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Modeling, simulation and emulation of Intelligent Domotic Environments

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ABSTRACT

Intelligent Domotic Environments are a promising approach, based on semantic models and commercially off-the-shelf domotic technologies, to realize new intelligent buildings, but such complexity requires innovative design methodologies and tools for ensuring correctness. Suitable simulation and emulation approaches and tools must be adopted to allow designers to experiment with their ideas and to incrementally verify designed policies in a scenario where the environment is partly emulated and partly composed of real devices.

This paper describes a framework, which exploits UML2.0 state diagrams for automatic generation of device simulators from ontology-based descriptions of domotic environments. The DogSim simulator may simulate a complete building automation system in software, or may be integrated in the Dog Gateway, allowing partial simulation of virtual devices alongside with real devices.

Experiments on a real home show that the approach is feasible and can easily address both simulation and emulation requirements.

1. Introduction

Intelligent Domotic Environments (IDE), i.e., “environments where commercial domotic systems are extended with a low cost device (embedded PC) allowing integration and interoperation with other appliances, and supporting more sophisticated automation scenarios” [1,2], currently promise to achieve advanced intelligence at a relatively low cost, enabling the creation of new building automation scenarios, with much more complex behavior and functionality. The design of such complex systems involves a high number of often conflicting aspects, which include user experience and satisfaction, intelligent behaviors and automated scenarios. Designers should be able to grasp a good understanding of the possible interactions between systems contributing to an IDE design (automatic plants, complex devices, control algorithms, context-dependent scenarios, and the users), and of the modalities with which such interactions will affect the overall correctness and effectiveness of designed solutions. In particular, both modeling tools (for expressing design requirements and programming system behaviors) and validation tools (for simulating different scenarios before actually implementing the system) are a necessary addition to the toolkits of system designers and integrators.

In the literature, very few works address this problem (a short survey is provided in Section 2) and most design methodologies heavily rely on individual designer's experience. To provide a more structured support to the design and test of automation and intelligence for domotic environments, sounder approaches should be developed, based on formal models, property checking, test pattern generation, and simulation based techniques.

Among these approaches, the ability to simulate domotic devices is useful in different design phases (see Table 1): in the preliminary design, a software model of the whole building automation system may be simulated for validating the overall design and the complex interactions that arise when combining advanced devices and control strategies. On the other hand, several scenarios (such as upgrading an existing system or evaluating a new component) require the interaction of real devices with simulated ones: in these cases, simulators must be generated only for the ‘missing’ devices, while interaction with real devices is provided by the house gateway (emulation).

To clarify the terminology adopted in the paper, we refer to simulation when all represented devices are “virtual” and their execution is done in a completely controlled context, i.e., inside simulation software, such as DogSim [3].Emulation, sometimes called “Hardware In the Loop simulation,” on the other hand, involves at least one real device, i.e., the Home Gateway, and possibly one or more controlled devices.

This paper proposes a simulation and emulation framework for intelligent environments that may be exploited over the entire IDE life-cycle, from early policy design to final on-the-field deployment. Our approach is based on the automatic generation of state charts from an ontology model (DogOnt [1]) of domotic devices, appliances,

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