Adithya Ramesh

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Website | Github | LinkedIn

Education

- **Indian Institute of Technology Madras** — Chennai, India
  Dual Degree (B.Tech, M.Tech) in Engineering Design, Stream : Automotive Engineering — *Aug 2011 - Jun 2016*
  Minor in Systems Engineering
  CGPA (Cumulative Grade Point Average) : 8.30/10.0

Professional Experience

- **Robert Bosch Centre for Data Science and AI, IIT Madras** — Chennai, India
  Research Associate — *Oct 2021 - Present*

- Physics-Informed Model-Based Reinforcement Learning

Research Guide : Prof. Balaraman Ravindran, Department of Computer Science and Engineering, IIT Madras

- One approach to improve RL's sample efficiency is model-based RL. We learn a model of the environment, use it to generate imaginary trajectories and backpropagate through them to update the policy, exploiting the differentiability of the model.
- We focus on robotic systems undergoing rigid body motion without contacts. We consider two dynamics models, a standard deep neural network and a much more accurate Lagrangian / Hamiltonian Neural Network, which utilizes the structure of the underlying physics. We train our model-based RL algorithm using both models and compare.
- We show that, in model-based RL, model accuracy mainly matters in environments that are sensitive to initial conditions. In these environments, the physics-informed version of our algorithm achieves significantly better average-return and sample efficiency. In environments that are not sensitive to initial conditions, both versions of our algorithm achieve similar average-return, while the physics-informed version achieves better sample efficiency. We measure the sensitivity to initial conditions using the finite-time maximal Lyapunov exponent.
- We also show that, in challenging environments, where we need a lot of samples to learn, physics-informed model-based RL can achieve better average-return than state-of-the-art model-free RL algorithms such as Soft Actor-Critic, by generating accurate imaginary data.
- This work has resulted in a few publications so far,
  - "Physics-Informed Model-Based Reinforcement Learning". Adithya Ramesh and Balaraman Ravindran. *arXiv preprint 2022, arXiv:2212.02179* (Link).
  - "Physics-Informed Model-Based Reinforcement Learning". Adithya Ramesh and Balaraman Ravindran. *Learning for Dynamics & Control Conference (L4DC) 2023* (Under review).
  - "Lagrangian Model Based Reinforcement Learning". Adithya Ramesh and Balaraman Ravindran. *Deep Reinforcement Learning Workshop, Neural Information Processing Systems (NeurIPS) 2022.*
  - "Hamiltonian Model Based Reinforcement Learning for Robotics". Adithya Ramesh and Balaraman Ravindran. *The Multi-disciplinary Conference on Reinforcement Learning and Decision Making (RLDM) 2022.*
  - "Hamiltonian Model Based Reinforcement Learning for Robotics". Adithya Ramesh and Balaraman Ravindran. *The RBCDSAI-FCAI conference on Deployable AI 2022* (Won the best paper award).

- **Honeywell** — Bengaluru, India
  R &D Engineer/Scientist II, Advanced Technologies Division, Honeywell Aerospace — *Jun 2018 - Mar 2021*

- Multi-Agent Co-operation using Reinforcement Learning

- Considered multi-agent problems where the agents must learn an efficient communication protocol to co-operate and execute a task.
- Considered a representative problem where two agents with complementary sensing modalities (depth and color), have partial information about a target and must communicate, navigate to reach it simultaneously.
- Treated depth data as a point cloud and processed it using a PointCNN. Processed color data using a standard CNN.
- Trained the overall multi-agent system using the MADDPG algorithm. Success rate on 4800 training environment configurations $\sim 99\%$. Success rate on 1200 test environment configurations $\sim 59\%$.

- Autonomous Navigation for Quadrotors using Reinforcement Learning

- Developed a RL based autonomous navigation system for quadrotors, in simulation.
- The task is to navigate to a goal position in the shortest path, without colliding with stationary obstacles, in an unknown environment. The RL agent uses the relative position of the goal and a depth image to determine which direction to move. A control algorithm then controls the quadrotor to move a small distance in that direction and the process repeats.
- Used the DQN algorithm for training. Success rate on 4800 training environment configurations $\sim 92\%$. Success rate on 1200 test environment configurations $\sim 72\%$.

- LSTM based Speaker Recognition

- Developed a LSTM based text-independent speaker recognition system. Trained on ~ 2000 hours of audio from 6000 speakers. Achieved accuracy of $\sim 91.8\%$ on a test dataset containing 1250 speakers.
- Explored use cases such as authentication of users in a speech based building automation system and enhancing automatic transcription of communication between aircrafts and air traffic control (ATC).
- Drove collaboration with Microsoft Research, India in development of light-weight recurrent neural networks for deployment on resource constrained edge devices.

- **Predible Health** — Bengaluru, India
  Deep Learning Engineer — *Sep 2017 - May 2018*

- Biomedical Image Processing

- Developed CNNs to classify nodules in lung CT scans as benign or malignant. Achieved sensitivity of $\sim 90\%$, specificity of $\sim 81\%$ after performing 5-fold cross-validation on a dataset of $\sim 40k$ images.
- Experimented with CNNs for liver CT segmentation, prostate MRI segmentation.

