Structured Simulation: A Framework for the Automated Analysis of Adaptive Systems

Project abstract

In current research e.g. in the field of intelligent traffic systems (ITS) or control schemes for (distributed) smart grids one of the most preferred approaches is to rely on *adaptive systems* for implementing control schemes. In the following we consider an **adaptive controller** as a control scheme that can change its behavior based on the diferent states of environments it has operated in its past, and a given objective function the controller has to optimize. Such adaptive controllers can be implemented by different techniques, like model-predictive control, machine learning techniques in general, AI-based planning, or Multi-Agent based systems, which can cause effects by emergence.

The behavior of adaptive systems are on the one hand influenced by the perceived state of it environment, as well as the entire history of perceived states that the controller has acted in. Thereby the state of the environment can be encoded in several dimensions, with a potential large domain of possible values for each dimension. Thus providing a formal proof, that can guarantee that the controller will not show any unexpected or undesired behavior becomes virtually impossible. In particular for domains like smart grids or traffic, where the environment is a socio-technical system, and currently no closed models exists.

Consequently within the project *Structured Sim* we follow a different approach, applying simulations in a structured way, to increase confidence in adaptive controllers. Simulation studies needs to be structured along two aspects.

- Simulation runs in complex domains like traffic or smart grids can become very complex and therefore computational hard. Thus an exploration of different environmental states cannot be achieved with a Monte-Carlo like sampling of the space of potential environments, as this will computational intrackteable. Thus, the space of potential environments that an adaptive controller will face have to be explored in a *structured way* to increase the value of potential analyzes with a smaller amount of simulation runs. Therefore scenarios needs to be generated depending on the probability in which they are likely to occur. This strategy allows for an exploration of the most probable scenarios an adaptive controller will face.

- The behavior of an adaptive controller depends on the history of environmental states the controller has perceived. Thus to evaluate the performance of an adaptive controller the different traces of environmental states needs to be created. The number of potential traces can be considered as countable infinite, and therefore a *structured* way to create traces of environmental states, and evaluate the behavior of the adaptive controller that has perceived a particular trace of environmental states.

The goal of the *Structured Sim* project is to create a framework that is capable of creating and running structured simulation studies, as outlined above. As it is important for the development of frameworks and in particular it's interface, we will together with partners develop first prototypical mappings of the framework's interface to simulation systems. This is necessary to refine and validate the interface design of the framework. The application domains will use domain specific simulation systems from the domains of smart grids, traffic, and social simulation.

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