Self-adaptive cyber-physical systems utilizing different machine learning techniques

Naum Gjorgjeski

October 2017

Examiner: Alexander Pretschner
Advisor: Ana Petrovska

1 Abstract

Cyber-physical systems (CPS) operate in a dynamic environment, in which they have to deal with many uncertainties. In order to mitigate the faults caused by specific uncertainties, we must be aware of their origins. The uncertainties could stem from different phases in the development or operation of the CPS and may be mitigated differently. Most of the uncertainties which affect the CPS originate from the requirements, design or runtime phase [3]. The runtime uncertainties themselves could again stem from various environments: the physical environment, the cyber environment or the CPS itself [1]. For example, uncertainties may appear when a CPS experiences new unforeseen situations in its physical environment or from unwanted interactions between different components within the CPS [1]. Again, runtime uncertainties with a different origin might require different approaches for fault mitigation.

The uncertainties may lead to faults and drive the CPS into a wrong state. The faults may further result in failures, making the CPS non-operational. We want to make the CPS self-adaptive without significantly affecting the system performance and to mitigate the faults at runtime, so that the normal operation of the system is not interrupted.

There are two notions of fault mitigation for CPS. First, fault mitigation can be understood as prevention, i.e. developing techniques to prevent the CPS of getting into a faulty state at all. The second notion of fault mitigation is reconfiguration. Once a fault in the CPS has occurred, we want the system to be able to recover and return into a normal state autonomously. In the notion of reconfiguration, a prerequisite for fault mitigation is fault detection, i.e. to mitigate a fault we must first detect that the fault has occurred [2]. Fault detection in CPS at runtime is not an easy task and is an active research area. We would assume that faults can be detected and fault detection would not be a focus of our research.

With the recent advancements, machine learning has found its applications in various disciplines and areas. However, the full potential of machine learning techniques for fault mitigation hasn't been utilized and we would like to contribute to this field. A CPS should be able to learn from its previous experiences and reconfigure without human intervention. A big challenge is that the reconfiguration should be done in runtime. This means that the used machine learning techniques should be efficient and preserve the functional and non-functional requirements of the CPS.

In this guided research, we would first summarize the state-of-the-art in the field of self-adaptive CPS which utilize machine learning techniques. By analyzing the state-of-the-art in this field, we can identify potential research gaps, which would help us in proposing a new technique.

References

[1] Betty H. C. Cheng, Andres Ramirez, and Philip K. McKinley. "Harnessing Evolutionary Computation to Enable Dynamically Adaptive Systems to Manage Uncertainty". In: *Proceedings of the 1st International Workshop on Combining Modelling and Search-Based Software Engineering*. CMSBSE '13. San Francisco, California: IEEE Press, 2013, pp. 1–6. ISBN: 978-1-4673-6284-9. URL: http://dl.acm.org.eaccess.ub.tum.de/citation.cfm?id=2662572.2662574.

[2] Martin Leucker and Christian Schallhart. "A Brief Account of Runtime Verification". In: *Journal of Logic and Algebraic Programming* 78.5 (May 2009), pp. 293–303. URL: http://dx.doi.org/10.1016/j.jlap.2008.08.004.

[3] Andres J. Ramirez, Adam C. Jensen, and Betty H. C. Cheng. "A Taxonomy of Uncertainty for Dynamically Adaptive Systems". In: *Proceedings of the 7th International Symposium on Software Engineering for Adaptive and Self-Managing Systems*. SEAMS '12. Zurich, Switzerland: IEEE Press, 2012, pp. 99–108. ISBN: 978-1-4673-1787-0. URL: http://dl.acm.org/citation.cfm?id=2666795.2666812.