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Learning Models of Cyber-Physical & Black-Box Systems

Cyber-Physical Systems (CPS) consist of embedded digital devices while interacting with their physical environment. Typical examples range from simple heating systems over robotic subsystems to highly complex control systems, e.g., industrial production systems or particle accelerators and their subsystems. Understanding and modeling these systems is difficult because they consist of multiple, often proprietary subsystems for which information on the inner functionality is unknown or incomplete. Thus, many CPS are Black-Box systems for which the inner functionality is unknown. Our goal is to learn models as discrete abstractions of CPS which make their functionality and environmental dependencies understandable. Apart from design understanding such models are needed for, e.g., test, monitoring, or debugging. Creating models of CPS manually is time consuming and difficult because of their interaction with the environment which relies on diverse physical signals. For Black-Box systems manual modeling is not even possible.

We consider methods to learn abstract models of CPS from observation of the system. A well established approach is automata learning which provides already a deep theoretical understanding. Extensions of common automata learning exist regarding timing (timed automata), continuous behavior over discrete modes (hybrid automata) or probabilistic behavior (probabilistic automata). We aim at analyzing and extending these approaches based on case studies. Automata learning results in exact models which is not always useful because CPS often show non-deterministic behavior and observations are disturbed by noise. Furthermore, automata learning requires to reset the system to an initial state before observation. These requirements rarely are realizable in practice. Thus, we develop a new modeling approach based on decision tree learning which allows to tackle both of the above described problems by using observations of bounded history. Our experimental results have already shown a performance superior to automata learning under practical restrictions and indicate possibilities for modeling continuous systems.

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