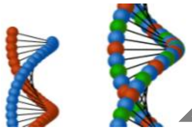
i = 1 .. l-1 *-> Nodes to be visited*

i=l *-> Landing location*



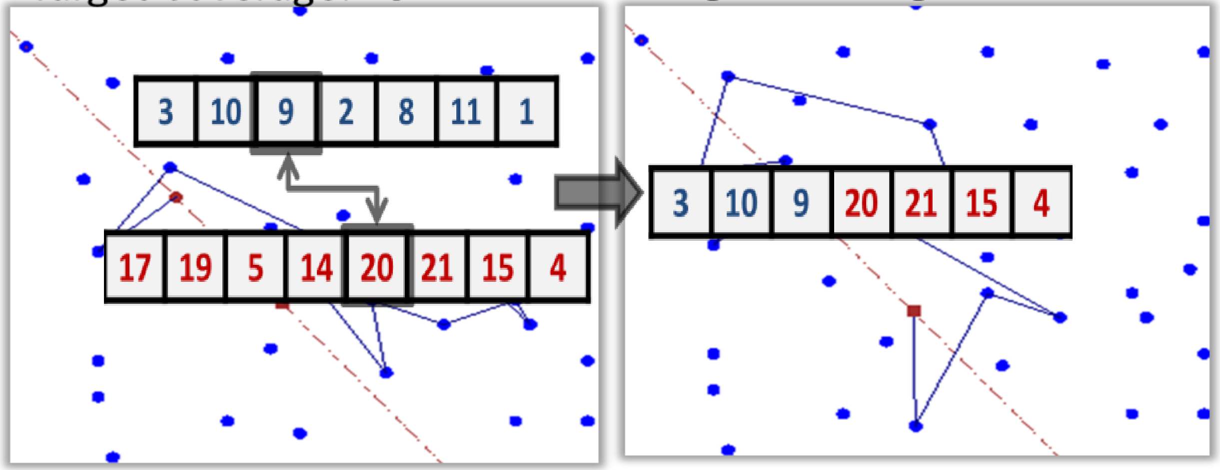
GA-CMoD



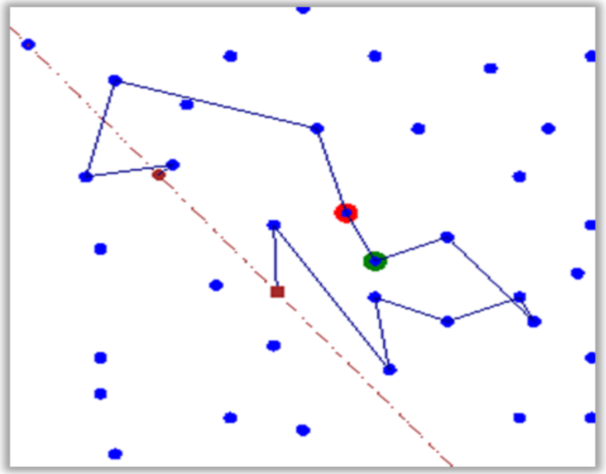


Parent 1: Tour Length: **862**
Target Coverage: **10**

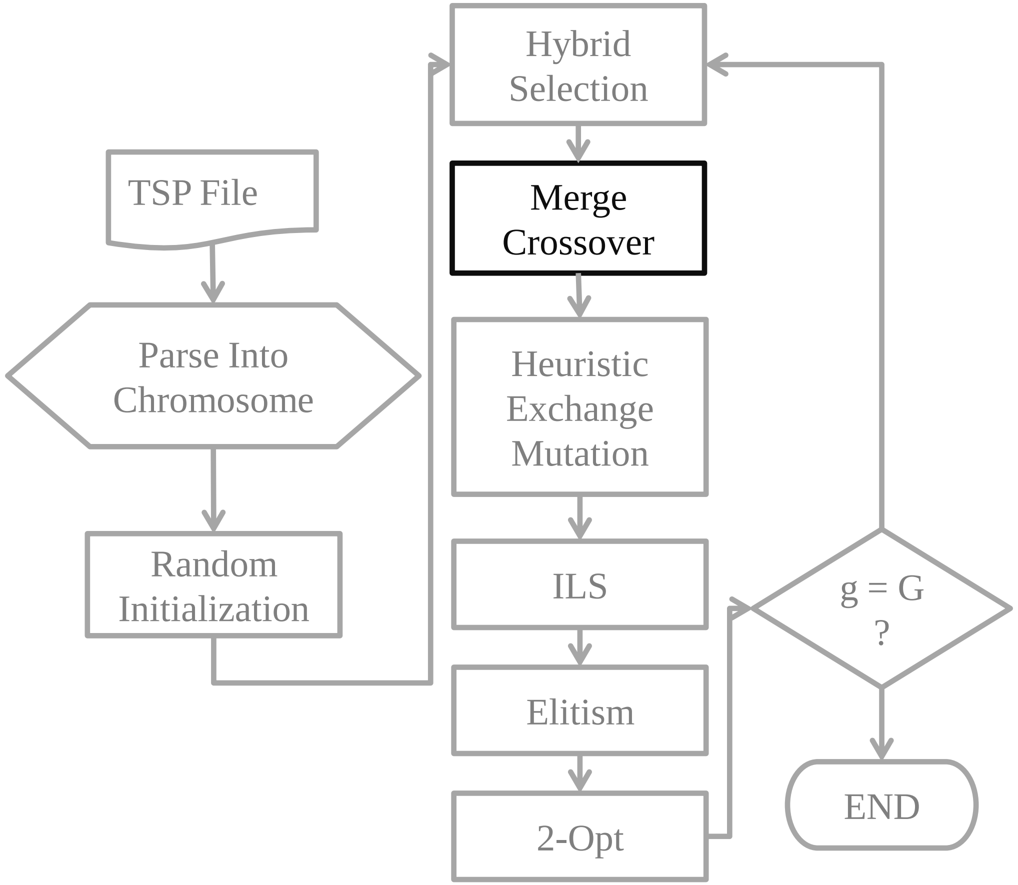
Parent 2: Tour Length: **983**
Target Coverage: **10**

