# POSTER

## Preliminary Results in Virtual Testing for Smart Buildings

Julien Bruneau[1], Charles Consel[1], Marcia O'Malley[2], Walid Taha[3,2]*, and Wail Masry Hannourah[4]

[1] INRIA, Bordeaux, France, {julien.bruneau,charles.consel}@inria.fr
[2] Rice University, Houston, Texas, USA, {omalleym,taha}@rice.edu
[3] Halmstad University, Sweden, Walid.Taha@hh.se
[4] HVAC Consultant, Cairo, Egypt, wail_hannourah@yahoo.com

**Abstract.** Smart buildings promise to revolutionize the way we live. Applications ranging from climate control to fire management can have significant impact on the quality and cost of these services. However, a smart building and any technology with direct effect on the safety of its occupants must undergo extensive testing. Virtual testing by means of computer simulation can significantly reduce the cost of testing and, as a result, accelerate the development of novel applications. Unfortunately, building physically-accurate simulation codes can be labor intensive. To address this problem, we propose a framework for rapid, physically-accurate virtual testing of smart building systems. The proposed framework supports analytical modeling and simulation of both a discrete distributed system as well as the physical environment that hosts it.

**Key words:** Virtual testing, Smart buildings, HVAC, Mixed (virtual/real) world infrastructures, Energy efficiency

## 1 Introduction

Buildings are designed to achieve a wide range of goals. For example, ensuring occupant safety and health requires specialized appliances such as fire alarm systems and proper ventilation. These concerns are very real: Each year, hundreds of people die from carbon monoxide poisoning due to poor ventilation design. Similarly, ensuring occupant comfort (which is generally essential for ensuring their productivity) also requires specialized appliances. The stringent uptime requirements placed on building appliances also give rise to concerns about energy, cost, and environmental impact. Traditional technologies such as brick and mortar, standard heating and airconditioning units, have all been carefully scrutinized with respect to their impact on all of these goals, and have passed the test of extended timelines.

**Smart Buildings.** Recently, there has been an increasing interest in smart building technologies. Such technologies bear a promise to revolutionize the way we live. Applications ranging from climate control to fire alarm systems, to lighting management, to security systems can be found in smart buildings.

Intrinsic to the idea of smart buildings is the introduction of higher levels of active control into the traditional components of a building. Higher levels of active control are achieved by the use of more sophisticated control algorithms, more extensive sensing of the physical environment, more actuation of various

* Funded by National Science Foundation (NSF) Embedded and Hybrid Systems (EHS), award number 0720857

physical subsystems, and more communication between different components of the system. However, because of the direct impact that buildings have on humans and on their resources, smart building technologies must be held to stringent standards for correctness, availability, and a wide range of other software quality considerations.

**Virtual Testing.** Testing is a crucial tool for eliminating poor designs, and developing a degree of confidence in promising designs. Testing is equally important for traditional physical design and design involving active control. But testing smart building technologies in physical buildings can be slow and prohibitively expensive. Addressing these two problems can accelerate the rate of innovation and deployment of successful smart building applications. In particular, using computer simulations to carry out some part of the testing virtually can help achieve this goal.

## 2 Our Approach

The goal of our approach is to address three technical challenges that must be overcome in order to enable effective virtual testing of smart buildings. The first is to accurately capture the distributed and networked nature of the active devices in the system. The second is to accurately capture the physical properties of the building. The third is to automatically map such models directly to executable simulation codes.

Existing approaches only cope at most with one of the three challenges raised by the virtual testing of smart buildings. For instance, MATLAB/Simulink [1] allows to simulate active devices but does not attempt to use analytically sound models of the physical environment surrounding such devices. Numerous existing approaches allow to model and execute this physical environment [2, 3]. However, they do not allow the modeling of active devices.

By addressing these three challenges, our approach makes smart building systems easier to write, more reliable and safer:

- The active components of smart homes are modeled explicitly in DiaSpec [4], a domain-specific language with specialized support for the modeling of active systems.
- The complete models, containing both physical models and active system models, are mapped to executable codes. This is achieved by combining (1) the simulation capability of Acumen [2], a physical environment modeling tool, and (2) the DiaSim simulator [5].
- Virtual experiments using different building models and control strategies can be analyzed.

## References


1. Simulink. `http://www.mathworks.com/products/simulink/`.
2. Y. Zhu, E. Westbrook, J. Inoue, A. Chapoutot, C. Salama, M. Peralta, T. Martin, W. Taha, M. O'Malley, R. Cartwright, A. Ames, and R. Bhattacharya. Mathematical Equations as Executable Models of Mechnical Systems. In *ICCPS 2010*.
3. M. Tiller. *Introduction to Physical Modeling With Modelica*. Kluwer Academic Publishers, 2001.
4. D. Cassou, B. Bertran, N. Loriant, and C. Consel. A generative programming approach to developing pervasive computing systems. In *GPCE '09*, October 2009.
5. J. Bruneau, W. Jouve, and C. Consel. Diasim, a parameterized simulator for pervasive computing applications. In *Proceedings of Mobiquitous'09*.