Coursework 2 – Genetic Algorithms

Date Released: Friday, 15th November 2024

Date Due: Friday 13th December 2024 at 4pm

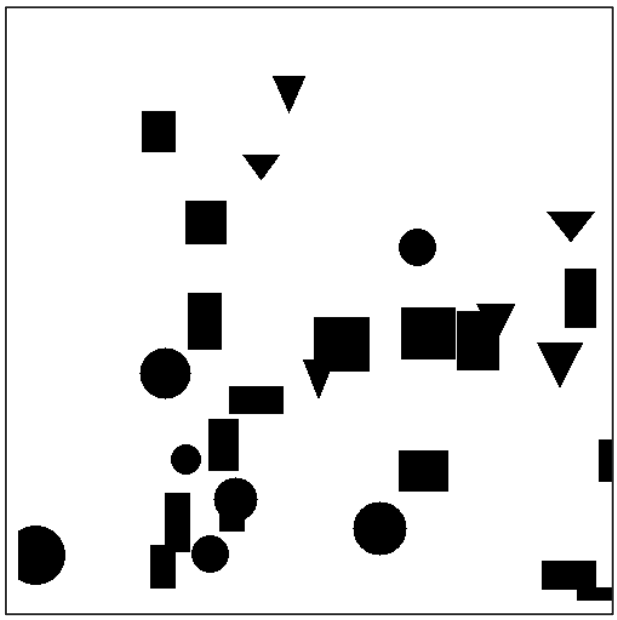
This coursework is worth 20% of your overall mark

1. Introduction

In this coursework, your task is to implement a Genetic Algorithm (GA) to address a designated problem, and subsequently present the results. The foundational concepts of GA were introduced and discussed during the week 6 lectures and the lab sessions in week 7 were dedicated to familiarizing you with GA. However, it's essential to note that this coursework involves applying GA to a distinct problem, different from those addressed in the lab sessions.

2. Problem Definition

The task at hand involves implementing and enhancing a robot motion planning algorithm using Genetic Algorithms (GAs). Assume that you have a robot with an overhead camera. The first step in motion planning is to create a representation of the robot's operating environment. This involves constructing a map that includes information about obstacles, terrain, and other relevant features. For the purposes of this CW, we simplify the process by assuming the existence of such a map, already provided as input, with dimensions of 500 pixels by 500 pixels. An illustrative example of such a map is shown in the figure below.



The next step is localisation, which refers to the process of determining the robot's precise position and orientation within its operating environment. It is a crucial aspect of robotics that enables a robot to understand and update its location relative to a given coordinate system or map. Effective

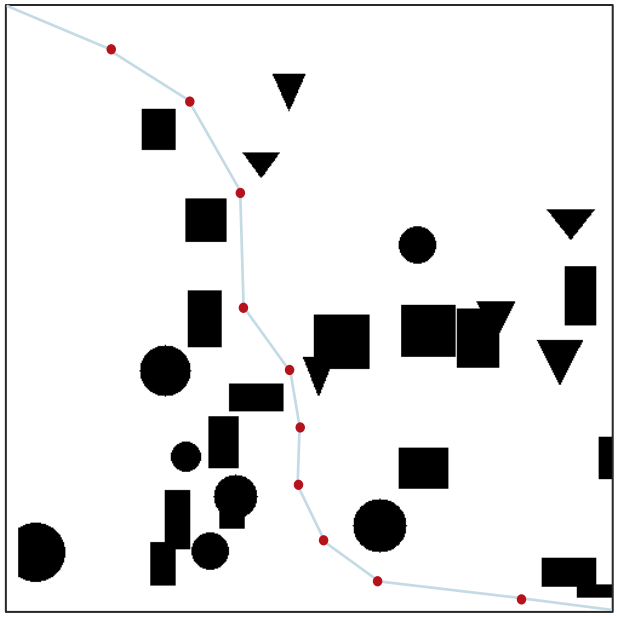
localization is essential for accurate navigation, as the robot needs to know where it is in order to plan and execute its movements successfully. For the purposes of this CW, it is presumed that both the starting point and the destination of the robot are provided as follows:

$$start = [1,1]$$

$$finish = [500,500]$$

The primary objective of the CW is thus limited to path planning for the robot.

Let a path be characterized by a fixed number of points n_p in the robotic map. As shown in the figure below for $n_p = 10$, the path is constructed by commencing from the start point $[1,1]$ and connecting it to the first point through a straight line. Subsequently, each point is connected to the next in sequence by straight lines until the final point is linked to the finish point $[500,500]$.



To keep things simple, we're treating the robot as a tiny point (or a pixel) instead of its actual size.

3. Problem Solving using Genetic Algorithms

In formulating the problem as an optimization challenge for resolution by a Genetic Algorithm (GA), two key elements are essential: defining an objective function and specifying the variables of that function along with their bounds. The objective function, in this context, is the length of the path, where a shorter path is considered more favourable. A penalty should be imposed if any part of the path intersects with an obstacle, with the penalty proportional to the path length within the obstacle.

The optimization variables are the coordinates (x, y) of each of the fixed number of points along the path. The variable bounds are determined such that each point resides within the map. Specifically, the lower bound is set to 1, and the upper bound corresponds to the length or width of the map for the x and y axes (i.e., 500). Each of these points, arranged one after another, constitutes the genetic individual utilized in the optimization process.

Each point in the path marks a point of turn. The total number of points “noOfPointsInSolution” should be considered as a parameter and should be equal to the maximum number of turns a robot is expected to make in the robot map.

