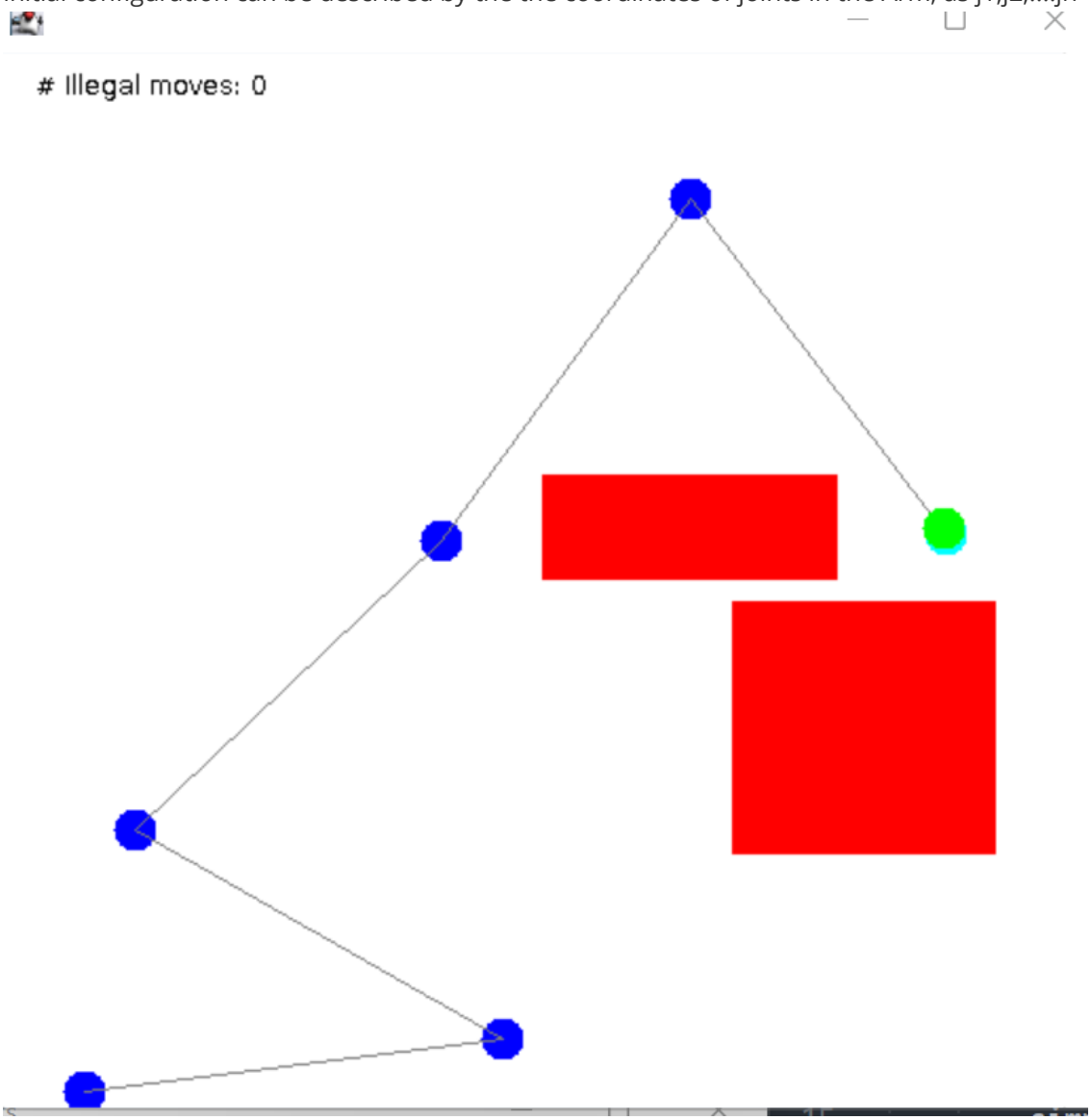
Exercise 1:

- initial configuration can be described by the the coordinates of joints in the Arm, as j1,j2,....jn
- 

