



# Optimizing the Home Care Service

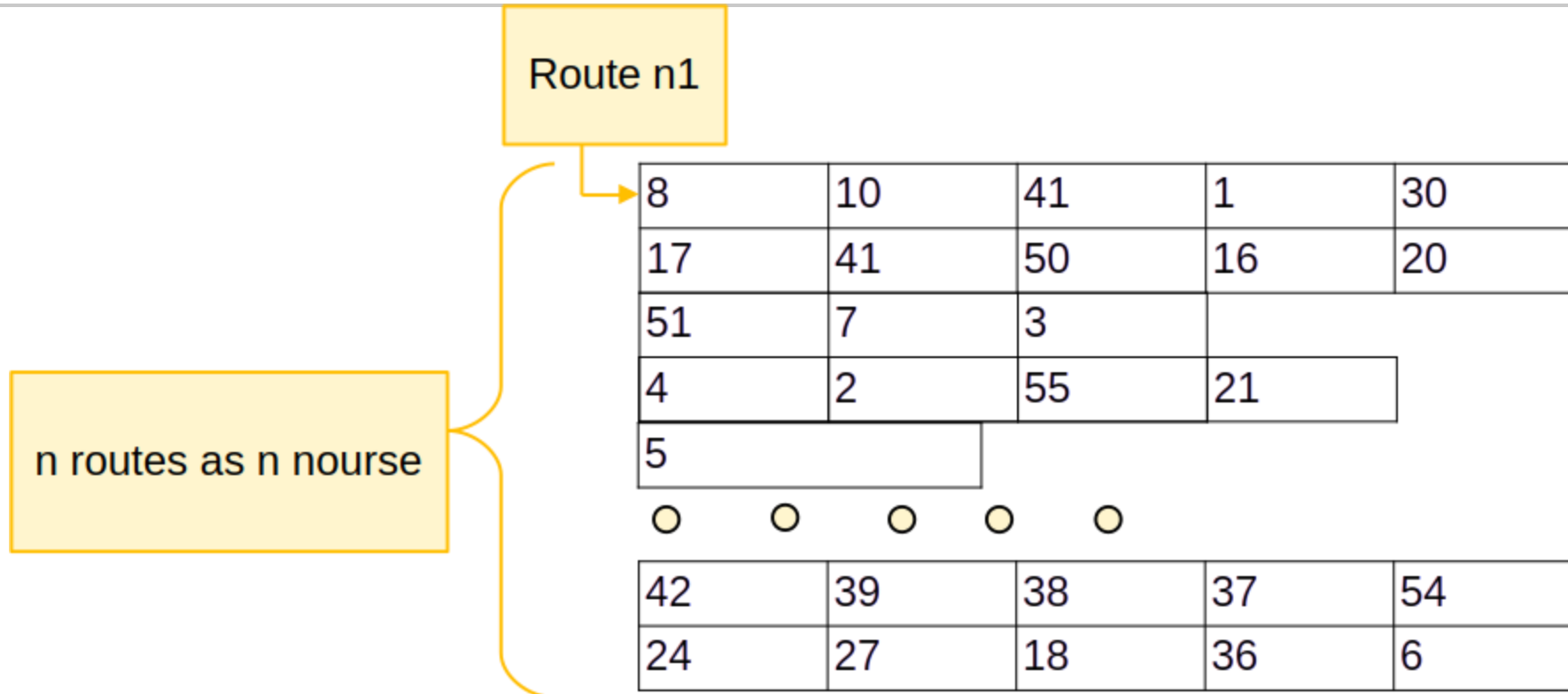
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Giorgio Melchiorri

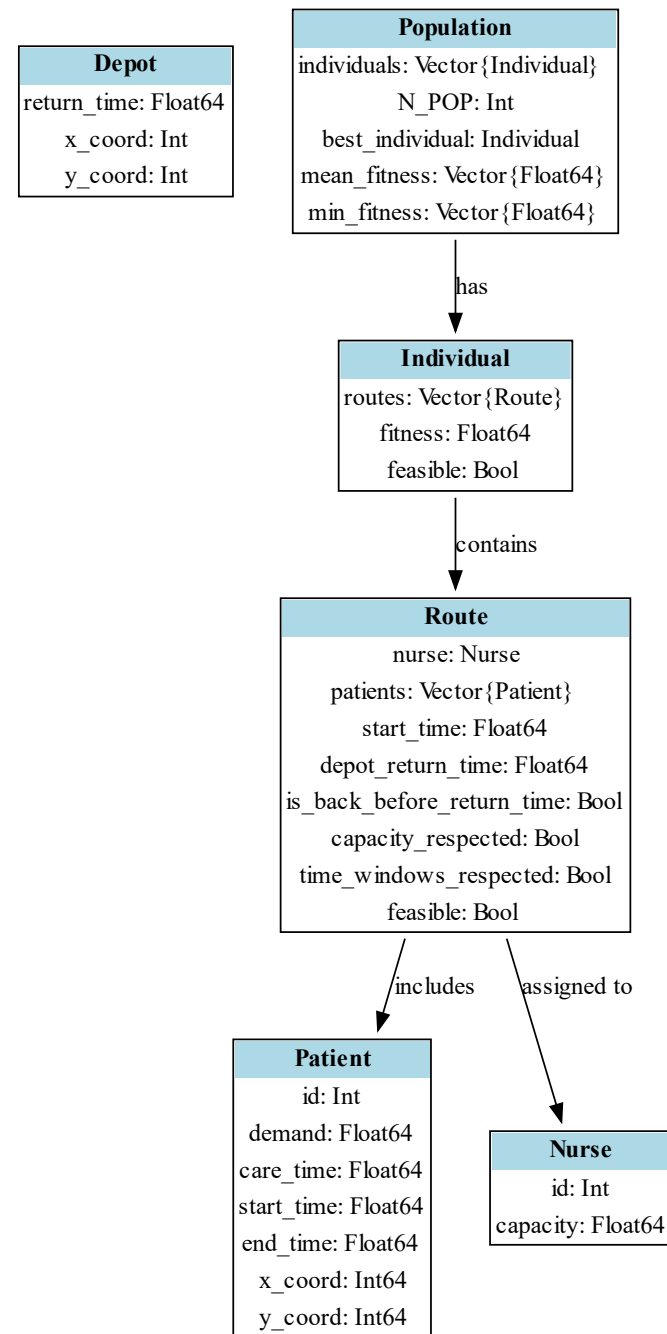
Giovanni Muzio

An abstract, flowing graphic on the right side of the slide, featuring a gradient of colors from light pink to deep blue, with soft, wavy edges that create a sense of movement and depth.