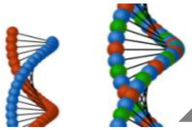


Offspring : Tour Length: **956**
Target Coverage: **13**

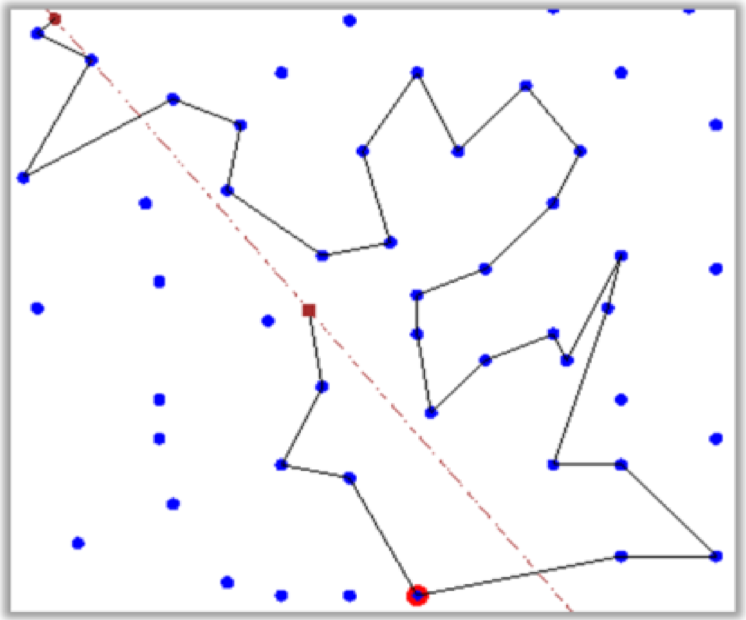


GA-CMoD

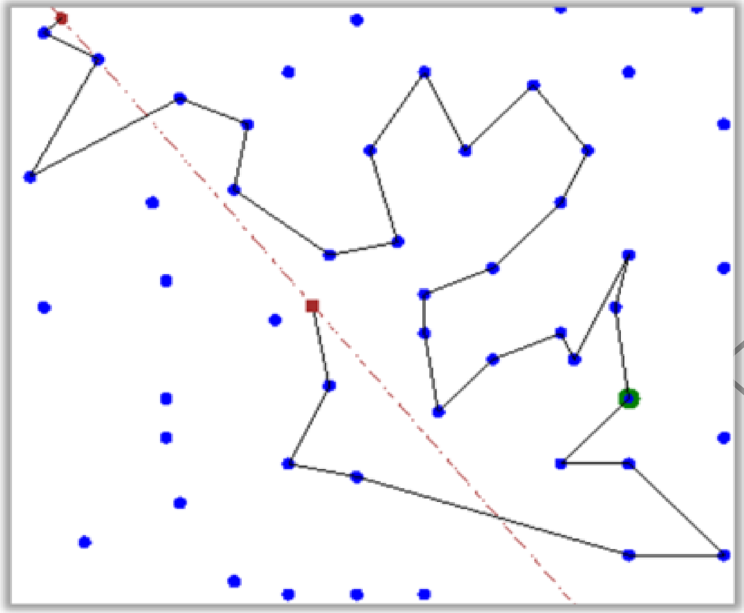




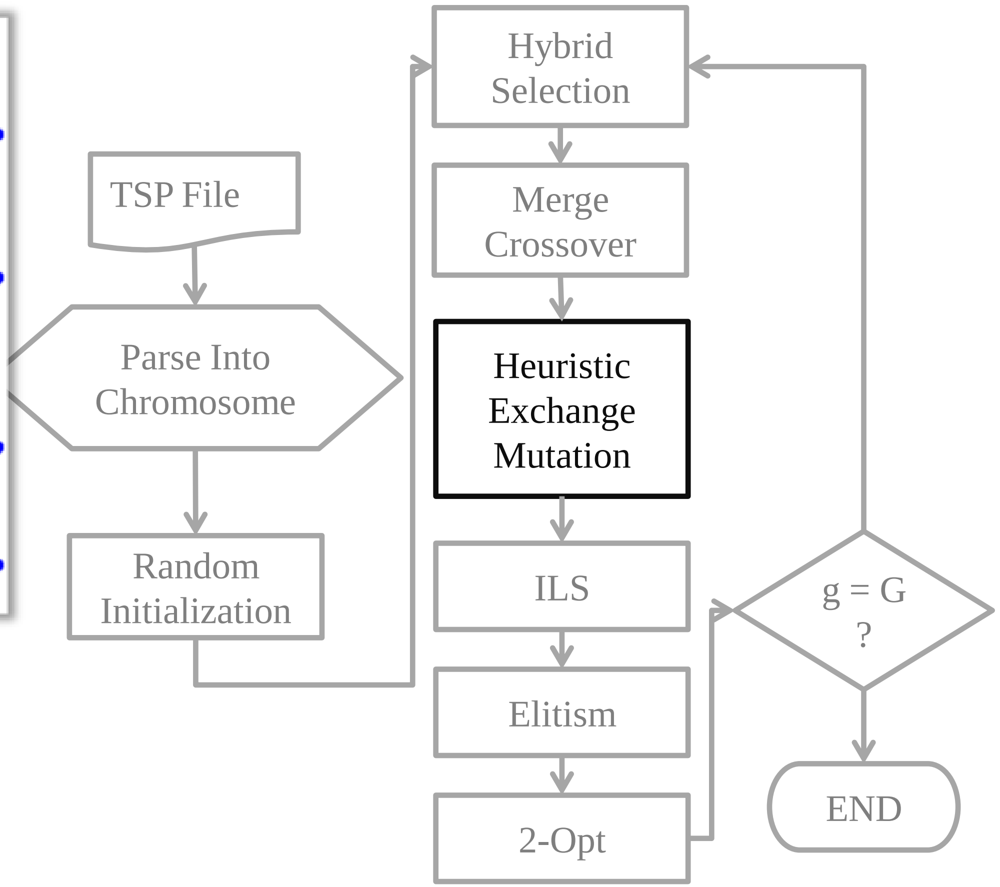
Before Mutation – Tour Length: 2181

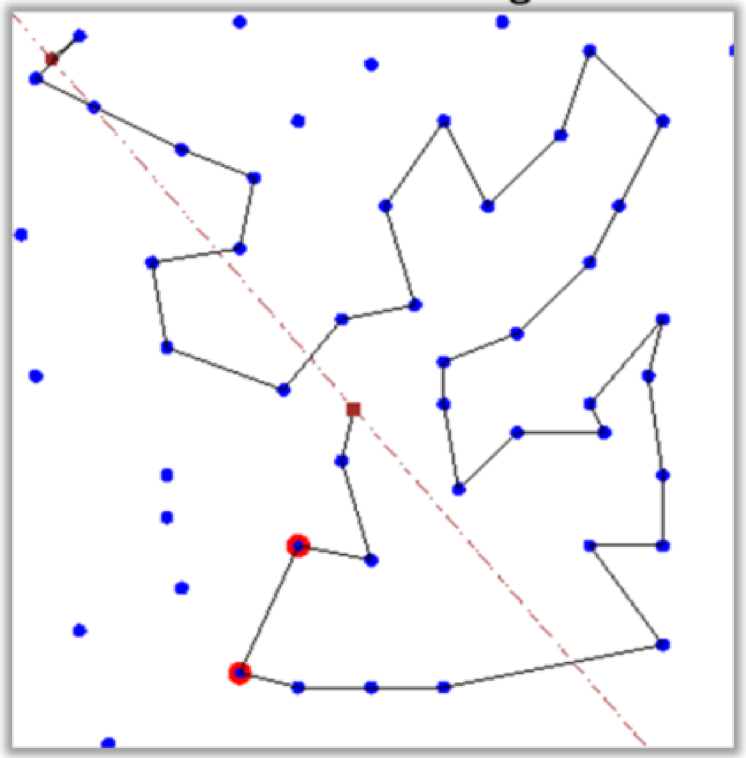


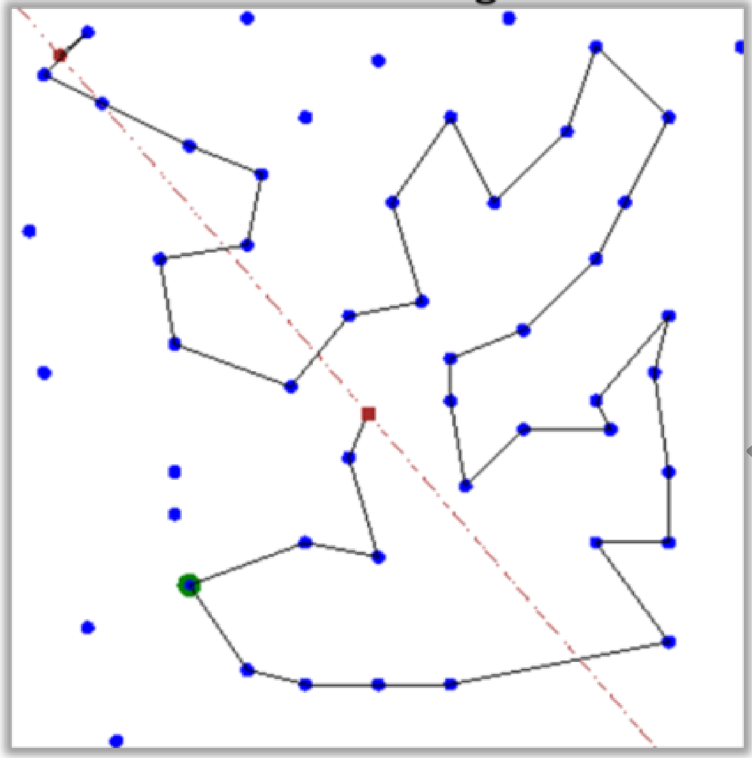
After Mutation – Tour Length: 2152



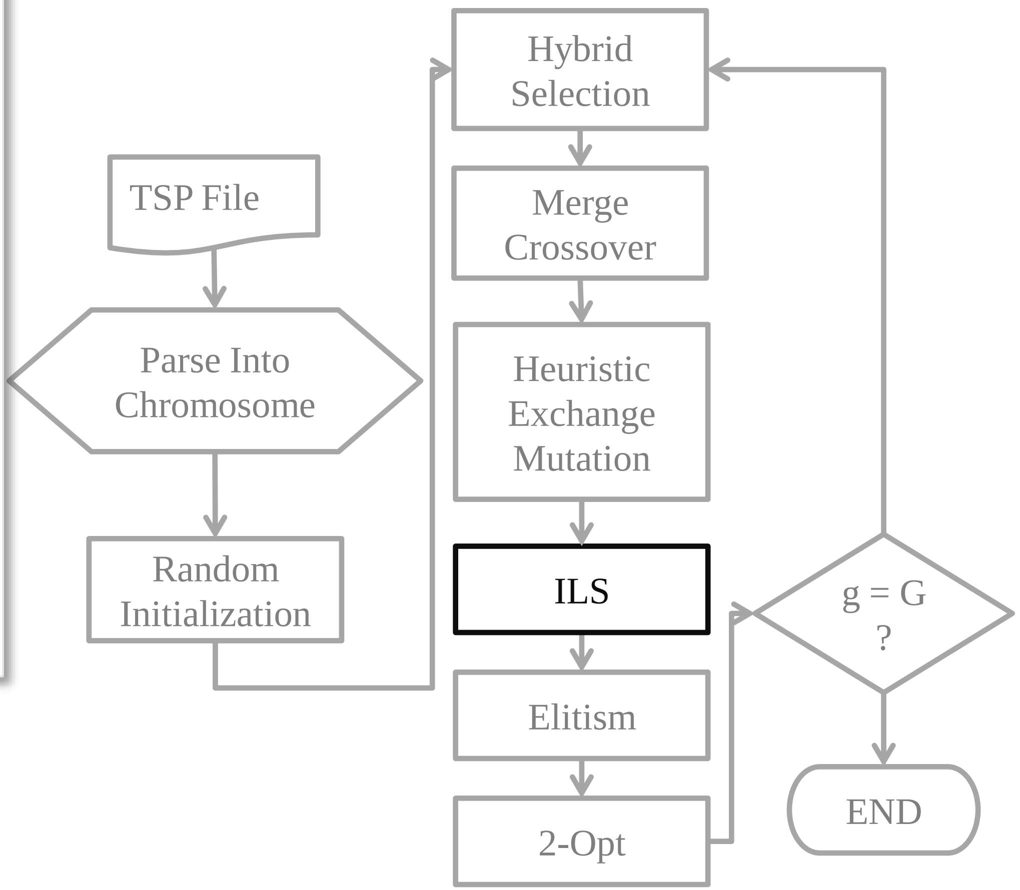
