16-811: Math Fundamentals for Robotics, Fall 2024
Assignment 6

DUE: Thursday, December 5, 2024

Please be aware:

- There will be no resubmission opportunity for this assignment. The three problems below are implementations. You will know yourself whether you have produced a successful solution.
- You will likely need to create some data structures to represent and manipulate polygons. Do/use whatever is convenient. Of course, don't use built-in convex hull functions, etc.
- You may assume that input is in general position if that is convenient.
- You do not need to implement optimally efficient algorithms. Implement whatever you find convenient (and correct).
- Submit code and demonstrate the correctness of your code by showing appropriate pictures of sample runs in your writeup: In Problem 1, show some examples of points and their convex hulls — show examples with just a few points and examples with many points, covering a range of half a dozen points to more than a thousand. In Problem 2, show paths found for environments. In Problem 3, show paths found for some robots and environments.

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1. Implement two-dimensional (2D) convex hull.

   Your algorithm should take as input a finite set of 2D points and produce as output a polygon constituting the boundary of the minimal convex set containing all the input points. ("minimal convex set" means that the set is a subset of any other convex set that contains all the input points.)

2. Implement an algorithm for finding shortest paths in 2D polygonal environments.

   The input to your algorithm should consist of a collection of nondegenerate convex polygons, a start location, and a goal location. The output should be a piecewise linear path that does not pass through the *interior* of any polygon and is as short as possible, if such a path exists. (Otherwise, your algorithm should indicate that no path exists.) One situation in which no path exists is if the start or goal is in the interior of a polygon.

   Notes: (i) The polygons are allowed to overlap. (ii) The solution path is allowed to touch the boundaries of polygons, but is not allowed to pass through any polygon's interior.

3. Combine your code for parts (1) and (2), along with some additional code, to implement shortest-path motion planning for convex polygons in two dimensions (translations only, no rotations).

   Specifically, the input to your algorithm should consist of a "robot" and its environment, along with start and goal configurations for the robot. The output should be a piecewise linear path as described below. (The robot moves only in straight lines. No rotations.)

   The robot should be a nondegenerate convex polygon. The environment should consist of a collection of nondegenerate (possibly overlapping) convex polygons. Given start and goal configurations of the robot, your algorithm should produce a shortest intersection-free path between the start and goal, if such a path exists. "Intersection-free" means that the robot may touch obstacle boundaries, even slide along obstacle boundaries, but may not touch the interior of any obstacle. If no such path exists, your algorithm should report that fact.