

Reinforcement Learning Environment for Robotic Suturing

Computer Integrated Surgery II

Spring 2023

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Introduction

We present an OpenAI Gym environment built on the AccelNet Surgical Robotics Challenge (SRC) and AMBF dynamics simulator to pave the way for reinforcement learning (RL) research within surgical robotics and more specifically autonomous robotic suturing.

A standardized, open-source environment enables rapid iteration of RL approaches and reward functions, as well as benchmarking of RL algorithm's ability to train autonomous robotic simulations.

Our aim is to address the lack of RL platforms and environments conducive to medical robotics. An open-source environment will produce wide applicability and drive more innovation in autonomous surgical robotics systems.

The Problem

Current RL techniques have seen significant progress in the robotics domain; however, there exist many problems with current implementations:

- Limited RL platforms for medical robotics
- Existing environments use kinematics simulators, which does not perform well in SimToReal experiments

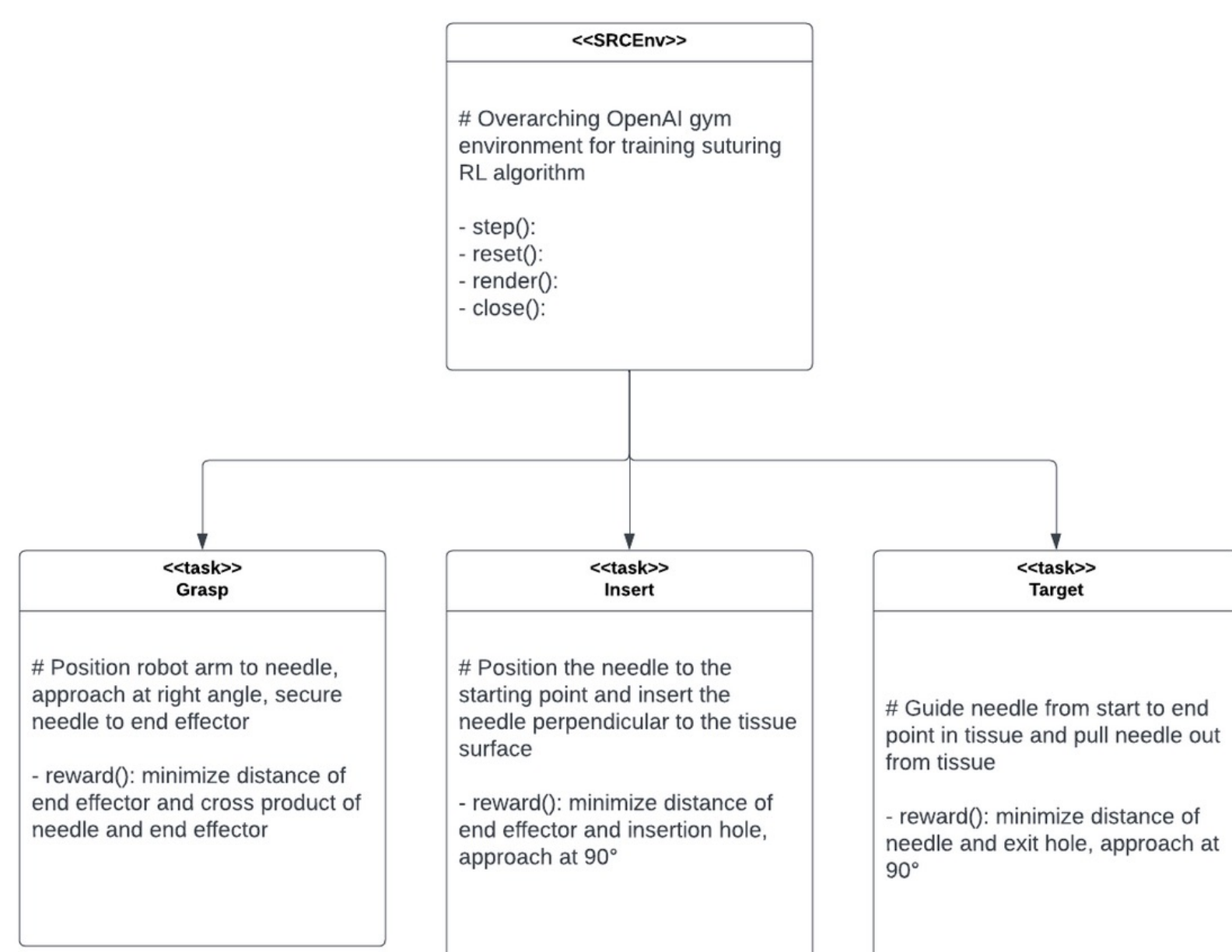
The Solution

To solve both problems, we present an OpenAI Gym environment based on the AccelNet Surgical Robotics Challenge, a dynamics simulator for robotic suturing. This environment is broken down into 3 challenge tasks: finding the needle, grasping the needle and driving through tissue, and suturing the phantom. We focus on the second challenge in this project.



