Towards hierarchical and distributed run-time monitors from high-level query languages

Márton Búr, Dániel Varró

Context. A *cyber-physical system (CPS)* consists of computation, communication and control components tightly combined with physical processes of different nature, e.g., mechanical, electrical, and chemical [1]. Compared to traditional embedded systems, key characteristics of a CPS include a (1) *massive number of heterogeneous nodes* ranging from cheap, low-energy smart devices to mobile phones to high-end cloud-based servers, (2) *adaptability to conditions* that differ significantly from the ones they were designed for (new requirements, new services, new platforms, failures) in dynamic environments, while (3) *delivering critical services in a trustworthy way*. Such systems include autonomous and connected cars, smart healthcare devices, smart factories, smart homes or smart cities.

Problem statement. Due to their dynamic nature, the assurance of smart and trusted CPS typically relies on run-time verification, which aims to check if their execution at run-time meets its requirements [2]. For instance, the data provided by force torque sensors and tactile sensors of an automated robot arm can be evaluated to decide if the arm is in a dangerous situation. High-level property languages are increasingly used for specifying complex structural conditions of the system. These properties are either evaluated over run-time models (which are directly connected to the system itself) or they serve as an input for synthesizing run-time monitors for a heterogeneous platform. However, due to resource constraints of these devices (e.g. CPU, memory, energy) and the continuously evolving platform and services, the deployment of hierarchical monitors to such a target platform is a very challenging task.

Objectives. In this line of research, we aim to continuously evaluate properties captured in high-level query languages over run-time models by deploying them over a heterogeneous platform for run-time verification purposes. While efficient incremental and search plan-based query optimization techniques have been developed in model-driven engineering [3] as well as for graph databases [4], their application in an environment with strict resource constraints and soft real-time requirements is a major challenge. As a first step, we illustrate these challenges in the context of the MoDeS3 demonstrator [5] developed for the Eclipse IoT Challenge 2016.

References

[1] Baheti, Radhakisan, and Helen Gill. "Cyber-physical systems." *The impact of control technology* 12 (2011): 161-166.

[2] Medhat, Ramy, et al. "Runtime Monitoring of Cyber-Physical Systems Under Timing and Memory Constraints." *ACM Transactions on Embedded Computing Systems (TECS)* 14.4 (2015): 79.

[3] Horváth, Ákos, Gergely Varró, and Dániel Varró. "Generic search plans for matching advanced graph patterns." *Electronic Communications of the EASST* 6 (2007).

[4] Schmidt, Michael, Michael Meier, and Georg Lausen. "Foundations of SPARQL query optimization." *Proceedings of the 13th International Conference on Database Theory.* ACM, 2010.

[5] MoDeS3 Project. http://inf.mit.bme.hu/en/research/projects/modes3