- We can still use coordinates of joints where the final joint is at the goal
- Intermediate configuration could be the whole arm expanded vertically

Exercise 2:

- With more obstacles the configuration is harder
- With longer distance to goal, the configuration is harder

Exercise 3:

- The goal state should be the arm tip touching goal and no arm segment has crossed obstacles.
- The complete description of this state should be all the coordinates of the arm joints

Exercise 4:

- Maze
  - O(N^2)
- N-puzzle
  - O(N!)
- Arm
  - continuous

Exercise 5:

- Maze
  - 4
- N-puzzle
  - 2-4
- Arm
  - inf

Exercise 6:

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

- Neighbor 1
  -
1	**2**	**3**
4	5	6
7		8
  - 1-1
1	**2**	**3**
4	5	6
	7	8
  - 1-2
1	**2**	**3**
4		6
7	5	8
  - 1-3

1	2	3
4	5	6
7	8	

- Neighbor 2

1	2	3
4	5	
7	8	6

  - 2-1

1	2	
4	5	3
7	8	6

  - 2-2

1	2	3
4		5
7	8	6

  - 2-3

1	2	3
4	5	6
7	8	

Exercise 7 :

See `PlanningGUI`

Exercise 8:

All are Correct

Exercise 9:

```
Starting plan generation ...
BFS: Solution of length=7 found with cost=6.0 after 26 moves
Starting plan generation ...
DFS: Solution of length=17 found with cost=16.0 after 20 moves
```

- The DFS tend to give a solution with less effort but with more cost

```
def recur(node){
    for (s:neighbor){
        if (s == goal):
            return s;
        s = recur(s);
        if  (s!=0){
            return s;
        }
    }
    return 0;
}
```

- Disadvantage
    - Recursive DFS need a more complicated way to store a visited nodes for they function in different level.
    - Recursive DFS need more overhead in function.
- Advantage
    - Recursive DFS can use multithread to enhance it's performance

Exercise 10:

- BFS will need more memory than DFS for it will need to expand every node and save them into frontier nodes.
- DFS:
    - all the nodes and their neighbor on the route to goal are stored in memory
    - If DFS finds a goal with 20 moves and 4 neighbor each node, then it will need to store about 80 nodes
- BFS:
    - All level of nodes and their neighbor are stored before finally reach the goal.
    - If BFS finds a goal with 6 depth and 4 neighbor each node, then it will need to store about 4^6 = 4096 nodes

Exercise 11:

- We used `not in` in both cases, it's O(n) regarding to list size.
- We can use a hash map and a array to store the nodes so that operation `not in` can be done in O(1)

Exercise 12:

- See `CPBlanner.java`

Exercise 13:

- CBP has a better performance than BFS

Exercise 14:

- The removeBest need O(N) time on each operation. We can use a priority queue or max heap to achieve the same goal using O(logN) time.

Exercise 15:

- We can use the distance between current position to goal as cost-to-goal for maze problem
    - it can fail if there are dead end in the maze. Then by cost-to-goal, the algorithm will explore the dead end and waste more time
- We can use how many block are same with the final goal as the cost-to-goal for puzzle problem
    - it can fail when the problem is not achievable even multiple block are the same as the goal status.

Exercise 16:

see `CBPlannerAStar.java`

Exercise 17:

