

IN2349 ADLR: Project Ideas

April 29, 2020

Here you can find a number of ideas for projects we collected. Take this as an inspiration for your own project. Some of the ideas are rather "big", meaning they could result in more than one project. After you have registered your team (including a draft proposal) you will discuss the extent of your final proposal with your assigned tutor.

1 Closing the Sim-to-Real Loop: Adapting Simulation Randomization with Real World Experience

In [Chebotar et al., 2018] an efficient method for solving the sim2real problem by iteratively adapting the simulation parameters to the real system is proposed.

- Change the experimental setup to a sim2sim setting because no real robot is available (i.e., try to adapt one simulation to a given one with unknown parameters).
- Investigate the convergence of estimated parameters.
- Investigate the influence of a broader starting distribution on the final performance.
- Investigate how re-using learned policies from previous iterations for initialization of the new network shortens training time and restrains the final performance.

2 Comparing Robustness of Learned (Quadruped Walking) Policies from Different Learning Algorithms

[?] claim that RL algorithms with stochastic policies such as SAC are able to express a much more diverse behavior compared to deterministic algorithms like DDPG. As a consequence, stochastic policies should be far more robust when deployed in a perturbed environment.

- Investigate how stochastic policies (SAC, PPO) perform in novel environments when compared to deterministic algorithms like DDPG.
- Investigate the influence of different distributions used for SAC on the performance in novel environments. Early version of SAC employ GMMs which are discarded in favor of a single Gaussian in later papers.
- Investigate the methods for a quadruped with more complex powertrain dynamics than the one used by [?].

3 Investigate Reinforcement Learning with Augmented Networks

In recent years, different methods to tackle problems in robotics have emerged. Especially for POMDPs or complex tasks that employ domain randomization for the sim2real transfer, the incorporation of LSTM cells into the network architecture leads to impressive results as shown by [?]. One downside to using recurrent architecture is the increased training complexity. Other methods like observation stacking or explicit physical parameter estimation using supervised learning are far easier to implement and train.

- [?] claim that memory augmented models exhibit 'meta-learning' behavior at test time, meaning that the policy trials the environment to adapt parameters before starting to work on the desired task itself. Investigate these claims in an environment inspired by a physical system.
- Investigate how LSTM cells, observation stacking and explicit parameter estimation perform in the same partially observable physics simulation when simple domain randomization is employed. Some task that require precise knowledge of the domain parameterization are particularly interesting

4 Generalized Hindsight for Reinforcement Learning

Generalized Hindsight for Reinforcement Learning presented by [?] combines Multi-Task Deep Reinforcement Learning with Sample-Efficient Learning.

- Design a physically inspired and meaningful task that can be used for Multi-Task learning, e.g. a more complex version of the ant environment used by [?]. This simulation can be used to learn different gaits, pranking as well as yawrate control at different speeds.

5 Comparing different methods for uncertainty estimation

Interesting methods include (but are not limited to) MC-Dropout [?] and Normalizing Flows [?]. These methods could be compared in vastly different settings.

- Investigate how the uncertainty estimation changes during the training process (relevant to RL since we generally don't update the networks until convergence before collecting more data).
- Investigate which methods are best suited for active learning in the framework proposed by [?].
- Investigate which methods perform best for DQNs in simple environments similar to the work by [?].
- Come up with your own ideas.

6 Curiosity-Driven Learning

A good starting point for projects in this area is the paper by *Large-Scale Study of Curiosity-Driven Learning* [?]. Individual projects could first reproduce some of the experiments and then:

- Compare with other curiosity "measures" (count based, predict next state, predict past action, random network distillation, reachability, goal based, and/or your own ideas).
- Extend the authors comparison to other sets of environments. One key question is whether or not there are certain characteristics that a task needs to fulfill in order to profit from curiosity-driven learning.

7 Geometric Representations in Reinforcement Learning

Note: Requires previous experience with GNNs [?].

- Modify PyBullet environments (Hopper, Walker, HalfCheetah, Ant) such that the observations contain a graph representing the robot. Use message passing network(s) in addition or instead of the MLP for value/Q function and policy in standard algorithms like PPO [?] or SAC [?].

