Problem Statement and Goals
2D Robot Arms for Path Planning

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Table 1: Revision History

Date	Developer(s)	Change
2025-01-20	Ziyang Fang	Initial the document.

1 Problem Statement

1.1 Problem

The project involves developing a framework for distance-geometric representation of 2D (planar) robot arms to facilitate path planning in environments with circular obstacles. Unlike traditional inverse kinematics (IK) methods, the proposed approach uses a geometric graph representation of the manipulator and formulates the IK problem as a distance-based graph problem. The goal is to determine the joint positions and angles along a feasible path that avoids obstacles and satisfies the goal configuration.

1.2 Inputs and Outputs

Inputs:

- Environment: Circular obstacles defined by positions (x,y) and radius.
- Robot arm: Number of joints and their respective lengths.
- Initial pose: Configuration of the robot arm at the start.
- Goal: Desired end-effector position or pose.
- Number of poses: Initial value for the number of intermediate poses along the path.

Outputs:

- Distance-geometric representation: Joint positions at each time step.
- Angular representation: Joint angles along the path to the goal.

1.3 Stakeholders

- Researchers and developers in robotics and motion planning.
- Robotics engineers working on manipulators and autonomous systems.
- End users interested in robust and scalable IK solutions.

1.4 Environment

Hardware: Simulation environment.
Software: Python or MATLAB-based implementation, integrating with existing libraries include GraphIK and Convex Iteration-based solvers.

2 Goals

- Develop a framework that generalizes to various 2D robotic manipulators.
- Ensure accurate and efficient path planning through distance-geometric representations.
- Validate the approach using benchmark problems and compare with traditional IK solvers.

3 Stretch Goals

- Extend the framework to include angular velocity and acceleration calculations.
- Incorporate additional obstacle types or dynamic obstacles.
- Optimize the algorithm for real-time applications.
- Extend the framework to handle 3D robot arms, enabling path planning in three-dimensional space.
- Enable real-world testing on physical robotic systems to validate the algorithm's practical applicability and performance.
- Achieve higher computational efficiency compared to existing solvers, demonstrating faster convergence and lower computational resource usage.

4 Challenge Level and Extras

Challenge Level: General.
Rationale:

- This is a problem with a general-level challenge.

- It requires a solid understanding of robotics kinematics, inverse kinematics solving techniques, and convex optimization theories.
- Solving this problem involves integrating these theoretical foundations into a path-planning framework for planar manipulators, with a focus on handling complex configurations and constrained environments effectively.

Extras:

- Provide user manual for researchers and engineers.