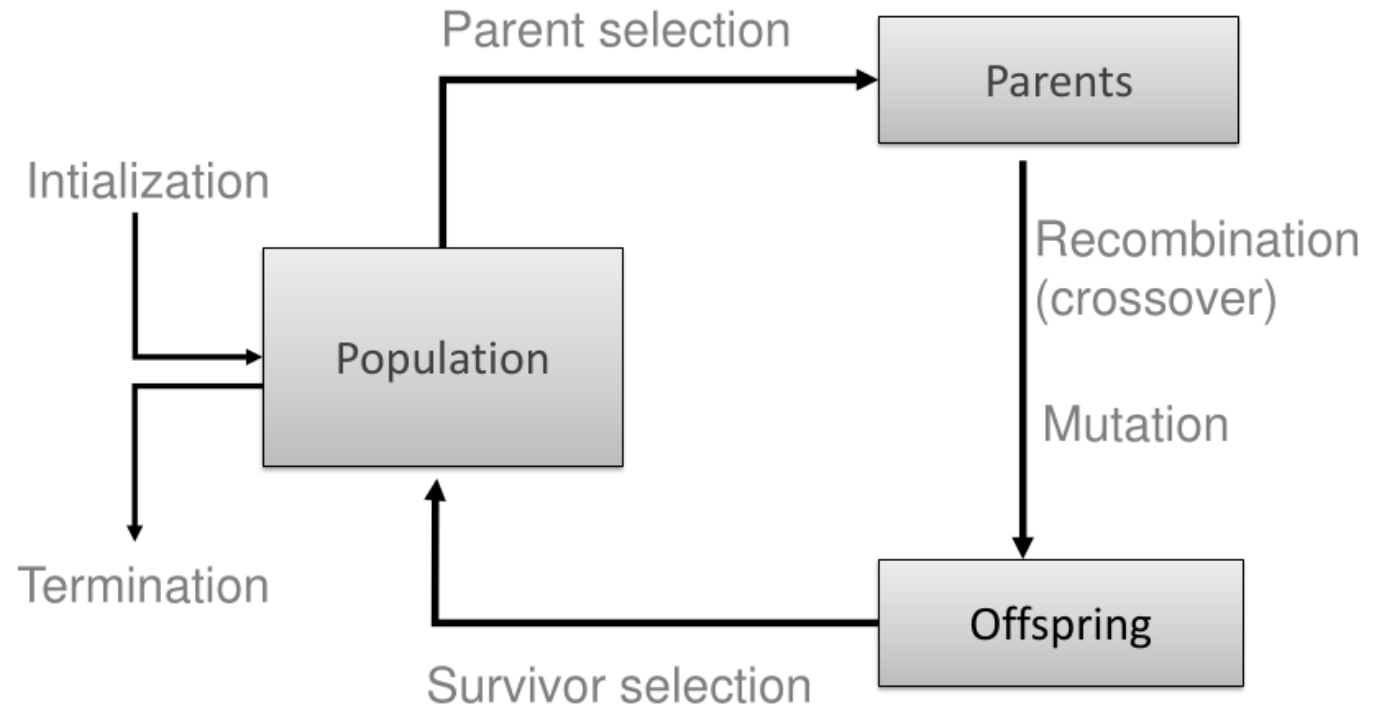
# Representation of the individual



# Structs used



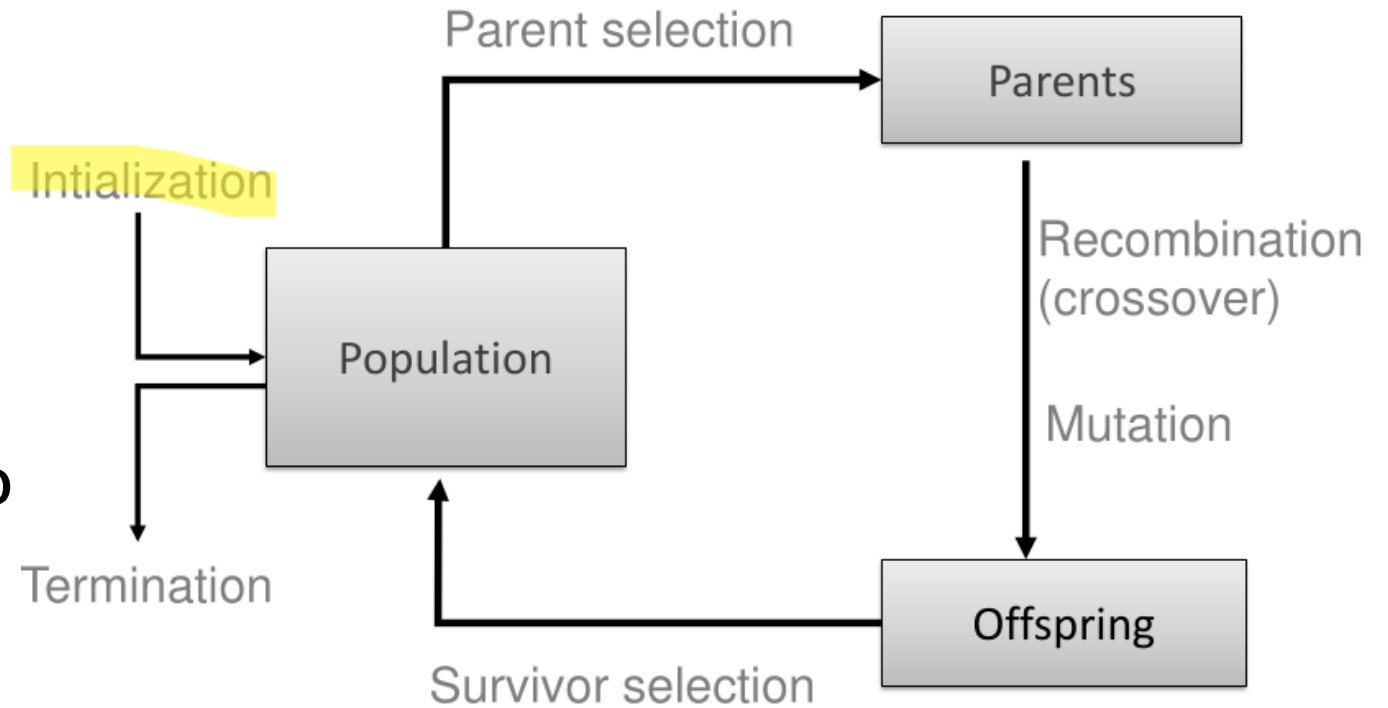
# Genetic Algorithm



**K-NN initialization: 70%**

\*with multiple different number of clusters

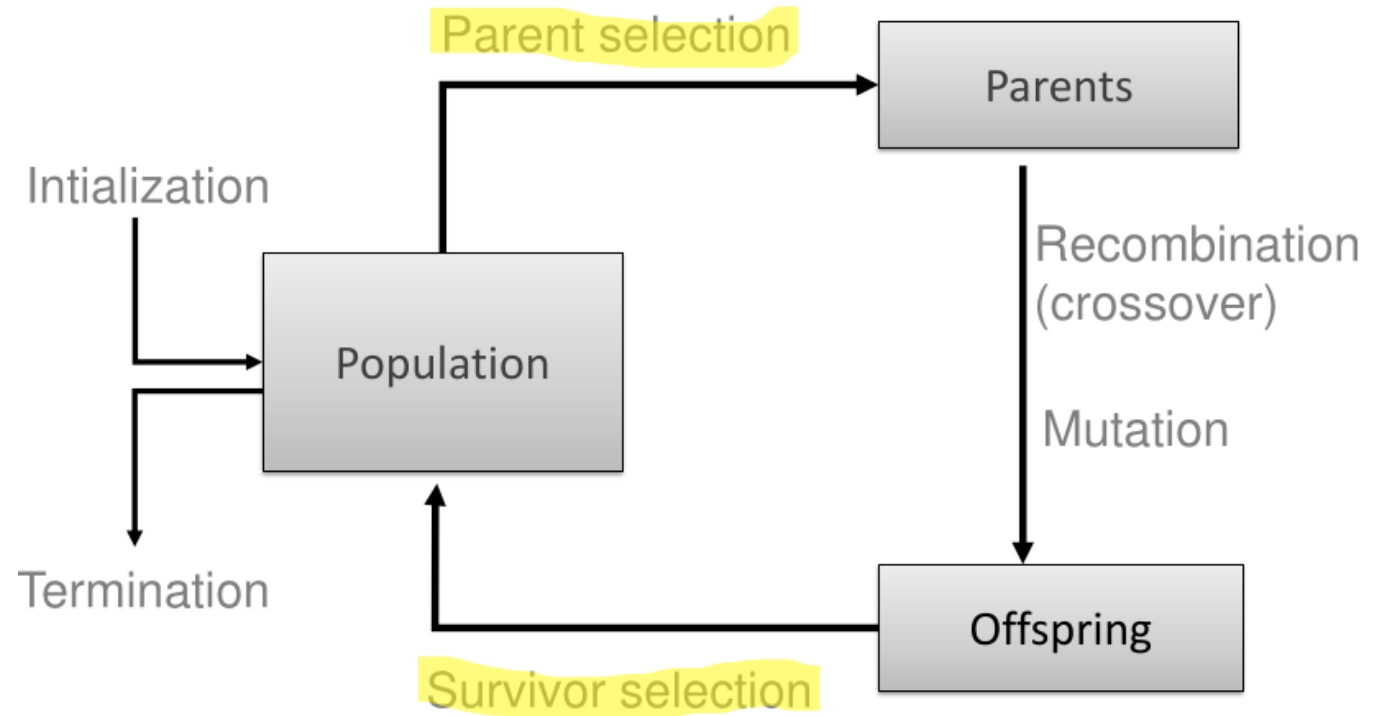