GA-CMoD

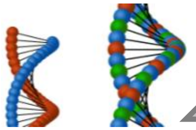



Before ILS Coverage: 39


After ILS Coverage : 40

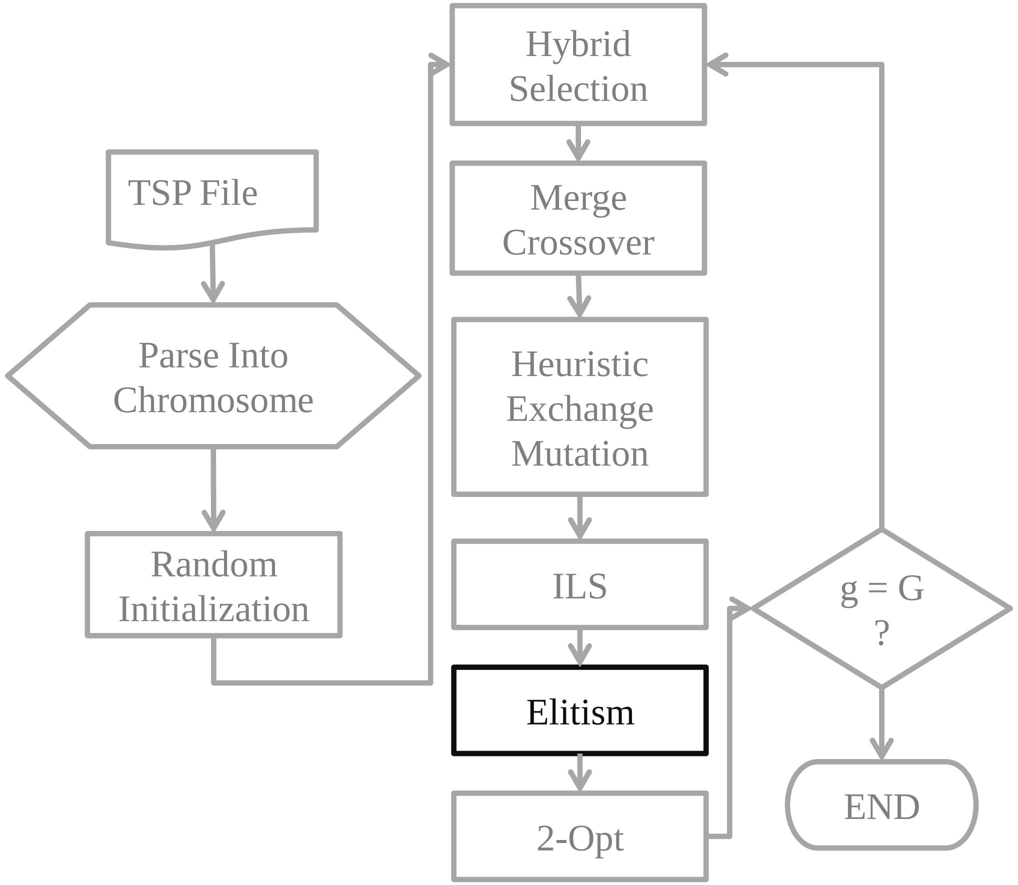
GA-CMoD

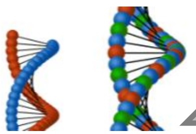

TSP File
Parse Into Chromosome
Random Initialization
Hybrid Selection
Merge Crossover
Heuristic Exchange Mutation
ILS
Elitism
2-Opt
g = G ?
END



GA-CMoD

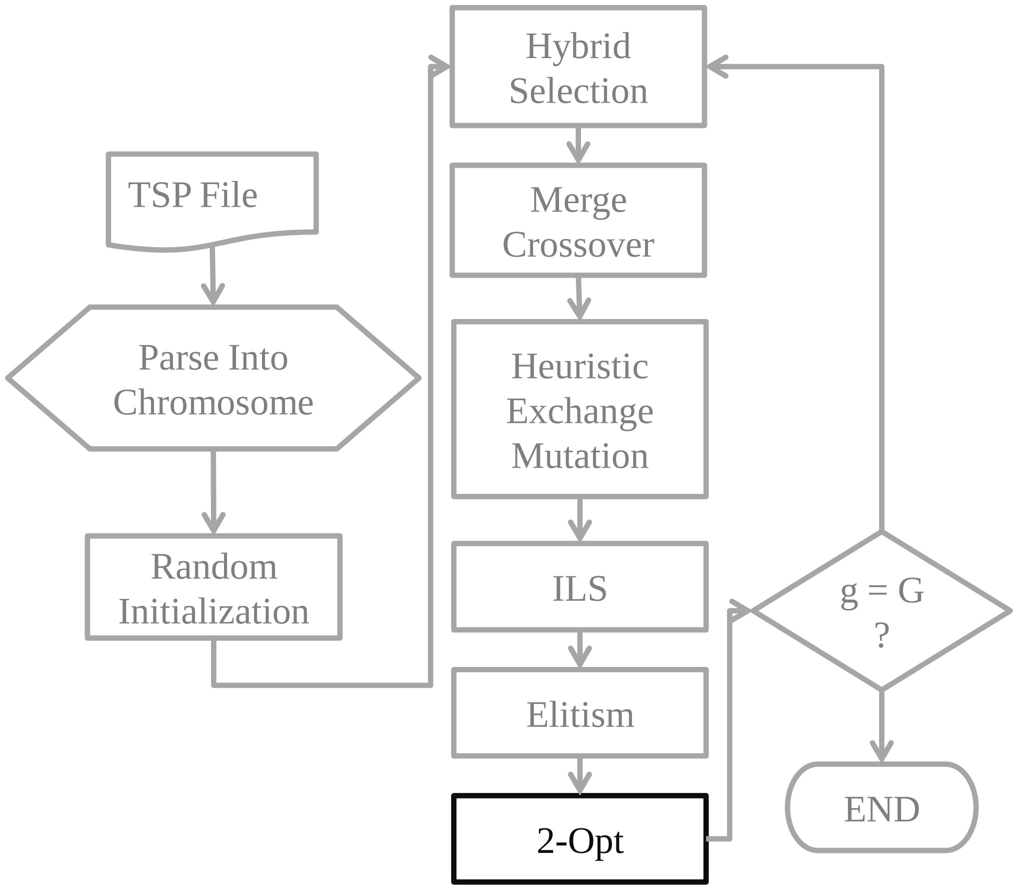
GA-CMoD clones the chromosome that has the greatest target coverage