8 AlphaZero Implementation & Tweaks

Deep dive into the AlphaGo/AlphaZero algorithm [?, ?, ?]. Pick a very small game for feasible computational & time cost and quick experimentation. Either implement from scratch or maybe get very familiar with an existing implementation. Then try variations or possible algorithm improvements.

Modification ideas:

- Refined handling of explore/exploit tradeoff in MCTS by adding Uncertainty Estimation (see section 5) in value & prior networks for better upper confidence bounds in PUCT. Can this speed up discovery of good strategies?
- Comparison to model-free RL: Does AlphaZero learn better/worse? Does this depend on environment (game) characteristics? What metrics should be compared here?

References

- [Burda et al., 2018] Burda, Y., Edwards, H., Pathak, D., Storkey, A., Darrell, T., and Efros, A. A. (2018). Large-scale study of curiosity-driven learning.
- [Chebotar et al., 2018] Chebotar, Y., Handa, A., Makoviychuk, V., Macklin, M., Issac, J., Ratliff, N. D., and Fox, D. (2018). Closing the sim-to-real loop: Adapting simulation randomization with real world experience. *CoRR*, abs/1810.05687.
- [Gal and Ghahramani, 2016] Gal, Y. and Ghahramani, Z. (2016). Dropout as a bayesian approximation: Representing model uncertainty in deep learning. In *Proc. Int. Conference on Machine Learning*.
- [Gal et al., 2017] Gal, Y., Islam, R., and Ghahramani, Z. (2017). Deep bayesian active learning with image data.

- [Haarnoja et al., 2018a] Haarnoja, T., Zhou, A., Abbeel, P., and Levine, S. (2018a). Soft actor-critic: Off-policy maximum entropy deep reinforcement learning with a stochastic actor. In *International Conference on Machine Learning*.
- [Haarnoja et al., 2018b] Haarnoja, T., Zhou, A., Ha, S., Tan, J., Tucker, G., and Levine, S. (2018b). Learning to walk via deep reinforcement learning.
- [Kipf and Welling, 2016] Kipf, T. N. and Welling, M. (2016). Semi-supervised classification with graph convolutional networks.
- [Li et al., 2020] Li, A., Pinto, L., and Abbeel, P. (2020). Generalized hindsight for reinforcement learning.
- [Louizos and Welling, 2017] Louizos, C. and Welling, M. (2017). Multiplicative normalizing flows for variational bayesian neural networks.
- [OpenAI et al., 2019] OpenAI, Akkaya, I., Andrychowicz, M., Chociej, M., Litwin, M., McGrew, B., Petron, A., Paino, A., Plappert, M., Powell, G., Ribas, R., Schneider, J., Tezak, N., Tworek, J., Welinder, P., Weng, L., Yuan, Q., Zaremba, W., and Zhang, L. (2019). Solving rubik’s cube with a robot hand.
- [Schulman et al., 2017] Schulman, J., Wolski, F., Dhariwal, P., Radford, A., and Klimov, O. (2017). Proximal policy optimization algorithms. *CoRR*, abs/1707.06347.
- [Silver et al., 2016] Silver, D., Huang, A., Maddison, C. J., Guez, A., and et.al. (2016). Mastering the game of go with deep neural networks and tree search. *Nature*, 529.
- [Silver et al., 2017] Silver, D., Hubert, T., Schrittwieser, J., Antonoglou, I., Lai, M., Guez, A., Lanctot, M., Sifre, L., Kumaran, D., Graepel, T., Lillicrap, T., Simonyan, K., and Hassabis, D. (2017). Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm. *ArXiv e-prints*.
- [Silver et al., 2017] Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., Hubert, T., Baker, L., Lai, M., Bolton, A., et al. (2017). Mastering the game of go without human knowledge. *Nature*, 550(7676):354–359.
- [Touati et al., 2018] Touati, A., Satija, H., Romoff, J., Pineau, J., and Vincent, P. (2018). Randomized value functions via multiplicative normalizing flows.