**Random initialization: 30%**



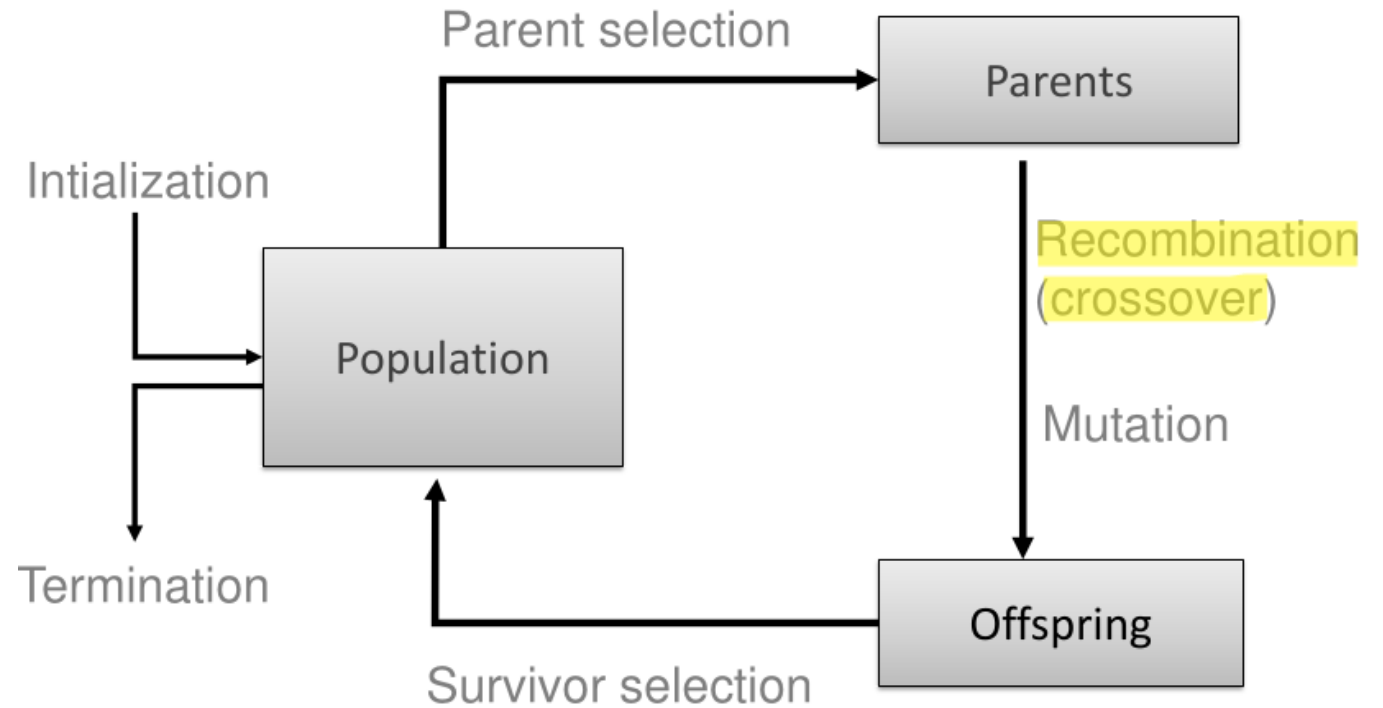
Elitism: 10%

Tournament  
selection: 90%

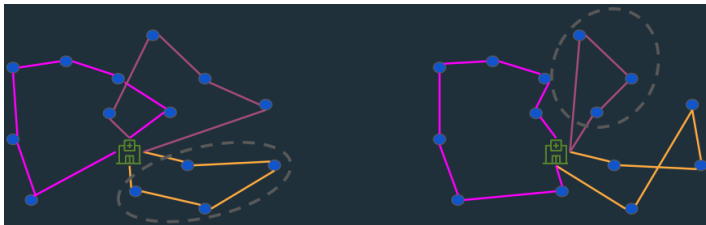
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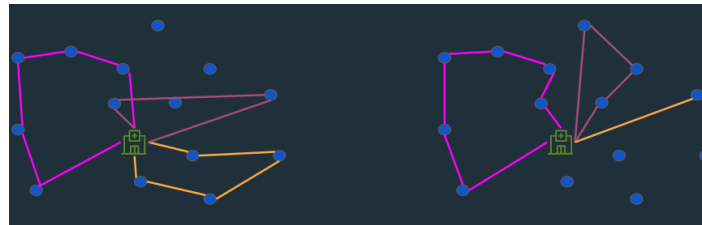
# Crossover