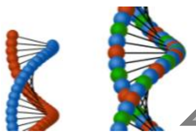




When a tour is rearranged by 2-Opt takeoff and landing locations are recalculated and updated

GA-CMoD



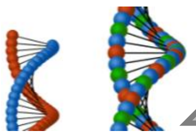


GA-CMoD is compared with :

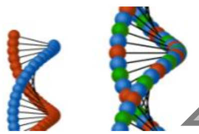
- Other GAs altered on operator basis
- Nearest Neighbor Heuristic
- Hill Climbing Heuristic

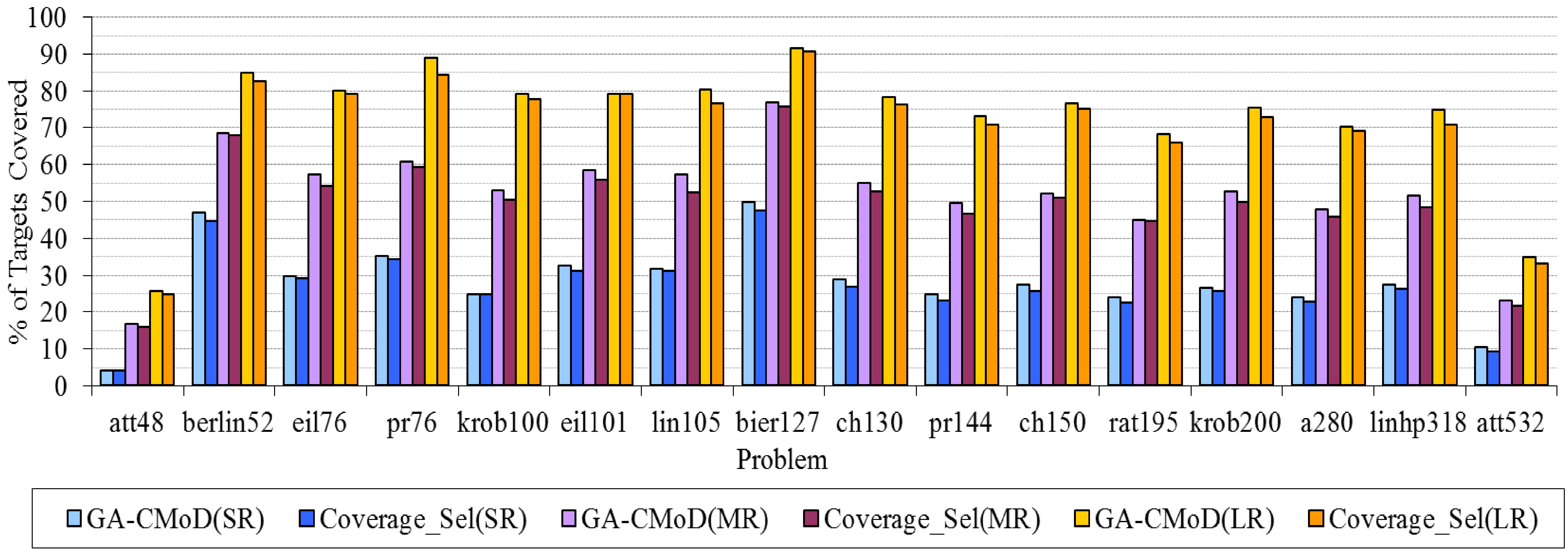
Experiments are conducted:

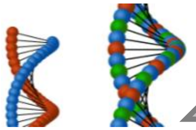
- On **16** benchmark problems, **3** ranges, **48** test cases
- Repeating 10 times, using averages
- Tuning N and G parameters with sensitivity tests

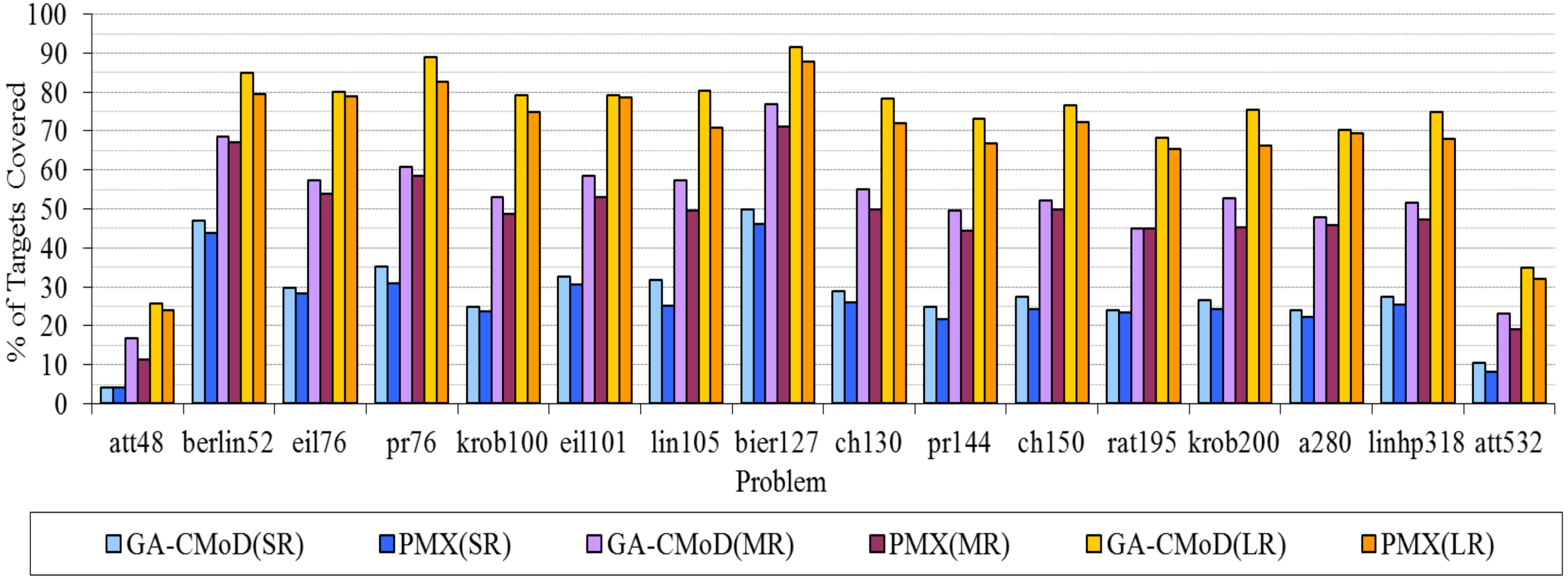


Operator	In GA-CMoD	In a Rival Algorithm
Selection	Hybrid	By-Coverage
Crossover	Merge	PMX, OX1
Mutation	Heuristic Exchange	Displacement, Insertion
Local Search	ILS	-NONE-
Elitism	Elitism	Elitism
Local Search	2-Opt	-NONE-




% of Targets Covered
100
90
80
70
60
50
40
30
20
10
0
att48
berlin52
eil76
pr76
krob100
eil101
lin105
bier127
ch130
pr144
ch150
rat195
krob200
a280
linhp318
att532
Problem
GA-CMoD(SR)
Coverage_Sel(SR)
GA-CMoD(MR)
Coverage_Sel(MR)
GA-CMoD(LR)
Coverage_Sel(LR)