Fig. 1. Surgical Robotics Challenge Simulation Environment
2021-2022 AccelNet Surgical Robotics Challenge

Our environment is structured as followed and supports the following methods:



Outcomes and Results

Our project successfully addressed the problems we identified by developing an OpenAI Gym environment tailored to medical robotics and surgical tasks. The outcomes and results of our work are summarized below:

1. Establishment of a Baseline Environment:

- We successfully created a baseline OpenAI Gym environment that encompasses the Surgical Robotics Challenge tasks. This environment serves to be the first RL environment for surgical robotics based on realistic physics and robot dynamics.

2. Reward Functions for Grasping and Driving Needle:

- Customized and tuned reward functions for grasping the needle, inserting the needle through the tissue, and the target exit position of the needle.
- We tuned our reward based on an ideal trajectory path for completing Challenge #2 and visualized the reward vs the distance between the needle and the PSM arm.

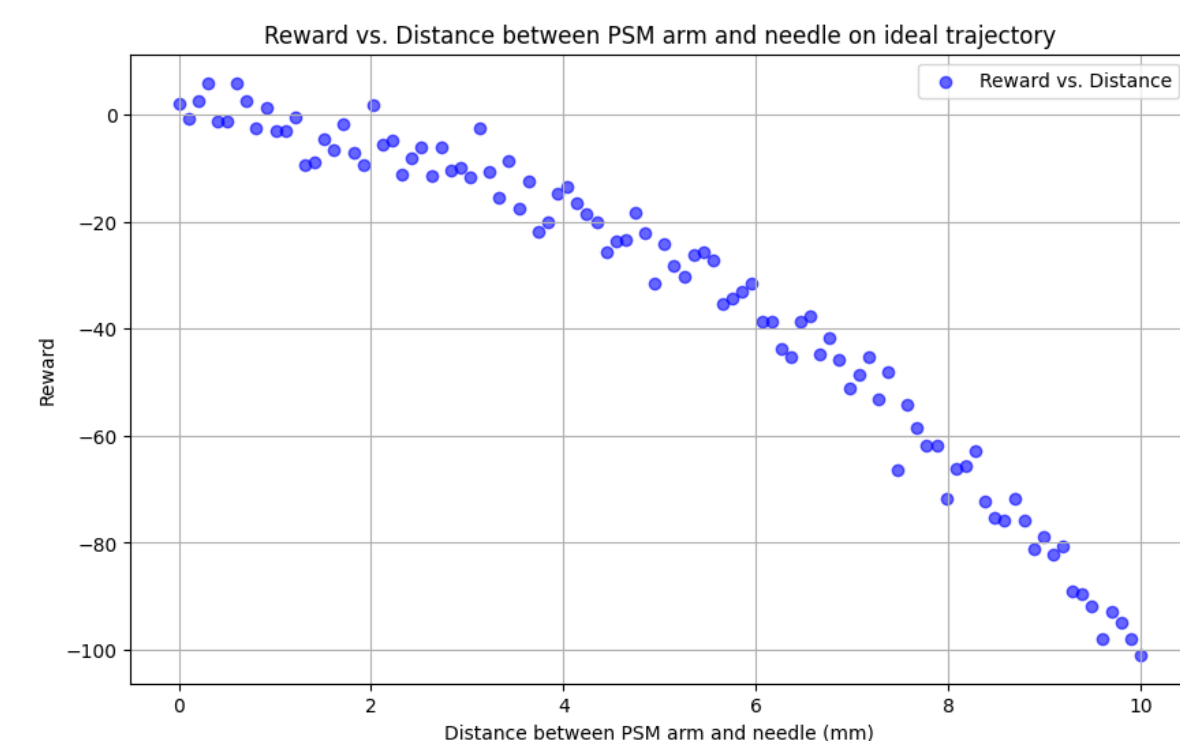


Fig. 2. Verification of Reward Function on Ideal Trajectory

3. Implementation of RL Algorithms:

- Implemented multiple RL algorithms (Deep Deterministic Policy Gradient, Hindsight Experience Replay) to train autonomous robotic simulations in our environment.
- However, due to computational and time limitations, we could not finish the training process.

Future Work

As all team members are graduating, we will not be furthering our work on this project. However, we plan on publishing our current work to IROS and ICRA workshop conferences. We've maintained thorough documentation so that any other members continuing the project will be able to utilize our implemented code.

Lessons Learned

- Explore different reward function modalities beyond modifying the function (binary, piece-wise)
- Maintain updated documentation at all times throughout the scope of the project

Credits

- Jocelyn: Development of SRCEnv
- Jihoon: RL Pipeline
- Walee: Reward function / RL

Publications

- Software Design Specification: https://ciis.lcsr.jhu.edu/lib/exe/fetch.php?media=courses:456:2023:projects:456-2023-20:software_design_requirements.pdf
- Manuscript preparation for future conferences

Acknowledgements

Thank you to our mentors for all the guidance and support throughout the entire project!