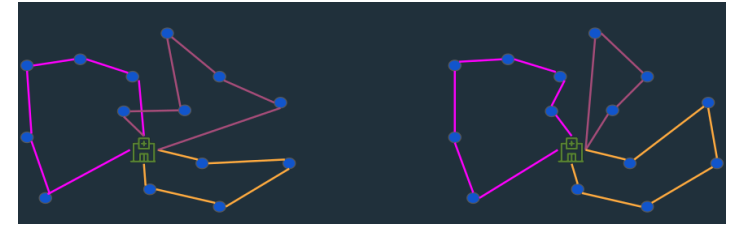
Select two random  
nurses' routes



Remove the  
patients



Find the best  
insertion for each  
patient without a  
visitor







# How to find best insertion?

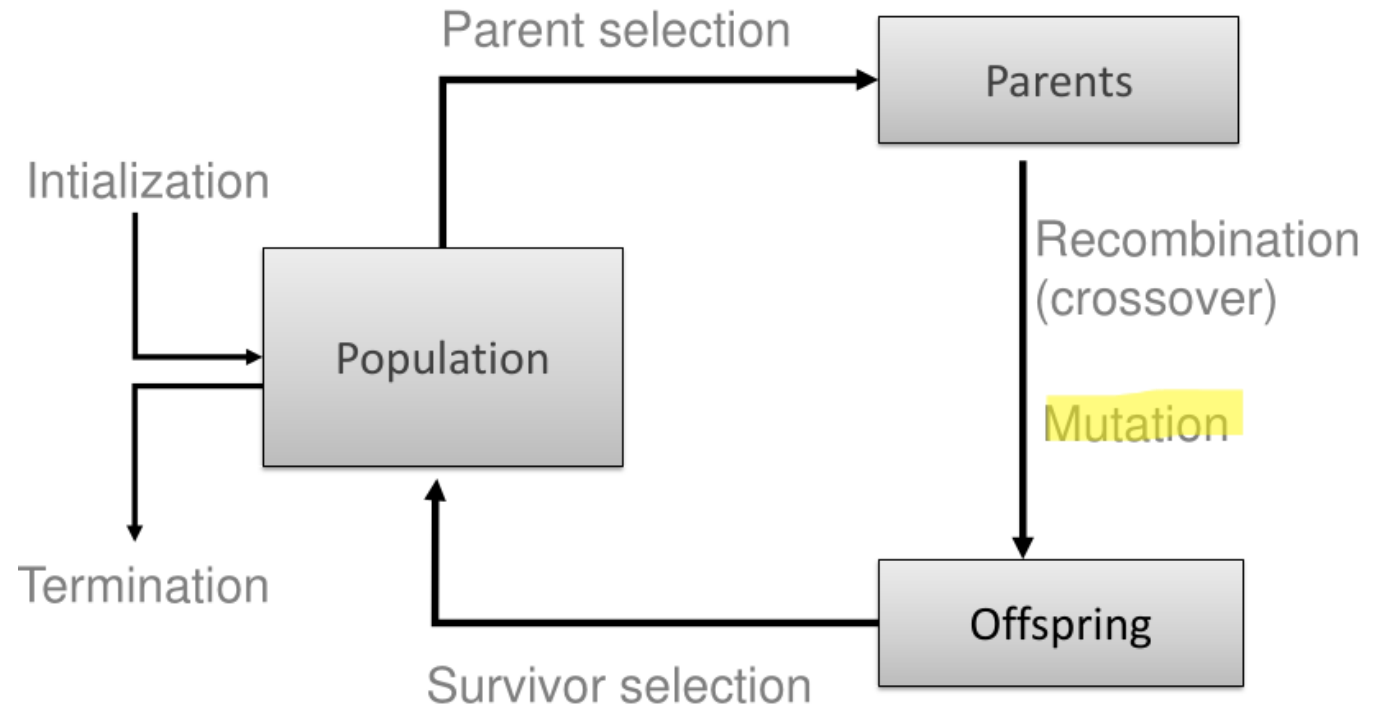
Evaluate all possible positions for a patient in each route selecting the one that minimizes total cost.

Computationally expensive but effective.

# Mutation

Two strategies:

- Intra-route
- Inter-route





# Intra-route

**Move-mutation:** Move a patient to another spot in the route

**Swap-mutation:** Swap two patients within a route

**Shuffle-mutation:** pick a subset from a route and shuffle

# Inter-route

**Shift-mutation:** Swap two patients in different routes

**Split-mutation:** split a route in two routes

# Adaptive mutation

To detect stagnation, we perform a one-sample t-test on the fitness values of the last 12 generations:

- If the p-value  $> 0.05$ , indicating no significant improvement, the mutation parameters are doubled to increase exploration.
- Otherwise, the mutation parameters are reset to their original values.

# Fitness function / constraints

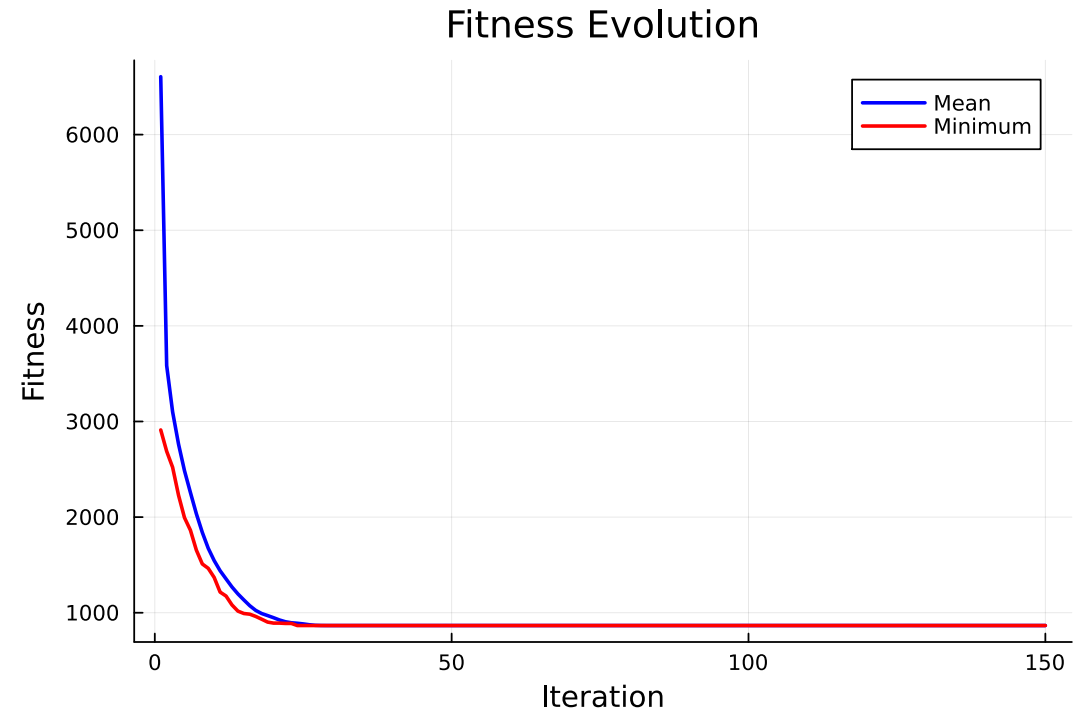
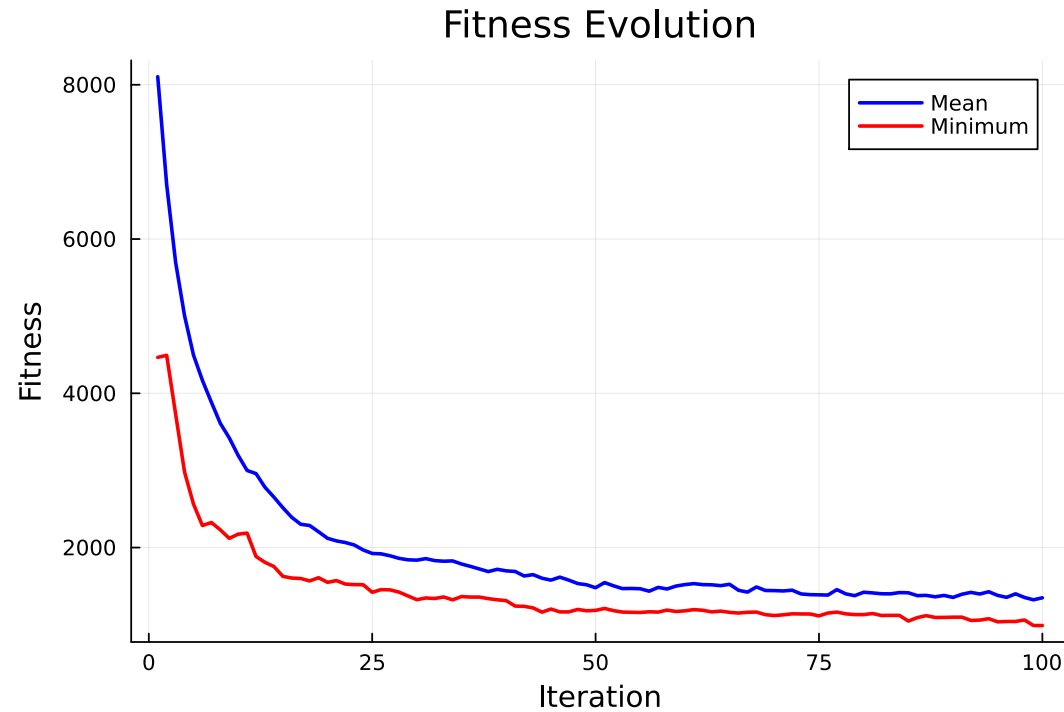
```
if !route.time_windows_respected
  tot_travel_time *= 4
end
if !route.capacity_respected
  tot_travel_time *= 4
end
if !route.is_back_before_return_time
  tot_travel_time *= 4
end
```