% of Targets Covered
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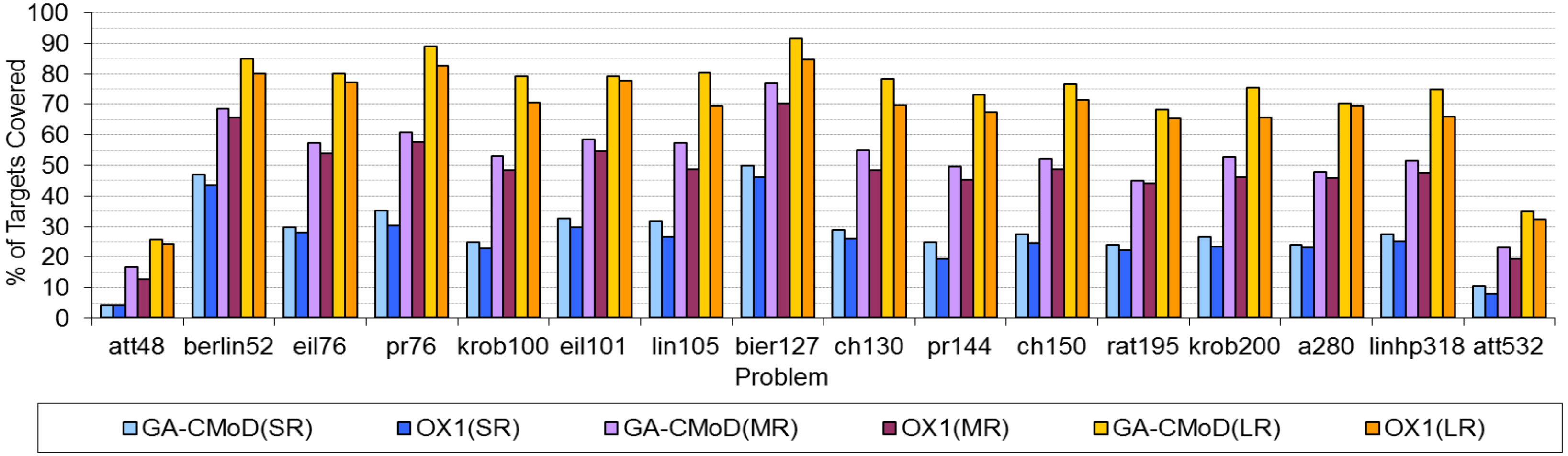
att48 berlin52 eil76 pr76 krob100 eil101 lin105 bier127 ch130 pr144 ch150 rat195 krob200 a280 linhp318 att532
Problem
GA-CMoD(SR)
PMX(SR)
GA-CMoD(MR)
PMX(MR)
GA-CMoD(LR)
PMX(LR)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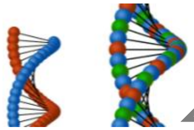
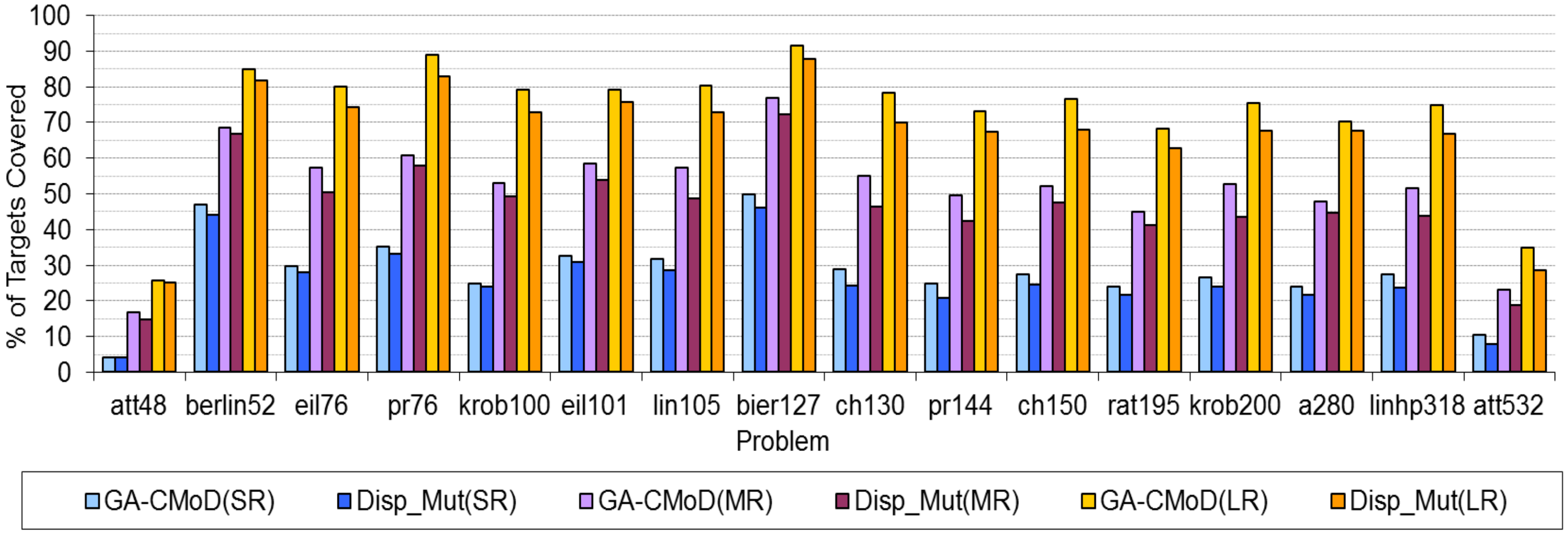
100
att48 berlin52 eil76 pr76 krob100 eil101 lin105 bier127 ch130 pr144 ch150 rat195 krob200 a280 linhp318 att532
Problem
GA-CMoD(SR)
OX1(SR)
GA-CMoD(MR)
OX1(MR)
GA-CMoD(LR)
OX1(LR)