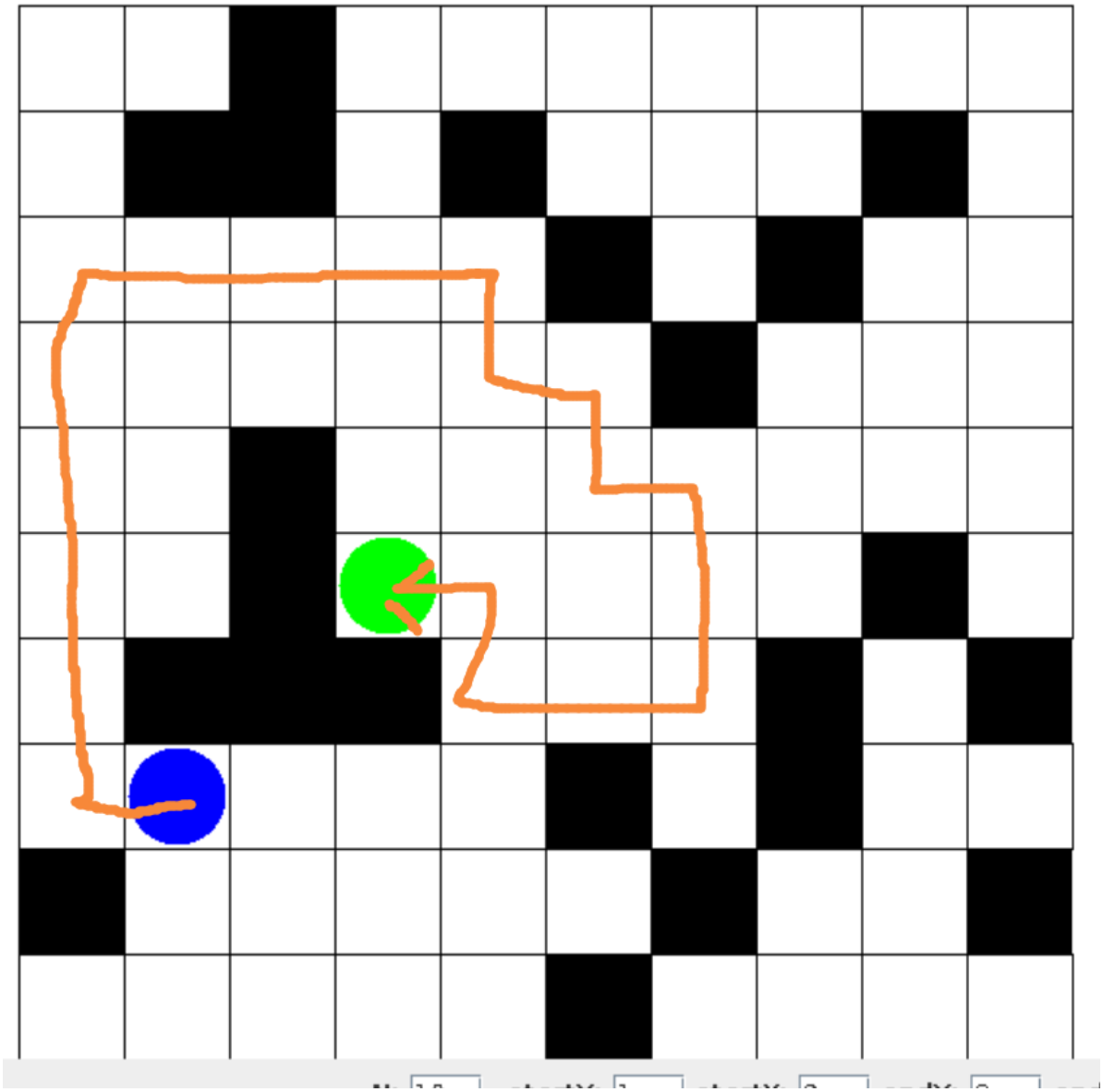
scenario	CB move	CB cost	AS move	AS step
1	16	4	8	4
2	7	4	4	4
3	32	10	20	10
4	52	10	27	10
5	37	8	18	8

Both CB and AS get the best path, but AS tend to use less moves when finding the best path.

Exercise 18:

- maze
    - Distance to goal
- puzzle
    - Distance to goal where distance is the differ of numbers between two configuration
- A possible alternative distance for the puzzle could be the numbers that are more than 1 move from the goal position. This can reduce some redundancy in search progress

Exercise 19:



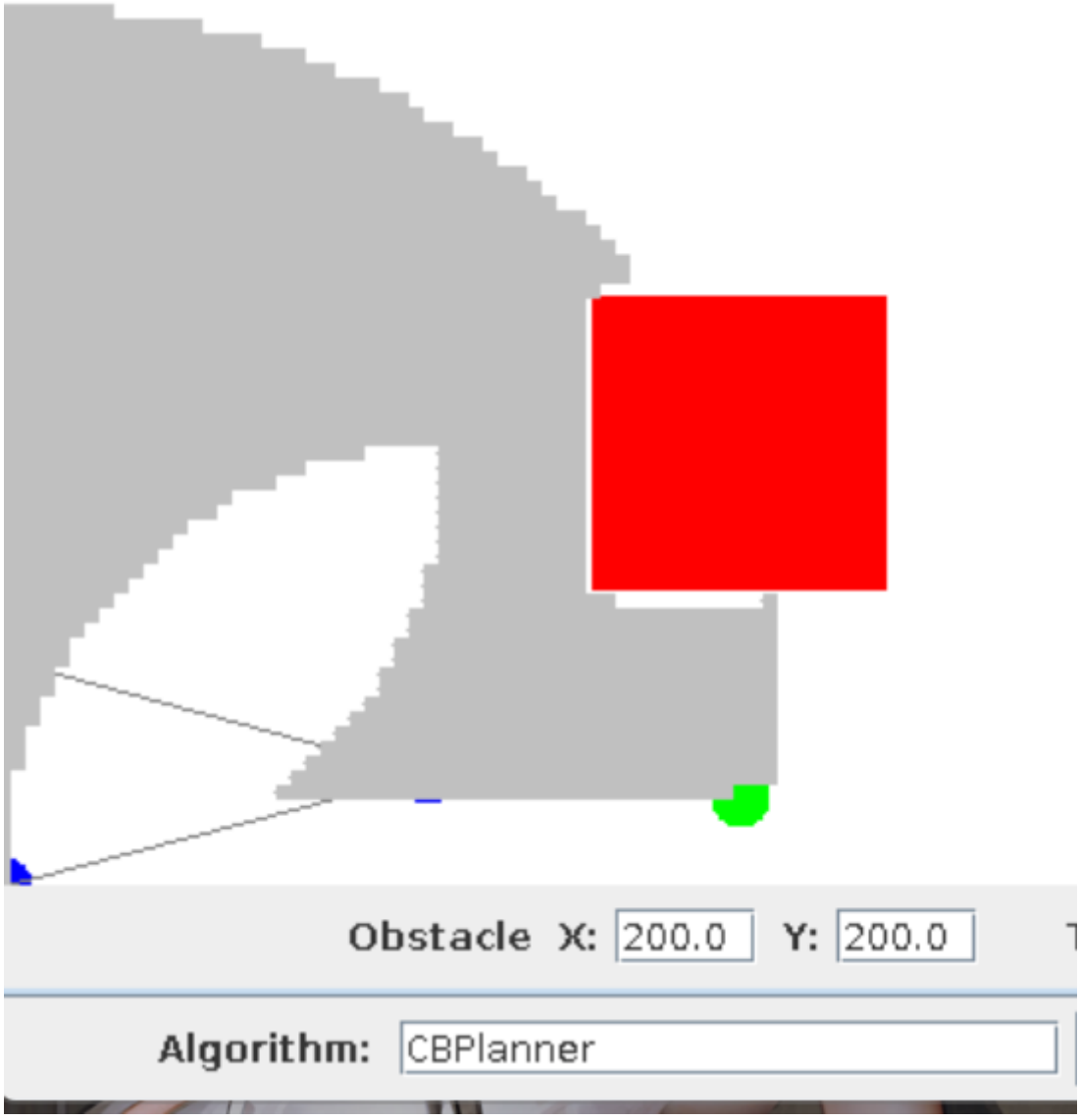
Although DFS finds the goal but it takes much longer than it can.

Exercise 20:

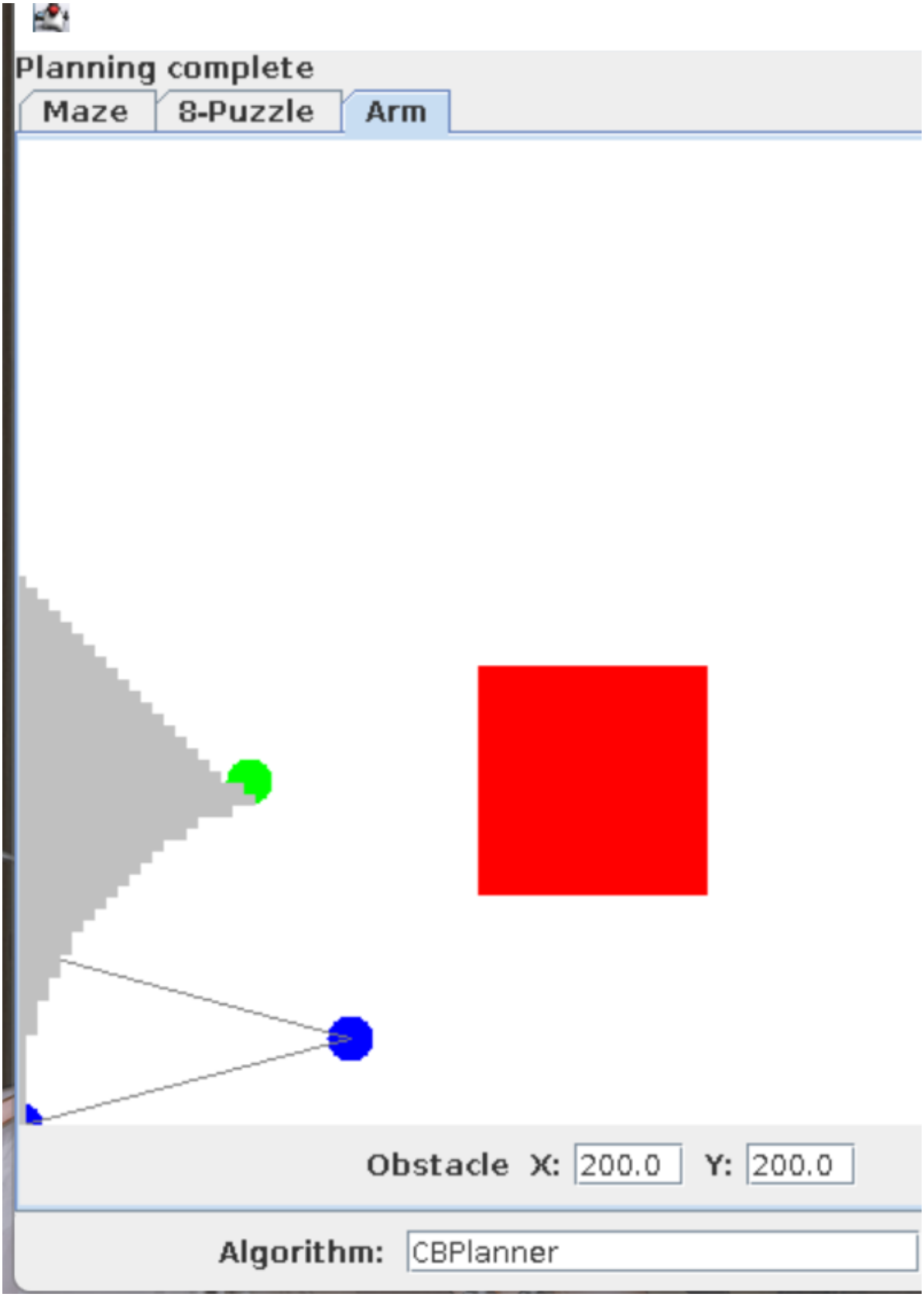
see `BFSPlanner.java,CBPlanner.java,BSFPlannerAStar.java`

Exercise 21:

- original 8 direction



- 4 direction



Exercise 22:

- We can know the visited state by storing points that the arm tip has been before. Can compare new state to it.
- This differs for the space is continuous so we need an estimate function to see if two points are close enough to be seen as the same point visited before.