The fitness of a solution is calculated as the total sum of the travel times of all routes, with each route's time being multiplied by a penalty factor for every violated constraint.

# GA: Complete vs Crossover only

Complete

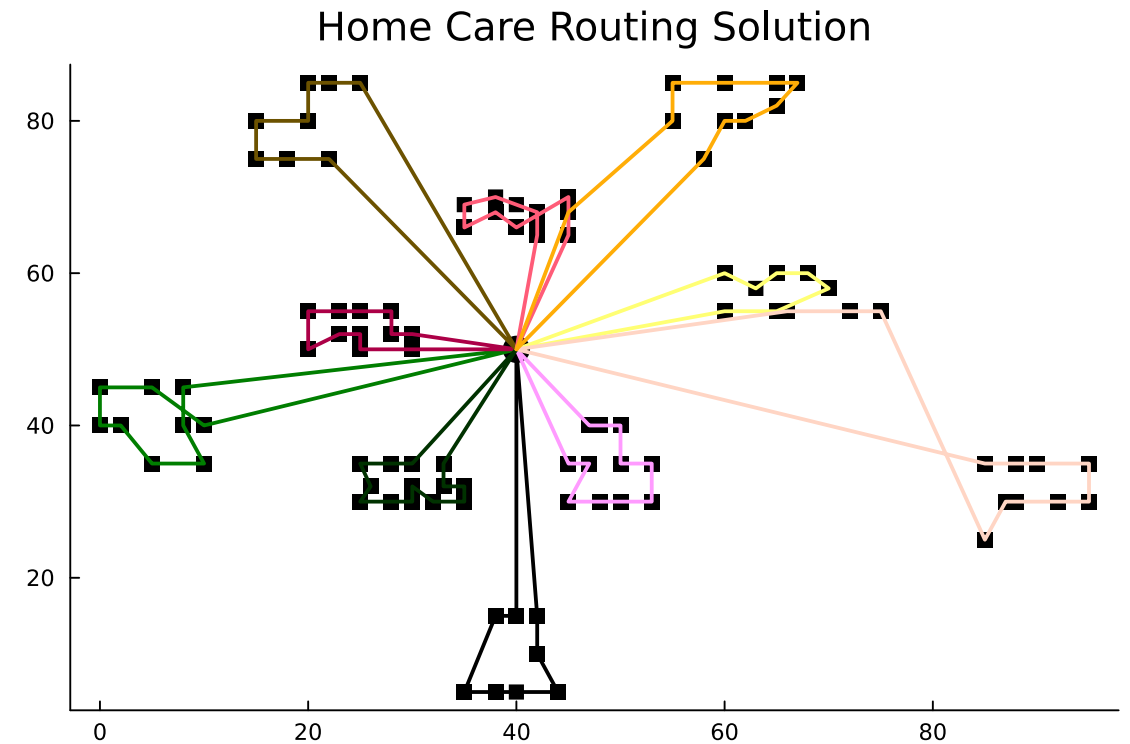
Crossover only



# Result: test\_0

Best time-travel: 845 (<5%)

N nurse	Route duration	Covered demand	Patient sequence
1	101.8	200	[55, 54, 53, 56, 58, 60, 59, 57]
2	66	130	[90, 87, 84, 85, 88, 89, 91]
3	59.4	200	[67, 65, 63, 62, 74, 72, 61, 64, 68, 66, 69]
4	104.2	200	[34, 33, 31, 35, 37, 38, 39, 36, 32]
5	50.8	170	[20, 24, 25, 27, 29, 30, 28, 26, 23, 22, 21]
6	142.9	190	[81, 78, 76, 71, 70, 73, 77, 79, 80, 82, 83, 86]
7	95.8	190	[13, 17, 18, 19, 15, 16, 14, 12]
8	62.4	170	[75, 2, 7, 8, 10, 11, 9, 6, 4, 3, 5]
9	64.8	160	[43, 42, 41, 40, 44, 46, 45, 48, 51, 50, 52, 49, 47]
10	96.7	200	[98, 96, 95, 94, 92, 93, 97, 100, 99, 1]



# Result: test\_0

Best time-travel: 845 (<5%)