- **Self Employed** — Chennai, India
  Entrepreneur — *Jun 2016 - Sep 2017*

- Cooking Robot

- Envisioned a system with two robotic arms and a camera, which can perceive the kitchen environment and dexterously manipulate objects, to autonomously prepare food.
- Initially, considered classical computer vision based perception, and planning and control based manipulation. As I researched further, came across deep learning and RL for the first time. Learnt the fundamentals of deep learning, with a focus on vision related architectures such as CNNs. Worked on representative problems such as CIFAR-10 classification. Learnt the fundamentals of RL. Worked on representative problems in tabular RL such as grid world, random walk and implemented algorithms such as TD(λ), value-iteration, SARSA, Q-learning etc. Worked on representative problems in deep RL such as Cartpole, Mountain Car and implemented DQN. Explored relevant papers in deep learning and RL.
- Decided to go with deep learning based perception and RL based manipulation for the cooking robot. As I worked on the details, I gradually understood that it was a tough problem and that deep learning based perception was a relatively well-developed area, while RL based manipulation was still in its early stages. Hence, I decided to not pursue the project further.

- **Airwood Pvt Ltd** — Chennai, India
  Intern — *Dec 2014 - May 2015*

- Flight Controller for Quadrotors

- Worked towards developing a flight controller for quadrotors. Worked on state estimation algorithms to estimate the quadrotor's state from noisy IMU data and PID based control algorithms to fly it.
- Owned all aspects of development - software and hardware. Extensively performed flight tests.

Projects

- Mixed State Entanglement in Quantized Chaotic Systems (Master's Thesis) Link

Research Guides : Prof. Arul Lakshminarayan, Department of Physics, IIT Madras
Prof. Sandipan Bandyopadhyay, Department of Engineering Design, IIT Madras

- Many physical systems in nature exhibit chaos when treated classically. The same systems when treated quantum mechanically exhibit quantum chaos. Quantum entanglement is a phenomenon where many particles interact in ways such that, given a quantum state for the system as a whole, each particle cannot be assigned a single state vector. Quantum chaos is known to impact entanglement in a non trivial manner. Whether it will potentially aid or hinder a quantum computer remains unanswered. Almost all previous work on entanglement in quantized chaotic systems have dealt only with pure states. In reality, even a carefully prepared and isolated system tends to interact with its environment, which has the effect of leaving it in a mixed state. Thus, the study of mixed state entanglement in quantized chaotic systems forms an important and unexplored problem.
- Considered a prototypical system, the quantum coupled standard map. Studied its entanglement under time evolution for initial states that are mixed, for different interaction strengths between the sub-systems and different dimensions of the surrounding environment.
- Found that, for a given interaction strength, as we increase the environment dimension, the tendency to get entangled reduces and there exists a critical dimension in most cases beyond which, the state remains separable at all times. Such a phenomenon is potentially a problem in situations where entanglement is desirable, such as in quantum computing.

- RL Repository (Link)

- Implemented RL algorithms such as DQN, A3C, DDPG, MADDPG, PPO, SAC, etc, from scratch in Pytorch. Tested the implementations on tasks from OpenAI Gym, Deepmind Control Suite. Open sourced the code on Github.

- Chaotic Dynamics in Robotic Manipulation (Course Project)

- Studied chaotic dynamics in robotic manipulation that can occur for certain values of controller gains and model mismatch.
- Simulated a parallel manipulator, a planar 5-bar, to track a periodic trajectory. Calculated Lyapunov exponents and plotted phase space plots to identify chaotic dynamics.

- Mechatronics / Embedded Systems

- Worked on a few projects that involve both software and hardware, such as wheeled robot, automatic transmission for a geared bicycle, electric assisted bicycle, WiFi based control of electric home appliances, dimmer circuit for incandescent light bulbs, etc, as a hobby.

Skills

- **Operating Systems** - Linux, Windows
- **Programming Languages** - Python, C, C++
- **Deep Learning Frameworks** - Pytorch
- **Scientific Computing** - Numpy, Scipy, Mathematica, Matlab
- **Visualization Tools** - Matplotlib, Tensorboard
- **Robotic Frameworks** - ROS
- **Robotic Simulators** - Mujoco, Deepmind Control Suite, OpenAI Gym, Airsim, Gazebo
- **Development Tools** - SSH, Docker, Git
- **Microcontrollers** - Arduino, NodeMCU
- **CAD** - Autodesk Inventor
- **Document Preparation** - Latex, Microsoft Office

Awards and Scholastic Achievements

- Awarded the NTSE (National Talent Search Exam) scholarship by NCERT, Government of India in 2007.
- Awarded the KVPY fellowship by Department of Science and Technology, Government of India in 2011.
- All India Rank 2264 in IIT-JEE (IIT Joint Entrance Examination) 2011 (total 0.5 million candidates).
- All India Rank 642, Tamil Nadu State Rank 20 in AIEEE (All India Engineering Entrance Examination) 2011 (total 1 million candidates).
- Featured in the top 300 in the National Standard Examination in Physics and subsequently participated in the Indian National Physics Olympiad in 2011.
- Cleared qualifying stages and participated in the Indian National Mathematics Olympiad in 2010 and the Indian National Olympiad in Informatics in 2009, 2010.

Relevant Course Work

- Deep Learning
- Reinforcement Learning
- Data Structures and Algorithms
- Mathematics - Calculus, Linear Algebra, Probability, Optimization, Numerical Methods etc
- Physics - Mechanics, Electromagnetism, Optics etc
- Kinematics and Dynamics of Machinery
- Analog and Digital Circuits
- Mechatronic System Design
- Modern Control Theory
- Mechanics and Control of Serial, Parallel Robotic Manipulators
- Vehicle Dynamics

Teaching

- Teaching Assistant for Reinforcement Learning course at Department of Computer Science and Engineering, IIT Madras in 2022.
- Teaching Assistant for Electronics Lab, CAD Lab courses at Department of Engineering Design, IIT Madras in 2015-16.