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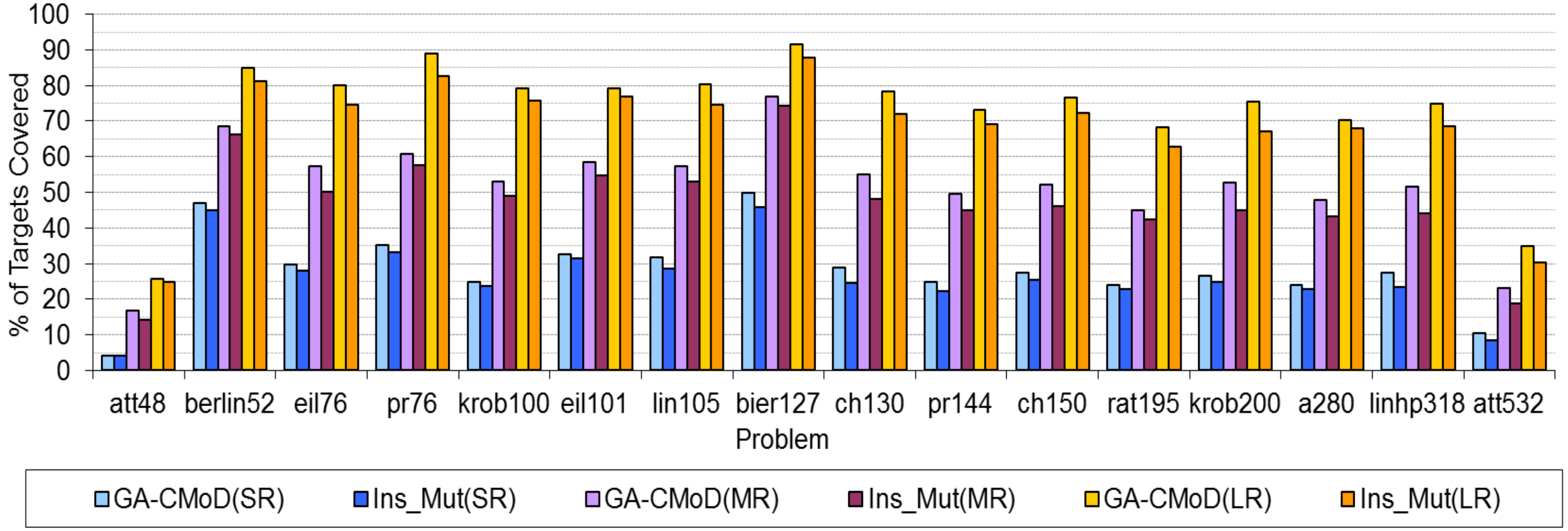
att48 berlin52 eil76 pr76 krob100 eil101 lin105 bier127 ch130 pr144 ch150 rat195 krob200 a280 linhp318 att532
Problem
GA-CMoD(SR)
Disp_Mut(SR)
GA-CMoD(MR)
Disp_Mut(MR)
GA-CMoD(LR)
Disp_Mut(LR)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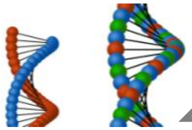
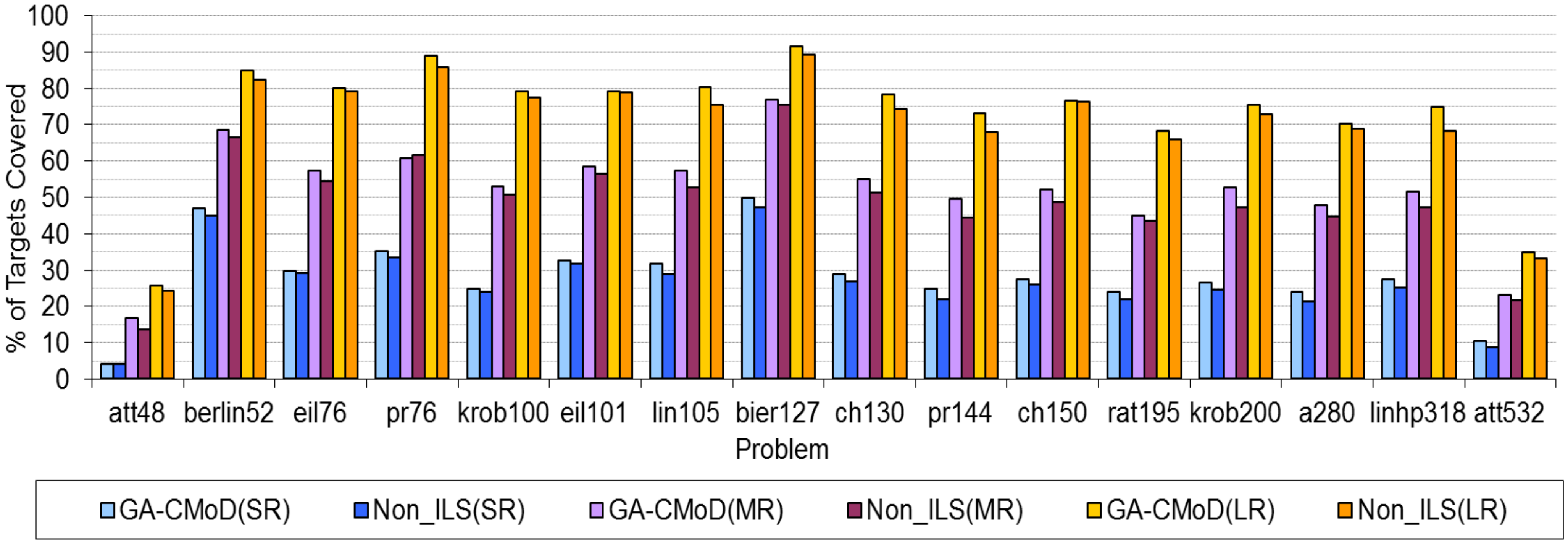
att48 berlin52 eil76 pr76 krob100 eil101 lin105 bier127 ch130 pr144 ch150 rat195 krob200 a280 linhp318 att532
Problem
GA-CMoD(SR)
Ins_Mut(SR)
GA-CMoD(MR)
Ins_Mut(MR)
GA-CMoD(LR)
Ins_Mut(LR)

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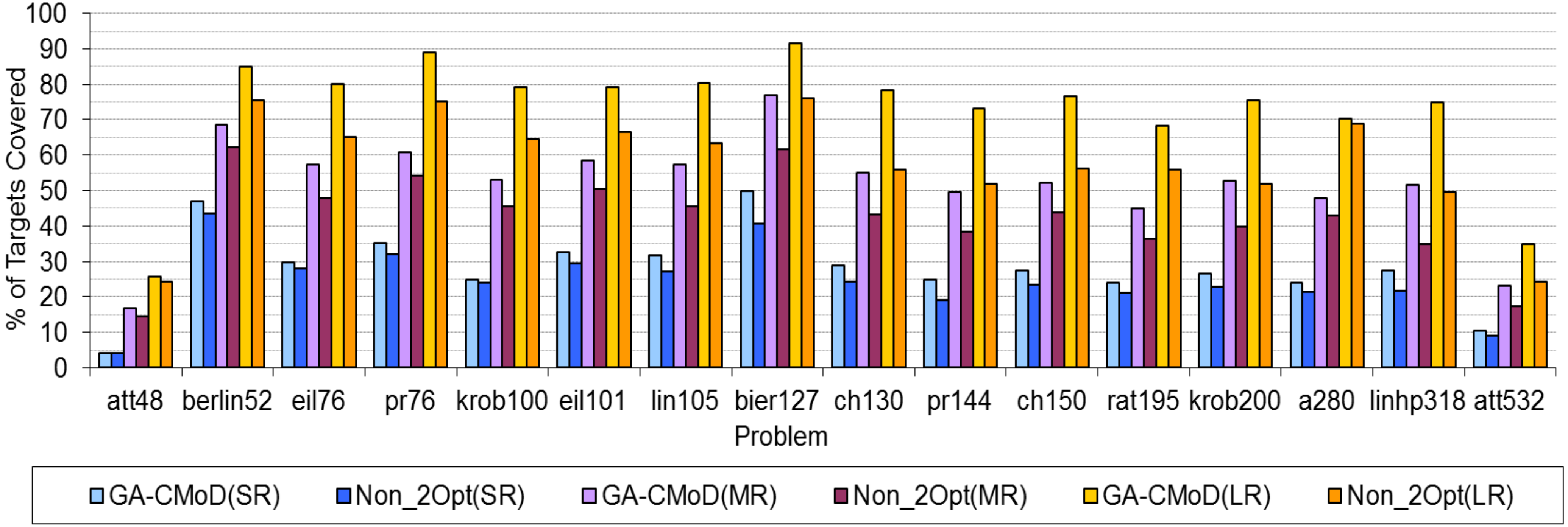
Problem
GA-CMoD(SR)
Non_ILS(SR)
GA-CMoD(MR)
Non_ILS(MR)
GA-CMoD(LR)
Non_ILS(LR)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ch130
pr144
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linhp318
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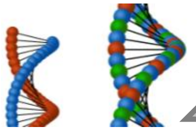
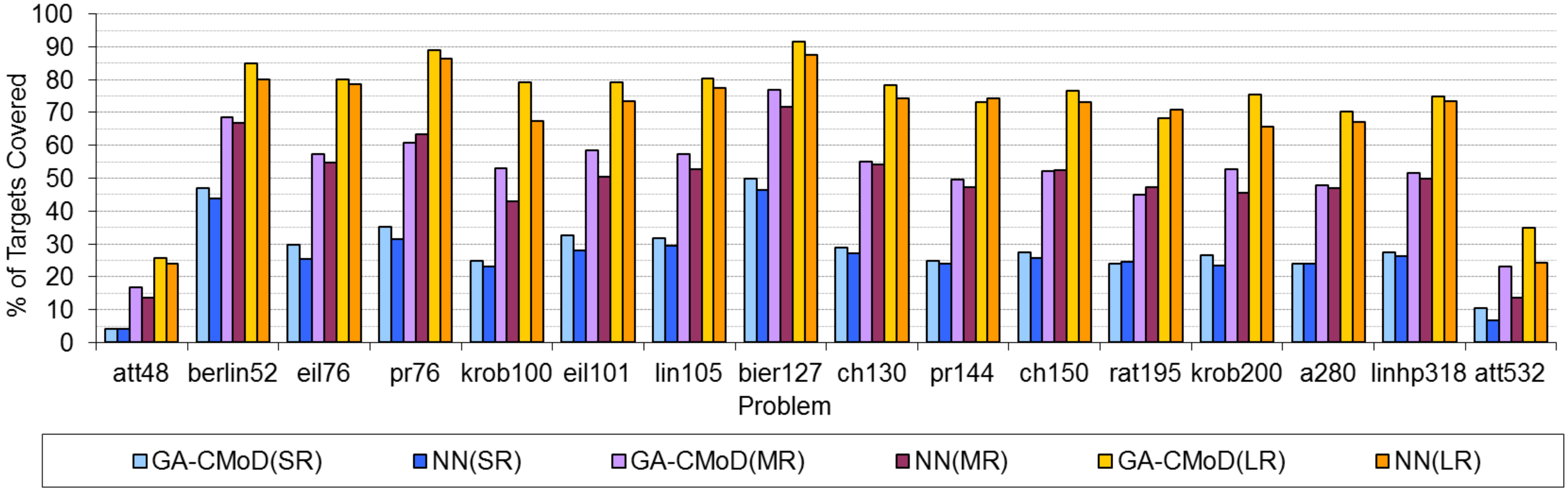
Problem
GA-CMoD(SR)
Non_2Opt(SR)
GA-CMoD(MR)
Non_2Opt(MR)
GA-CMoD(LR)
Non_2Opt(LR)