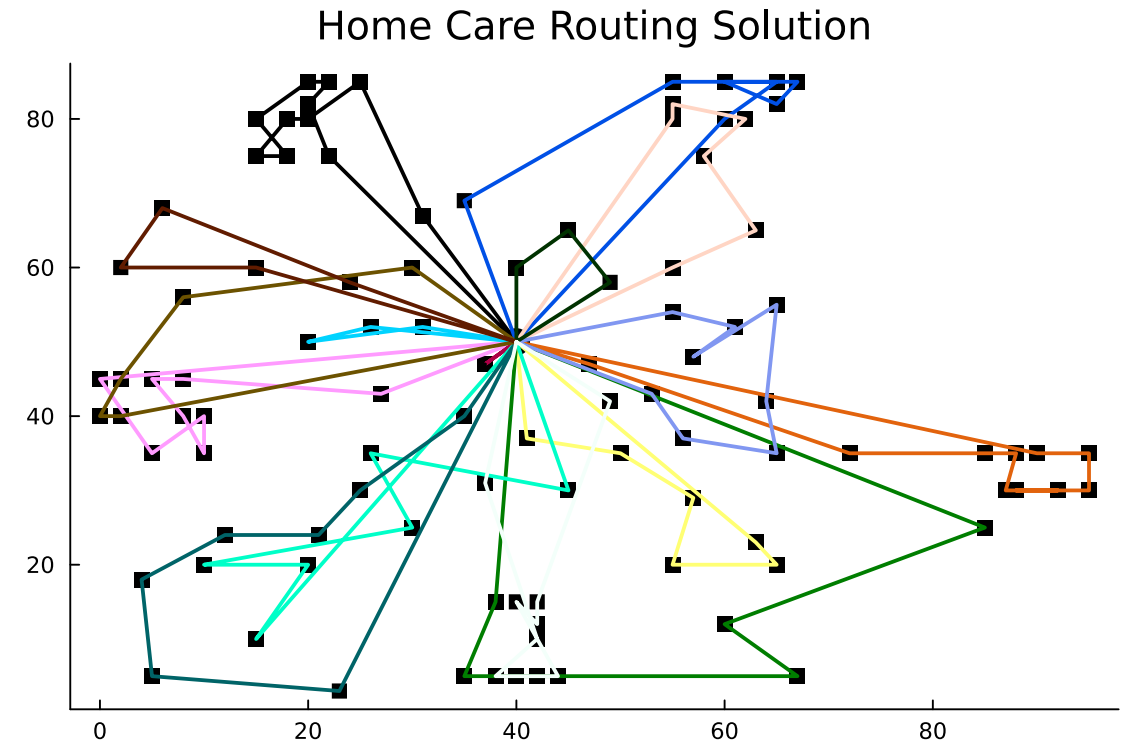
```
D(0) -> P:55 (95.0-185.0) [95-248] P:54 (190.0-280.0) [0-1195] P:53 (286.0-376.0) [286-437] P:56 (385.0-475.0) [385-526] P:58 (477.0-567.0) [471-624] P:60 (570.0-660.0) [0-1190] P:59 (670.0-760.0) [0-1200] P:57 (762.0-852.0) [0-1201] D(101.00)
Route duration: 101.88256760196126
Nurse capacity:200.0
D(0) -> P:90 (20.62-110.62) [0-1215] P:87 (116.0-206.0) [85-234] P:84 (450.0-540.0) [450-613] P:85 (551.0-641.0) [0-1206] P:88 (645.0-735.0) [645-798] P:89 (730.0-820.0) [0-1211] P:91 (831.0-921.0) [0-1213]
D(66.07)
Route duration: 66.06956532288788
Nurse capacity:130.0
D(0) -> P:67 (12.21-102.21) [12-167] P:65 (103.0-193.0) [76-219] P:63 (195.0-285.0) [0-1221] P:62 (290.0-380.0) [262-407] P:74 (383.0-473.0) [353-502] P:72 (478.0-568.0) [0-1212] P:61 (571.0-661.0) [0-1213] P:64 (663.0-753.0) [632-783] P:68 (756.0-846.0) [734-867] P:66 (852.0-942.0) [826-965] P:69 (944.0-1034.0) [916-1059] D(59.4)
Route duration: 59.403108723710105
Nurse capacity:200.0
D(0) -> P:34 (32.39-122.39) [0-1203] P:33 (127.0-217.0) [87-248] P:31 (223.0-313.0) [0-1202] P:35 (318.0-408.0) [283-434] P:37 (414.0-504.0) [0-1196] P:38 (506.0-596.0) [479-612] P:39 (601.0-691.0) [567-714] P:36 (696.0-786.0) [665-806] P:32 (793.0-883.0) [0-1204] D(104.3)
Route duration: 104.29823059693237
Nurse capacity:200.0
D(0) -> P:20 (10.0-100.0) [0-1226] P:24 (105.0-195.0) [0-1221] P:25 (197.0-287.0) [169-314] P:27 (289.0-379.0) [261-406] P:29 (383.0-473.0) [0-1216] P:30 (478.0-568.0) [449-594] P:28 (571.0-661.0) [0-1210] P:26 (663.0-753.0) [0-1220] P:23 (756.0-846.0) [732-867] P:22 (849.0-939.0) [812-973] P:21 (941.0-1031.0) [0-1225] D(50.0)
Route duration: 50.80359030264955
Nurse capacity:170.0
D(0) -> P:81 (47.43-137.43) [0-1180] P:78 (140.0-230.0) [109-260] P:76 (232.0-322.0) [203-350] P:71 (327.0-417.0) [0-1178] P:70 (421.0-512.0) [387-546] P:73 (515.0-605.0) [0-1180] P:77 (609.0-699.0) [574-733] P:79 (700.0-790.0) [669-821] P:80 (796.0-886.0) [769-910] P:82 (917.0-1007.0) [0-1200] P:83 (1010.0-1100.0) [0-1203] P:86 (1106.0-1196.0) [0-1209] D(142.92)
Route duration: 142.91851090109142
Nurse capacity:190.0
D(0) -> P:13 (30.81-120.81) [30-102] P:17 (125.0-215.0) [99-238] P:18 (218.0-308.0) [0-1200] P:19 (313.0-403.0) [0-1196] P:15 (406.0-496.0) [384-519] P:16 (503.0-593.0) [0-1195] P:14 (595.0-685.0) [0-1196] P:12 (688.0-778.0) [0-1197] D(95.00)
Route duration: 95.88470913001027
Nurse capacity:190.0
D(0) -> P:75 (15.81-105.81) [0-1220] P:2 (111.0-201.0) [0-1215] P:7 (207.0-297.0) [0-1220] P:8 (300.0-390.0) [255-414] P:10 (394.0-484.0) [357-500] P:11 (487.0-577.0) [448-595] P:9 (580.0-670.0) [534-695] P:6 (672.0-762.0) [621-792] P:4 (764.0-854.0) [727-872] P:3 (856.0-946.0) [0-1219] P:5 (947.0-1037.0) [0-1220] D(62.42)
Route duration: 62.41565050407444
Nurse capacity:170.0
D(0) -> P:43 (16.55-106.55) [0-1219] P:42 (110.0-200.0) [68-239] P:41 (202.0-292.0) [166-325] P:40 (294.0-384.0) [264-411] P:44 (387.0-477.0) [359-502] P:46 (479.0-569.0) [0-1215] P:45 (571.0-661.0) [541-690] P:48 (663.0-753.0) [0-1212] P:51 (756.0-846.0) [0-1211] P:50 (849.0-939.0) [0-1213] P:52 (942.0-1032.0) [0-1214] P:49 (1035.0-1125.0) [1001-1156] P:47 (1127.0-1217.0) [0-1217] D(64.81)Route duration: 64.80747440690114
Nurse capacity:160.0
D(0) -> P:90 (30.81-120.81) [0-1205] P:96 (126.0-216.0) [0-1199] P:95 (210.0-300.0) [0-1198] P:94 (312.0-402.0) [0-1195] P:92 (405.0-495.0) [360-531] P:93 (497.0-587.0) [475-600] P:97 (592.0-682.0) [0-1195] P:100 (687.0-777.0) [647-816] P:99 (782.0-872.0) [743-910] P:1 (888.0-978.0) [0-1217] D(96.7)
Route duration: 96.70415280364391
Nurse capacity:200.0
845.1075595847503
```



# Result: test\_1

Best time-travel: 1560(<5%)

N nurse	Route duration	Covered demand	Patient sequence
1	112.7	193	[2, 45, 3, 5, 8, 6, 7, 46, 4, 1, 100]
2	89.7	80	[85, 63, 51, 84, 56, 66]
3	111.6	159	[82, 12, 14, 11, 9, 10, 13, 17]
4	40.8	41	[69, 53, 98]
5	134.6	183	[29, 27, 26, 30, 28, 32, 31, 34, 50, 80]
6	167.0	116	[33, 76, 89, 48, 21, 25, 24]
7	114.8	153	[39, 36, 40, 37, 35, 43, 70]
8	8.4	6	[90]
9	139.9	102	[64, 99, 57, 59, 74, 58],
10	132.6	118	[65, 52, 86, 87, 97, 75, 77],
11	87.8	94	[42, 44, 38, 41, 72, 54],
12	95.7	93	[15, 16, 47, 78, 55],
13	88.9	98	[92, 95, 62, 67, 71, 94, 93, 96],
14	37.1	40	[81, 61, 68],
15	87.3	71	[88, 79, 73, 60],
16	110.5	177	[83, 19, 23, 18, 22, 49, 20, 91],



