Augmenting Robots with Distributed AI Capabilities

Company: Nokia Bell Labs (`https://www.bell-labs.com`)
Department: Augmented Machine Interaction, Nokia Bell Labs, Route de Villejust, Nozay, France
Supervisors: Myriana Rifai, *Research Engineer, Nokia Bell Labs*
                  Tianzhu Zhang, *Research Engineer, Nokia Bell Labs*
                  Fabio Pianese, *Group Leader, Nokia Bell Labs*
Duration: TBD
Starting date: TBD
Contact: {myriana.rifai, fabio.pianese}@nokia-bell-labs.com, tianzhu.zhang@nokia.com

Background

In recent years, a lot of research endeavors have been devoted to edge intelligence [7–9]. Indeed, by bringing Artificial Intelligence (AI) solutions to edge devices (e.g. Internet-of-Things (IoT) devices, access points), large volumes of locally generated data can be collected and analyzed to provide real-time insights [3, 10]. However, despite the proliferation of edge intelligence, little progress has been made to unleash its full potential in robotic systems. As robotic operations usually involve intricate interactions among distributed components, integrating real-time AI workloads into robotic applications imposes unprecedented pressure on both the control plane and the infrastructure. Currently, it is unclear whether existing robotics middleware can deal with this unprecedented AI pressure and how they can efficiently integrate real-time AI techniques such as Reinforcement Learning without introducing delay or impairing system integrity and performance.

Objective

In this project, we will benchmark real-time robotics middleware for AI-enabled applications. The study aims at comparing the communication and computation performance of these middleware under the classical robotic control traffic vs. real-time AI-generated workload. Using the study results, we will select the best AI-workload-friendly middleware and extend its functionalities to enable the integration of distributed Reinforcement Learning within the robotic system. The resulting middleware is expected to support AI-based robotics applications without degrading the reliability and performance of the robots. This work will be conducted under the support of an international research team. Sound experimental results and prototype implementations can be considered for future publication in prestigious international conferences or journals.

Tasks

- Develop a comprehensive understanding of realtime robots middlewares (e.g. ROS2 DDS [4], Fast RTPS [1], RoboFrame [5]).

- Benchmark the performance of a selected set of real-time middleware under AI generated communication and computation workload.

- Propose a design method to extend existing middleware to integrate distributed AI solutions (e.g. reinforcement learning).

Required skills

- Solid background on academic research and system development. Familiar with programming languages including Python, C, and C++.

- Experience with robotic systems (e.g., ROS [6]).

- Fundamental understanding of Reinforcement Learning.

- Knowledge of network softwarization [2] and edge computing is a plus.

- Fluent communication in English.

References

[1] Fast-rtps. `https://fiware-academy.readthedocs.io/en/latest/robotics/fast-rtps/index.html`, 2020.

[2] Ibrahim Afolabi, Tarik Taleb, Konstantinos Samdanis, Adlen Ksentini, and Hannu Flinck. Network slicing and softwarization: A survey on principles, enabling technologies, and solutions. *IEEE Communications Surveys & Tutorials*, 20(3):2429–2453, 2018.

[3] En Li, Zhi Zhou, and Xu Chen. Edge intelligence: On-demand deep learning model co-inference with device-edge synergy. In *Proceedings of the 2018 Workshop on Mobile Edge Communications*, pages 31–36, 2018.

[4] Yuya Maruyama, Shinpei Kato, and Takuya Azumi. Exploring the performance of ros2. In *Proceedings of the 13th International Conference on Embedded Software*, pages 1–10, 2016.

[5] Sebastian Petters, Dirk Thomas, and Oskar Von Stryk. Roboframe-a modular software framework for lightweight autonomous robots. In *Proc. Workshop on Measures and Procedures for the Evaluation of Robot Architectures and Middleware of the 2007 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, 2007.

[6] Morgan Quigley, Ken Conley, Brian Gerkey, Josh Faust, Tully Foote, Jeremy Leibs, Rob Wheeler, and Andrew Y Ng. ROS: An open-source robot operating system. In *ICRA workshop on open source software*, volume 3, page 5. Kobe, Japan, 2009.

[7] Amir M Rahmani, Pasi Liljeberg, Jürgo-Sören Preden, and Axel Jantsch. *Fog computing in the internet of things: Intelligence at the edge*. Springer, 2017.

[8] Ke Zhang, Yongxu Zhu, Sabita Maharjan, and Yan Zhang. Edge intelligence and blockchain empowered 5g beyond for the industrial internet of things. *IEEE Network*, 33(5):12–19, 2019.

[9] Yin Zhang, Xiao Ma, Jing Zhang, M Shamim Hossain, Ghulam Muhammad, and Syed Umar Amin. Edge intelligence in the cognitive internet of things: Improving sensitivity and interactivity. *IEEE Network*, 33(3):58–64, 2019.

[10] Zhi Zhou, Xu Chen, En Li, Liekang Zeng, Ke Luo, and Junshan Zhang. Edge intelligence: Paving the last mile of artificial intelligence with edge computing. *Proceedings of the IEEE*, 107(8):1738–1762, 2019.