A Guide to Support Uncertainty Awareness During Designing Self-Adaptive Cyber-Physical Systems

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Abstract Cyber-physical systems (CPS) are emerging in everyday lives. Essential properties of CPS include the ability to observe its environment or monitor an associated physical process, the ability to perform computations to reach decisions, and the ability to influence its environment or the associated physical processes. Comparing to embedded systems that are a combination of hardware and software for fixed functionality and Internet of Things (IoT) that connects objects, CPS involves interaction between computation and physical components allowing the system to adapt to environmental changes.

Designing a Cyber-Physical System (CPS) requires a multi-disciplinary knowledge and multiple modeling paradigms for the development process stages such as gathering requirements, architecture design, and simulation. Looking into the CPS characteristics, the heterogeneity, and the collaborative behavior are sources of many inherent uncertainties, which have varying impact on the system behavior. In some cases, components in the system need to adapt to environmental changes and collaborate to satisfy the system requirements. Without proper management of the uncertainties, the decision-making process in the components is compromised and could even lead to faulty behavior. Thus, the developers need to ask the right questions to collect and trace the information needed for the system to make the right adaptation decisions at runtime. Consequently, the developers need guidance to properly support uncertainty awareness in the self-adaptive CPS components.

To help the developers, we present a guide that we have developed based mainly on the information extracted from the systematic review performed over EU projects. The guide links high-level and low-level concepts that need to be considered by developers. It describes a step-by-step process for designing uncertainty-aware CPS components. When following the guide, the developers will acquire the information needed to determine the impact of uncertainties in the adaptation decisions and select the appropriate methods to handle the uncertainties in the design of autonomous components.

Keywords cyber-physical system, self-adaptive systems, cooperative behavior, uncertainty