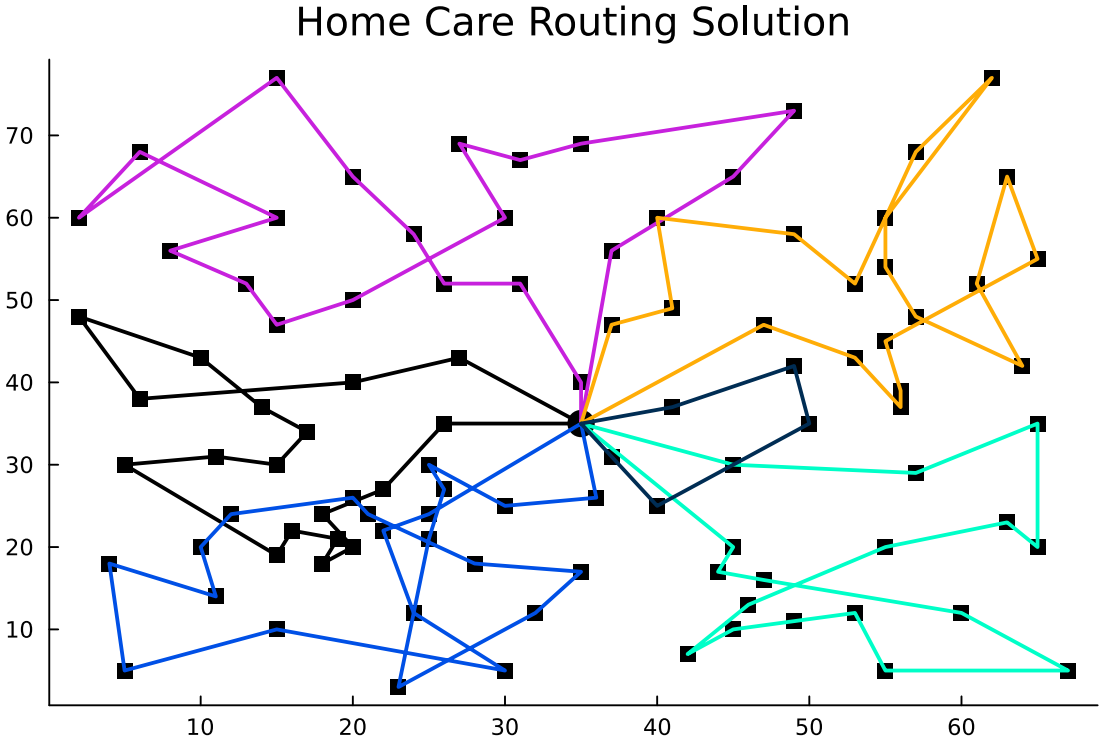
# Result: test\_1

Best time-travel: 1560(<5%)

```
D(0) -> P:2 (30.01-40.01) [30-100] P:45 (48.0-50.0) [37-80] P:3 (64.0-74.0) [64-104] P:5 (76.0-86.0) [40-170] P:8 (101.0-111.0) [101-121] P:6 (117.0-127.0) [96-133] P:7 (130.0-140.0) [35-105] P:46 (146.0-156.0) [96-167] P:4 (150.0-160.0) [151-171] P:1 (175.0-185.0) [71-201] P:100 (204.0-214.0) [200-220] D(112.7)
Route duration: 112.70450420230641
Nurse capacity:193.0
D(0) -> P:85 (42.0-52.0) [42-172] P:63 (56.0-66.0) [39-118] P:51 (76.0-86.0) [69-136] P:84 (106.0-116.0) [106-126] P:56 (130.0-140.0) [130-160] P:66 (140.0-150.0) [134-171] D(80.77)
Route duration: 89.77088515068434
Nurse capacity:80.0
D(0) -> P:82 (14.76-24.76) [14-144] P:12 (44.0-54.0) [32-162] P:14 (57.0-67.0) [35-127] P:11 (73.0-83.0) [49-89] P:9 (101.0-111.0) [101-121] P:10 (123.0-133.0) [123-154] P:13 (152.0-162.0) [152-172] P:17 (173.0-183.0) [147-190] D(111.65)
Route duration: 111.64868937761317
Nurse capacity:150.0
D(0) -> P:69 (51.0-61.0) [51-71] P:53 (101.0-111.0) [101-121] P:98 (117.0-127.0) [14-144] D(40.87)Route duration: 40.86657528885055
Nurse capacity:41.0
D(0) -> P:29 (52.2-62.2) [52-122] P:27 (67.0-77.0) [60-103] P:16 (82.0-92.0) [58-181] P:30 (99.0-109.0) [75-112] P:28 (113.0-123.0) [55-130] P:32 (120.0-130.0) [116-105] P:31 (143.0-153.0) [50-180] P:34 (156.0-166.0) [62-192] P:50 (179.0-189.0) [71-201] P:80 (217.0-227.0) [190-232] D(134.65)
Route duration: 134.64717461173354
Nurse capacity:183.0
D(0) -> P:33 (51.48-61.48) [51-95] P:26 (90.0-100.0) [81-105] P:89 (110.0-120.0) [105-187] P:48 (145.0-155.0) [64-104] P:21 (157.0-167.0) [45-175] P:25 (173.0-183.0) [171-191] P:24 (192.0-202.0) [128-204] D(167.05)
Route duration: 167.05385404358435
Nurse capacity:116.0
D(0) -> P:39 (36.06-46.06) [36-84] P:36 (53.0-63.0) [43-88] P:40 (87.0-97.0) [87-122] P:37 (103.0-113.0) [40-100] P:35 (130.0-140.0) [130-179] P:43 (160.0-170.0) [117-178] P:70 (196.0-206.0) [172-220] D(114.82)
Route duration: 114.82246330003456
Nurse capacity:151.0
D(0) -> P:90 (74.0-84.0) [74-137] D(0.49)
Route duration: 8.48528137623867
Nurse capacity:6.0
D(0) -> P:64 (53.0-63.0) [53-92] P:99 (87.0-97.0) [87-107] P:57 (100.0-110.0) [82-149] P:59 (130.0-140.0) [42-172] P:74 (158.0-168.0) [151-171] P:58 (180.0-190.0) [172-192] D(140.0)
Route duration: 139.9985141226161
Nurse capacity:102.0
D(0) -> P:65 (11.18-21.18) [11-53] P:52 (35.0-45.0) [25-155] P:86 (77.0-87.0) [77-136] P:87 (100.0-110.0) [100-120] P:97 (120.0-130.0) [112-167] P:75 (143.0-153.0) [57-182] P:77 (171.0-181.0) [163-183] D(132.66)
Route duration: 132.6627401472372
Nurse capacity:118.0
D(0) -> P:42 (33.54-43.54) [33-76] P:44 (74.0-84.0) [74-94] P:38 (91.0-101.0) [85-105] P:41 (100.0-110.0) [92-131] P:72 (129.0-139.0) [27-157] P:54 (148.0-158.0) [127-150] D(87.87)
Route duration: 87.8663311869857
Nurse capacity:94.0
D(0) -> P:15 (48.0-58.0) [68-88] P:16 (80.0-90.0) [50-124] P:47 (95.0-105.0) [38-119] P:78 (110.0-120.0) [90-129] P:55 (150.0-160.0) [150-170] D(91.71)
Route duration: 95.71179370878292
Nurse capacity:93.0
D(0) -> P:92 (15.0-25.0) [15-35] P:95 (32.0-42.0) [20-150] P:62 (62.0-72.0) [62-82] P:67 (80.0-90.0) [90-100] P:71 (103.0-113.0) [52-117] P:94 (124.0-134.0) [50-180] P:93 (173.0-183.0) [173-218] P:96 (180.0-190.0) [87-217] D(88.94)
Route duration: 88.93777455112824
Nurse capacity:90.0
D(0) -> P:81 (90.0-90.0) [80-131] P:61 (90.0-100.0) [55-116] P:68 (144.0-154.0) [144-183] D(37.17)
Route duration: 37.174908138956324
Nurse capacity:40.0
D(0) -> P:88 (67.0-77.0) [67-106] P:79 (90.0-100.0) [90-119] P:73 (110.0-120.0) [61-128] P:60 (141.0-151.0) [137-212] D(87.35)
Route duration: 87.349998947644
Nurse capacity:71.0
D(0) -> P:83 (10.24-20.24) [10-140] P:19 (58.0-68.0) [58-125] P:23 (75.0-85.0) [75-95] P:18 (91.0-101.0) [79-134] P:22 (112.0-122.0) [94-129] P:40 (125.0-135.0) [109-138] P:20 (138.0-148.0) [111-172] P:91 (176.0-186.0) [97-227] D(110.54)
Route duration: 110.535668274511
Nurse capacity:177.0
```