How to Read and Generate Random Maps

In order to implement your code, you need to first read a map as a binary image as follows:

```
map=im2bw(imread('random_map.bmp'));
```

where 'random_map.bmp' is the name of an example map. A MATLAB script named "Generate_Random_Map.m" is provided to generate different (simple to complex) binary maps.

Implement Genetic Algorithm

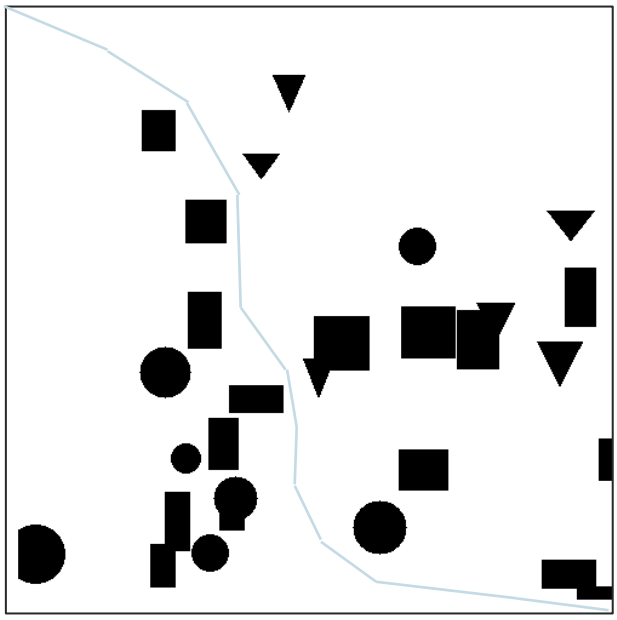
Your main task involves the implementation, using MATLAB, of a genetic algorithm designed to discover an optimal path through an evolutionary process. It is important to note that the built-in `ga` function in MATLAB is not permissible for use in this task. Instead, you are required to develop an approach akin to what was covered in the lab sessions during week 7.

Your algorithm should make use of appropriate crossover and mutation operators. Numerous design decisions, including the implementation details of the algorithm and the selection of parameter values, will be required.

Your code should output an image displaying the final best path using the provided code below:

```
path = [start; [solution(1:2:end)'*size(map,1) solution(2:2:end)'*size(map,2)]; finish];
clf;
imshow(map);
rectangle('position',[1 1 size(map)-1],'edgecolor','k');
line(path(:,2),path(:,1));
```

The solution is a row vector of size $2 \times n_p$. One possible output is shown below.



Your code should include functionality to display both the execution time of the Genetic Algorithm (GA) and the total Euclidean distance of the optimal path.

Important Notes

1. You need to implement **THREE selection methods** including Roulette wheel selection (RWS), Tournament selection and Rank-based Selection. The code for RWS is available in Week 6's lab material on Moodle. Conduct some research to gain an understanding of how Rank-

based selection operates, and subsequently, incorporate this knowledge into the implementation. Note that for the Tournament selection method, you need to consider its variants/parameters as variables.

2. You need to implement **TWO appropriate cross-over operators**. Note that k-point cross-over is counted as one method, and thus, changing k to 1, 2, 3 doesn't count as three cross-over operators.
3. You need to implement **TWO appropriate mutation operators**.
4. Your algorithm should provide optimal or near optimal solutions for **any combination** of selection/cross-over/mutation.
5. Upon initiation, the code **should prompt the user** to specify the types of selection, crossover, and mutation to be employed. For both crossover and mutation operators, the user should input a binary digit (0 or 1) to signify a specific type for each operator. For example, when selecting the crossover method, entering 0 signifies opting for crossover method 1, while entering 1 indicates the adoption of crossover method 2. Regarding selection, the user should input 0, 1, or 2 to indicate the chosen method.
6. The code should output **an image displaying the final best path** similar to the one shown in the figure above.
7. The code should be efficient and produces the required outputs. Try to use **minimum number of loops** in your code.
8. The maximum number of iterations/generations and the size of population should be as **small as possible**.

6. Submission

Please save your code in a zip file called "CW2_ID.zip", substituting ID with your student ID. submit the code on Moodle on or before the **deadline of 4pm on Friday, 13th December, 2024**. The code could be submitted as a single .m file or with multiple separate function files and a "main.m" file. If for some reason, you cannot upload your submission, please zip it up and e-mail it to b.williams6@lancaster.ac.uk and scc-teaching-office@lancaster.ac.uk as soon as possible.

Your submission should be anonymous and not include your name in the code.

7. Marking

There are a total of 20 marks for this coursework and the coursework mark constitutes 20% of your overall mark for this module.

- 2 marks are allocated to the structure of the code. It should be well-structured and easy to understand. The code should be run by pressing the Matlab RUN button without requiring any changes.
- 10 marks are allocated to the correctness of the results. The code is expected to produce a solution that is close to optimal. Your code will be executed 10 times to assess how frequently it generates an optimal or near-optimal solution. The expectation is to achieve optimal results in 80% of the runs.
- 2 marks are allocated to the commenting. There should be enough comments to understand the code. A report is not required for this coursework; the code should be well-commented with enough detail on methods used/ implemented.
- 6 marks are allocated to time complexity of the algorithm (in all settings). The code should prioritise time efficiency and use matrix operations for computational advantage. The

maximum number of iterations/ generations and population size should be minimised for optimal performance.