Department of Informatics
Institute for Anthropomatics und Robotics (IAR)
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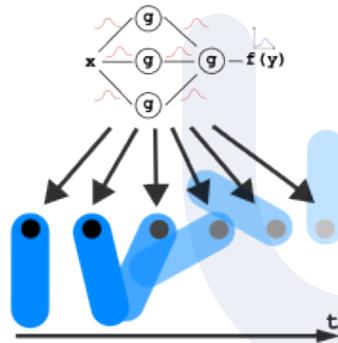https://isas.iar.kit.edu

Bachelor/Master Thesis

Filter-based Bayesian Neural Networks in Reinforcement Learning

Modern Reinforcement Learning (RL) faces a fundamental tension: the need to explore unknown states versus the requirement to mitigate risks in sensitive environments. Conventional "point-estimate" neural networks often struggle here, as they provide no measure of their own ignorance. Bayesian Neural Networks (BNNs) offer a mathematically rigorous solution by treating weights as distributions rather than fixed values, allowing for the decomposition of uncertainty into aleatoric (inherent noise) and epistemic (lack of data) components. While standard BNN training often relies on batch-based variational inference, filter-based methods (such as Extended or Unscented Kalman Filters applied to weights) allow for truly sequential, recursive updates. This project aims to leverage these "streaming" updates to build RL agents that can adapt their risk profiles in real-time as new transitions are observed.

What to do

- Analyze the intersection of BNNs and RL
- Develop or adapt a recursive filtering framework to update BNN weights sequentially.
- Implement the BNN as a probabilistic Policy (π) or Value Function (V or Q) to enable uncertainty-aware decision-making.
- Derive and implement risk-aware control laws that utilize the BNN's uncertainty estimates.
- Test the agent in environments where safety and efficient exploration are paramount

Requirements
Students in Computer Science, Robotics, Electrical Engineering, Mechatronics or related. You should have a good idea of probability theory and machine learning. Experience in scientific programming in Python is welcome. Strong self-motivation, endurance and mathematical problem solving skills are expected.

Emphasis:

Theoretical Study	
Software Implementation	
Hardware Implementation	

We offer:

- excellent support and advice
- highend infrastructure
- contact to industry and research partners

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Language:

German or English