# Result: test\_2

Best time-travel: 937(<5%)



N nurse	Route duration	Covered demand	Patient sequence
1	134.0	221	[52, 18, 45, 46, 8, 83, 60, 5, 84, 17, 91, 85, 98, 100, 37, 93, 96, 89]
2	191.4	323	[95, 92, 42, 15, 14, 38, 86, 44, 16, 61, 99, 59, 87, 2, 57, 43, 97, 94, 6, 13, 58]
3	158.6	250	[21, 73, 72, 39, 67, 23, 56, 75, 22, 41, 74, 4, 55, 25, 24, 54, 26]
4	207	319	[27, 31, 88, 62, 11, 64, 36, 49, 19, 47, 48, 82, 7, 10, 63, 90, 32, 66, 20, 70]
5	48.1	71	[28, 76, 12, 40, 53],
6	197.7	274	[69, 1, 30, 51, 33, 71, 65, 9, 81, 79, 29, 78, 35, 34, 3, 68, 80, 77, 50]

# Result: test\_2

Best time-travel: 937(<5%)

```
D(0) -> P:52 (11.31-21.31) [11-758] P:18 (229.0-239.0) [229-592] P:45 (253.0-263.0) [29-319] P:46 (338.0-348.0) [338-815] P:8 (393.0-403.0) [393-502] P:83 (418.0-428.0) [21-852] P:60 (449.0-459.0) [449-981] P:5 (463.0-473.0) [20-916] P:84 (478.0-488.0) [425-532] P:17 (673.0-683.0) [673-940] P:91 (698.0-708.0) [222-974] P:85 (711.0-721.0) [110-737] P:98 (724.0-734.0) [21-758] P:108 (821.0-831.0) [821-975] P:37 (834.0-844.0) [339-970] P:93 (848.0-858.0) [691-979] P:96 (863.0-873.0) [344-963] P:89 (882.0-892.0) [409-991] D(134.01)
Route duration: 134.00541204143656
Nurse capacity:221.0
D(0) -> P:95 (14.87-24.87) [14-883] P:92 (28.0-38.0) [18-169] P:42 (49.0-59.0) [25-302] P:15 (176.0-186.0) [176-309] P:14 (282.0-212.0) [32-704] P:38 (298.0-388.0) [298-419] P:86 (321.0-331.0) [238-633] P:44 (339.0-349.0) [238-353] P:16 (355.0-365.0) [102-553] P:61 (378.0-388.0) [126-551] P:99 (388.0-398.0) [328-447] P:59 (408.0-418.0) [17-982] P:87 (419.0-429.0) [397-480] P:2 (436.0-446.0) [18-882] P:57 (452.0-462.0) [246-715] P:43 (475.0-485.0) [458-877] P:97 (503.0-513.0) [462-833] P:94 (519.0-529.0) [190-759] P:6 (532.0-542.0) [355-584] P:13 (694.0-784.0) [694-833] P:58 (854.0-864.0) [854-990] D(191.43)
Route duration: 191.43328414874264
Nurse capacity:323.0
D(0) -> P:21 (18.03-28.03) [18-737] P:73 (143.0-153.0) [143-574] P:72 (156.0-166.0) [22-925] P:39 (180.0-190.0) [33-354] P:67 (291.0-301.0) [291-414] P:23 (313.0-323.0) [206-335] P:56 (525.0-535.0) [525-762] P:75 (539.0-549.0) [27-721] P:22 (553.0-563.0) [349-564] P:41 (567.0-577.0) [336-581] P:74 (681.0-691.0) [681-812] P:4 (702.0-712.0) [679-810] P:55 (721.0-731.0) [628-749] P:25 (826.0-836.0) [826-966] P:24 (851.0-861.0) [435-970] P:54 (871.0-881.0) [475-910] P:26 (893.0-903.0) [328-937] D(158.61)
Route duration: 158.60658525963183
Nurse capacity:258.0
D(0) -> P:27 (44.0-54.0) [44-325] P:31 (67.0-77.0) [17-754] P:88 (219.0-229.0) [219-458] P:62 (235.0-245.0) [168-307] P:11 (253.0-263.0) [206-335] P:64 (276.0-286.0) [154-403] P:36 (308.0-318.0) [41-338] P:49 (441.0-451.0) [441-610] P:19 (463.0-473.0) [95-562] P:47 (481.0-491.0) [34-612] P:48 (498.0-508.0) [280-972] P:82 (513.0-523.0) [23-771] P:7 (529.0-539.0) [72-679] P:10 (553.0-563.0) [517-702] P:63 (572.0-582.0) [34-598] P:90 (587.0-597.0) [225-664] P:32 (601.0-611.0) [482-965] P:66 (626.0-636.0) [532-763] P:20 (645.0-655.0) [418-839] P:78 (668.0-678.0) [668-978] D(287.32)
Route duration: 287.31857333616094
Nurse capacity:319.0
D(0) -> P:69 (165.0-175.0) [165-300] P:1 (190.0-200.0) [190-984] P:30 (211.0-221.0) [199-424] P:51 (230.0-240.0) [176-635] P:33 (247.0-257.0) [24-309] P:71 (274.0-284.0) [98-547] P:65 (294.0-304.0) [49-318] P:9 (394.0-404.0) [394-513] P:81 (410.0-420.0) [268-689] P:79 (426.0-436.0) [377-486] P:29 (446.0-456.0) [29-523] P:78 (466.0-476.0) [324-569] P:35 (626.0-636.0) [626-883] P:34 (646.0-656.0) [265-888] P:3 (670.0-680.0) [289-832] P:68 (686.0-696.0) [577-822] P:80 (719.0-729.0) [719-978] P:77 (821.0-831.0) [821-958] P:50 (838.0-848.0) [272-927] D(197.74)
Route duration: 197.73665713293735
Nurse capacity:274.0
D(0) -> P:28 (6.32-16.32) [6-536] P:76 (281.0-291.0) [281-392] P:12 (298.0-308.0) [15-735] P:40 (322.0-332.0) [300-507] P:53 (403.0-413.0) [403-510] D(48.15)
Route duration: 48.15287977548874
Nurse capacity:71.0
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