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REINFORCEMENT LEARNING BASED HYBRID CONTROLLER FOR ROBOTIC MANIPULATOR

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
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Declaration

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

27/04/2024

Signature: Date:

The above candidate has carried out research for the PhD/MPhil/Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. A. T. P. Silva

Signature of the Supervisor: Date:28/04/2024

DEDICATION

I wish to dedicate this thesis to my family, whose steadfast support and encouragement have been my guiding force throughout this academic journey. Your sacrifices, understanding, and unwavering love have ignited my ambition and provided me with strength during every obstacle.

This thesis is dedicated to each and every one of you, with heartfelt gratitude and appreciation for your unwavering support, encouragement, and belief in me. Thank you for being a part of this journey and for helping me to realize my dreams.

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ABSTRACT

Reinforcement learning provides robotics with a framework and a set of tools to develop complex and challenging behaviors that are difficult to engineer. Although reinforcement learning showed a significant improvement of applying into the robotics field, we could find only very few industrial applications. The intrinsic challenge of data inefficiency represents a significant obstacle that restricts the application of reinforcement learning algorithms in addressing practical problems in robotics. Looking back at the development of reinforcement learning over the past, it could be identified that applying it alone is not sufficient for real industrial application in robotics. Therefore, the proposed solution is trying to apply reinforcement learning in more innovative way by introducing it to hybrid the existing controller by taking the inspiration from muscle memory concept in human.

This thesis reports on the development of hybrid solution to robotic manipulator with the use of reinforcement learning alone with classical deterministic controller. Here, we utilize both PILCO, a practical and data-efficient model-based policy search method in reinforcement learning, which operates without the need for expert knowledge, alongside a PD controller as the deterministic controller. These components function in parallel to create a hybrid system. This proposed controller switches the control when observability is not sufficient for the deterministic controller to act, and the RL takes control over and executes the learned policy to robot to take its usual maneuvers. The assessment involved conducting an experiment using a basic two-wheeled line-following robot. During the experiment, the robot's camera view was disabled halfway through to activate a hybrid mechanism transitioning into RL mode. Upon executing this test scenario, the RL mode based on PILCO demonstrated promising outcomes compared to other machine learning methods.

Research further emphasizes the importance of hybrid AI systems to cope with any uncertainty or disastrous situation in future mission critical applications of robotics. Discussion also suggesting future enhancements that can add to this concept as further improvements.

Keywords: Reinforcement Learning, PILCO, Robotic manipulator, Hybrid Controller, ROS, Gazebo, MATLAB.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AI	Artificial Intelligence
GP	Gaussian Processes
RL	Reinforcement Learning
PILCO	Probabilistic Inference for Learning Control
ML	Machine Learning
ROS	Robotic Operating System
URDF	Unified Robot Description Format
RMSD	Root Mean Squared Deviation
BFGS	Broyden–Fletcher–Goldfarb–Shanno algorithm
MDP	Markov decision process
PID	Proportional, Integral and Derivative
SVM	Support Vector Machines

LIST OF APPENDICES