CSC 790: Computational Robotics
Assignment #3
Due Date: (Before Midnight) Nov. 04, 2021

Write a program that implements Expansive-Spaces Trees (EST) for a planar translational point robot in an environment where obstacles are represented by their bounding sphere (i.e., circles in 2D environment). Your program should implement a validity checker (i.e., a collision detector) to check for collision of the robot with the obstacles and an extender that grows the EST towards a new configuration.

There is an input file (.env) represents the environment containing the obstacle information and the workspace boundary. An example is shown below:
Boundary: -100 : 100; -100 : 100
5
1.0 3.0 2.0
6.0 4.0 4.0
-1.0 6.0 1.0
-2.0 3.0 1.0
-1.0 -1.0 3.0
where the format is of the type
Boundary: $x_{low} : x_{high}$; $y_{low} : y_{high}$
n *:Number of obstacles*
x_1 y_1 $radius_1$
...
x_n y_n $radius_n$

The output file (.map) should be the constructed tree generated by your program in the given format:
Number of nodes(nv) Number of edges(ne)
vx_1 vy_1
...
vx_{nv} vy_{nv}
$e\_v - index1_1$ $e\_v - index2_1$
...
$e\_v - index1_{ne}$ $e\_v - index2_{ne}$
where the edges are represented by the index of the end vertices in which they appear in the file (with indexing starting from 1).

Programming Language: C++ or Python. Do not use any external packages. Your code should compile and execute without downloading any external software, library or API.

Deliverable

1. Software code as a zipped file (.zip) containing all the code files. A README text file providing information the version of the programming language you used, usage for the program and compilation instructions (if any).

2. A PDF (.pdf) or Word (.doc or .docx) document:
   (a) Report the implementation design. The implementation design should state the details of your implementation of the collision detection, random sampling of new node, local planner to check validity of edge and the extender used in the EST algorithm. All implementation details should be given in either pseudo-code or algorithmic steps. No language specific code will be accepted.
   (b) Report the experimental results. You need to evaluate the algorithm on 2 type of analysis:
      i. Given an environment of boundary (-50:50; -50:50), randomly generate 5 start configurations for 50, 100 and 150 attempts to expand the tree. Report the average of total computation time taking the average over the 5 start configuration. Also report the fraction of time spent on collision detection and fraction of time spent on extending.
      ii. Given 3 environments of a given boundary (-50:50; -50:50): one completely empty, one medium occupancy and one heavy occupancy. For each environment, generate randomly 5 start configurations for 50 attempts to expand the tree. Report the average of the total computation time taking the average over the 5 start configuration.
   (c) Please provide a summary and critical analysis for the following paper:
   J. Denny, K. Shi and N. M. Amato, "Lazy Toggle PRM: A single-query approach to motion planning," 2013 IEEE International Conference on Robotics and Automation, 2013, pp. 2407-2414, doi: 10.1109/ICRA.2013.6630904.
   Online paper link: https://ieeexplore.ieee.org/abstract/document/6630904
   Your analysis should include the things you like and dislike about the paper and the questions you have on the paper. The summary should not exceed 500 words and should be precise and accurate. Write in your own words and check for grammar and spelling.
   (d) Include any references (website, book, people, etc).

General Instructions

1. Your code should be properly documented (comments in the code).
2. Your code should be properly indented with proper variable names.
3. Your code should be modular with use of functions and procedures for repetitive code.
4. Do NOT copy code. You are allowed to discuss concepts with friends but any copying will result in loss of credit and will be reported as academic dishonesty at the least.
5. Submit your report as a single PDF or word document.
6. Your answers must be typed.
7. Provide a list of references for the people you discussed with and materials you referred (books, papers, web-site, etc.)
8. Write the report in your own words.