Learning-Based Quadruped Locomotion with Liquid Time-Constant Neural Networks

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Abstract *The following document fleshes out a project statement for a semester project at EPFL's Biorobotics laboratory.*

1 What are LTCs

Liquid Time-Constant Neural Networks (LTCs) [**Hasani2021LiquidTN**] are a class of time-continuous recurrent neural models. They formulation closely match the dynamical model of non-spiking neurons such as the ones observed in the neural circuits of worms such as *c. elegans* [**Lechner2020NeuralCP**]. The LTC-network formulation exhibits several desirable properties [**Hasani2021LiquidTN**]:

- they can be shown to be a universal approximator.
- They display stable and bounded behavior.
- They can be shown to express superior expressivity within a family of neural ordinary differential equations (compared to RNNs and LSTMs, according to a path-length metric).

LTCs can be trained with gradient descent, similarly to RNNs using *backpropagation through time (BPTT)*, which enables fast convergence and makes them suitable for reinforcement learning.

2 Model-Based v.s. Model-Free

The model-free v.s. model-based question is currently open and perhaps one of the most key problems in reinforcement learning (and perhaps of artificial intelligence as a whole). As of 2022, the choice between model-based and model-free presents itself as a tradeoff [**Pong2018TemporalDM**]:

- Model-based methods achieve *faster convergence* (are more data-efficient), and tend to generalize better (which especially relevant for *sim2real* transfer), at the cost of worst asymptotic convergence.
- Model-free methods show the best results in asymptotic convergence, but are more data-intensive and tend to be less robust.

3 Rough bibliography

1. From the MIT CSAIL team, on LTC networks:
- the LTC paper, [**Hasani2021LiquidTN**]
- on building a "worm brain" with LTCs [**Lechner2020NeuralCP**]
- on the worm brain circuit [**Lechner2019wormInspiredNN**].
- on causality and LTCs [**VorbachCausalNavigation2021**].

2. on model based and model free
- the alphaStar paper [**Vinyals2019GrandmasterLI**]
- temporal difference models [**Pong2018TemporalDM**]
- state of the art on on-policy methods (PPO [**Schulman2017ProximalPO**] and TRPO [**Schulman2015TrustRP**])