Chair for Embedded Systems

Prof. Dr. J. Henkel

Master Thesis

Online Learning for Self-Adaptive and Autonomous Embedded Systems

This thesis explores **continual learning** and online **reinforcement learning (RL)** for autonomous and self-adaptive embedded systems that can adjust their behavior to a changing environment. This can involve runtime adaptation to changing data distributions or the integration of new tasks at runtime. It has additional benefits like increased privacy and personalization. However, it also entails several challenges: The model should retain previously acquired knowledge (a characteristic known as stability), while still being able to absorb new knowledge (plasticity). Furthermore, the limited resources available to embedded devices (e.g., computational power, energy, and memory) must be considered when designing suitable algorithms.

Key research questions include:

- When to update model parameters, trading off the training overhead (time/energy) and the reduction in task performance if such an update is postponed?
- How to quantify or predict the impact of newly arrived data points on the model quality?
- How to keep an efficient summary of past data points, carrying relevant information about tasks and environmental changes while preventing excessive memory consumption?
- How to maintain safe operation in systems that explore the environment and update model parameters at runtime?

The thesis focus can be set within the context of microprocessor resource control or on the resource efficiency of the continual learning process itself.

Potential techniques investigated:

- Online RL and multi-armed bandits for decision-making with guided, adaptive, and safe exploration strategies.
- Concept drift detection, data stream algorithms, and continual learning techniques.
- NN inference optimization techniques like distillation and quantization to constrain the HW footprint of the deployed techniques.

Skills required/beneficial for the thesis:

- Programming skills and curiosity to learn about advanced concepts in machine learning.
- Experience with machine learning frameworks (PyTorch/Tensorflow) is a plus.
- Experience with continual learning, RL, or data stream algorithms is beneficial but not required.

Skills acquired within the thesis:

- In-depth understanding of machine learning for non-stationary data.
- Application of state-of-the-art algorithms for online learning and RL.
- Work in a research environment.

Language

- The collaboration with the colleagues can be in English or German.

Contact

- Benedikt Dietrich, benedikt.dietrich@kit.edu
- Dr. Heba Khdr, heba.khdr@kit.edu