Exercise 23:

- $L_0cos(\theta_0)$ is the x of L0, $L_1cos(\theta_0+\theta_1)$ is the x of L1. So their sum is the x of the tip
- $L_0sin(\theta_0)$ is the y of L0, $L_1sin(\theta_0+\theta_1)$ is the y of L1. So their sum is the y of the tip

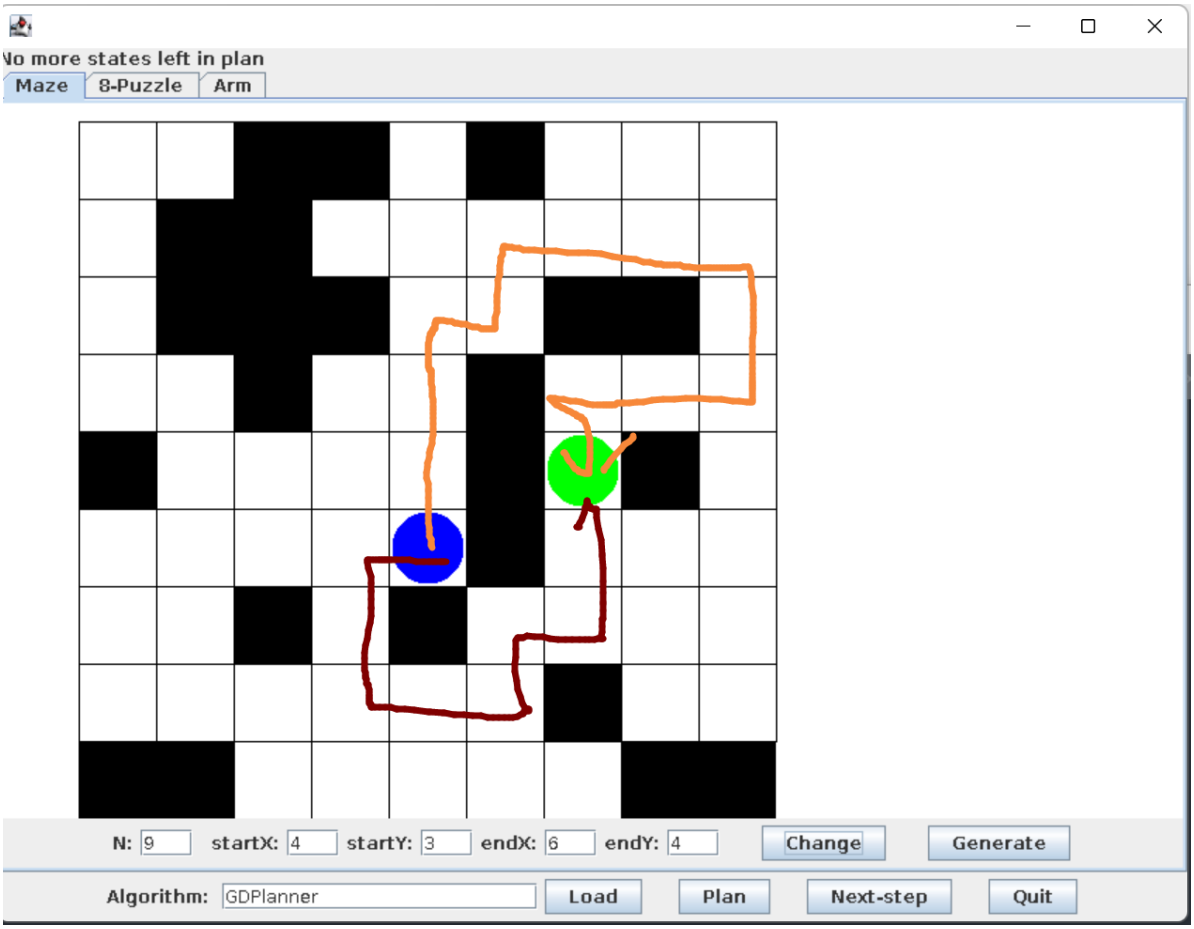
Exercise 24:

- straightening
  - $\Delta\theta_0$ is positive
  - $\Delta\theta_1$ is negative
- move down
  - $\Delta\theta_0$ is 0
  - $\Delta\theta_1$ is negative
- 3 rd phase:
  - $\Delta\theta_0$ is negative
  - $\Delta\theta_1$ is positive

Exercise 25:

See `twolinkexamplezip/TwoLinkController.java`

Exercise 26:



In this case, `GDPlanner` choses the yellow path(13 step) instead the optimal red path(9 step)