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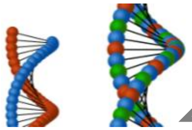
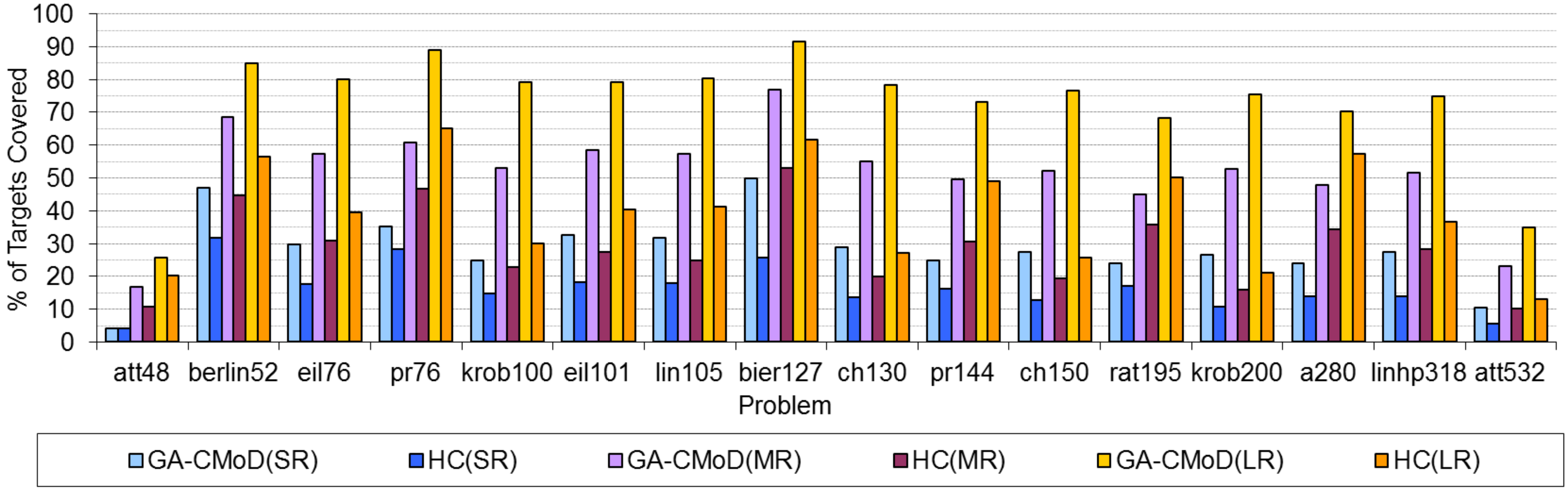
Problem
GA-CMoD(SR)
NN(SR)
GA-CMoD(MR)
NN(MR)
GA-CMoD(LR)
NN(LR)




NY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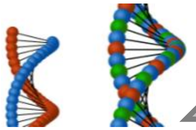
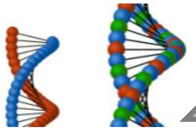
eil76
pr76
krob100
eil101
lin105
bier127
ch130
pr144
ch150
rat195
krob200
a280
linhp318
att532
Problem
GA-CMoD(SR)
HC(SR)
GA-CMoD(MR)
HC(MR)
GA-CMoD(LR)
HC(LR)



Work	Published in	# of Problems	Depot Mobility	Range Capacity	Solution highlights	Methods Employed
[33]	SAVTEK 2014	1	✓	✗	Multiple runs on discrete takeoff locations	GA, 2-Opt
[34]	LNSE 2015	6	✓	✗	Single run on discrete takeoff locations	GA, 2-Opt, NN
[35]	Soft Computing*	16	✓	✓	Dynamic determination of takeoff location	GA, 2-Opt, ILS, NN, HC



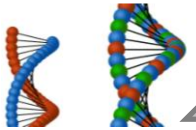
Main achievements of this Thesis :

- A novel VRP variant (**C-MoDVRP**) proposed
- Practical problem of route optimization for a carrier deployed UAV is modeled with C-MoDVRP
- A solution method is proposed (**GA-CMoD**) for C-MoDVRP
- 2 Other solution methods (NN and HC) are adapted for C-MoDVRP

Performance of the proposed GA-CMoD:

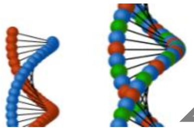
For 48 test cases:

- 11% to 21% superiority over designed GAs
- 75% to 260% superiority over NN and HC heuristics



Future Work:

- Multiple Vehicles – C-MoDmVRP
- Parallel implementation of GA-CMoD for computational time efficiency



Question & Answer