Learning-based Approaches for Taming Uncertainty in Self-Adaptive Software Systems

Research team

The Ph.D. student will join the Spirals Research Group. Spirals is a joint project-team between Inria and University of Lille within UMR 9189 CRIStAL.

Spirals Research Group - https://team.inria.fr/spirals/

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Context

Software systems are, more than ever, forced to deal with change. Recently, cloud computing and Internet-of-Things have emerged, where various devices are connected together and controlled through the Internet. These paradigms have promoted the seamless integration of the digital and physical worlds, where massively distributed, software-intensive, external systems composed of sensors, devices, and software services collaborate together with people and adapt to their needs to support key societal activities: health, transportation, education, finance, and so on. These systems also come up with a high variability − they propose several different configurations − and can modify their behavior at runtime by switching from a configuration to another depending on changes in their environment, *i.e.,* by performing self-adaptation [1]. When developing a system's self-adaptation logic, software developers have to anticipate (at design time) the possible changes that a self-adaptive system may encounter at run time to define which situations the system should be able to handle by means of self-adaptation. However, anticipating all relevant changes at design time is not straightforward, or may even be impossible, due to incomplete knowledge (*aka*. uncertainty) about the system environment [2]. For instance, developers may not know about services and their actual quality provided during run time, about the availability of sensors during system operation to obtain environment information, about the availability of other systems to interact and cooperate with, or about the amount and quality of data obtained. In addition, software developers have to determine how the system should modify itself to handle these possible changes, *i.e.,* how it should evolve. Yet, this requires the difficult understanding of how a modification of the system impacts on its behavior and quality. Software developers thus may make assumptions during design time which are violated at run time. As a result, a self-adaptive system may encounter situations that have not been fully understood or anticipated, thus leading to ineffective adaptations. Uncertainty software developers face is thus twofold: uncertainty about possible run time configuration changes (adaptation) and uncertainty about future system modifications (evolution).

Research agenda and objectives

While software evolution and software self-adaptation have been widely studied by the software engineering community [3], evolution of self-adaptive systems still remains an unexplored research direction. Yet, like any software systems, self-adaptive systems may undergo evolution (for bugs fixing, maintenance, adding new functionalities, etc.). Our objective is thus to understand what kind of uncertainty is brought by evolution – both in the system and the context, how complex and uncertain this uncertainty actually is, and what knowledge can be learned from this uncertain space for then being reused in future adaptations. That is, we aim at providing means for automatically expanding the system's self-adaptation capabilities at run time by continuously pushing back the border between the certain space and the uncertain one, thus making the system more and more autonomous.

First, the thesis will start by providing a systematic literature review of learning-based approaches for self-adaptive systems (*e.g.,* see [4]). A particular attention should be paid to systems from highly-configurable environments such as cloud-based systems, cyber-physical systems or Internet of Things. This work will serve as basis to understand what kind of uncertainty can be learned, and how it can be reused to improve the adaptation logic. Then, the work will focus on applying a suitable learning technique for updating the system's adaptation logic by reasoning on the impact of evolution of the system, *i.e.,* by learning how the adaptation logic was updated after evolution occurred, depending on which "region" of the system was evolved, and how. This would also be interesting to investigate how evolution or uncertainty in the system's context triggers evolution of the system (to deal with unanticipated changes), in order to understand how learning techniques could help the developers anticipate future evolution. Developers would greatly benefit from such an approach, that could be used to perform predictive adaptations or relate context with particular system's features to improve its performance. The research conducted during this work clearly fits within the scope of the self-adaptive systems community and its related annual venue, the SEAMS symposium [5].

References

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[4] Moeka Tanabe, Kenji Tei, Yoshiaki Fukazawa, and Shinichi Honiden. 2017. Learning environment model at runtime for self-adaptive systems. In *Proceedings of the Symposium on Applied Computing* (SAC '17), pp. 1198-1204.

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