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AN APPROACH TO MODELING INTERNET OF THINGS BASED SMART BUILT ENVIRONMENTS

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ABSTRACT

Smart built environments enhanced with technology can improve the lives of individuals, groups, and the broader community. We describe an approach to modeling IOT-based smart built environments that uses a large-scale virtual environment where a building model is aligned with the physical space. This approach takes advantages of affordances and embodied cognition in a large physical space to model user interaction with built spaces. The built space contains 'smart objects' with embedded sensors/actuators/controllers (e.g., kitchen appliances). A 'smart object' has the corresponding virtual object in the virtual environment. A case study (FutureHAUS) demonstrates the proposed approach.

1 INTRODUCTION

New sensor, mobile, and control technologies have great promise in connecting users to their environment. Smart built environments (e.g., a smart house) enhanced with technology can support better living to improve the lives of individuals, groups, and the broader community, including increased awareness of information in the user's surroundings, integrated control over factors in one's surrounding and home environments, and increased ability to support sustainable living for both individuals and groups.

The concept of Internet of Things (IoT) (Atzori, Iera, and Morabito 2010) describes the pervasive presence of things or objects which use a unique addressing scheme to interact with each other and cooperate with their neighbors to reach common goals. These physical objects have a social existence that could be supported through the IoT. The applications of IoT range from automation and manufacturing to assisted living and e-health. Designing and deploying IoT into the built environments provides capacities that can change how systems behave and how users interact with them. IoT could support sustainability through design, simulation, planning, monitoring, optimization, and visualization tools.

2 APPROACH

We describe an approach to evaluation of IoT-based built environments using a large-scale virtual environment (VE) where a building model is aligned with the physical space. This approach takes advantages of affordances

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and embodied cognition in a large physical space to model user interaction with built spaces. We build on the preliminary work (Gračanin, Eck II, Silverman, Heivilin, and Meacham 2014) that uses Virginia Tech's Cube facility (http://www.icat.vt.edu/facilities/living_labs), an enclosed space 50x40x40 feet with real-time tracking and spatial audio capabilities. Several users can simultaneously move in the physical space and view the simulation results from different points of view. The physical location and orientation of a user is used in real-time to determine the corresponding view in the VE. The user can also observe other users and collaborate to change the simulation.

The modeling framework (Figure 1a) provides a connection between the real world IoT-based collection of devices, sensors, and actuators and the corresponding virtual world representations. Each sensor is modeled based on the set of the corresponding environmental and control parameters. The corresponding VE is constructed by creating the list of devices; identifying, for each device, its physical characteristics for modeling purposes; identifying the set of virtual sensors that will produce virtual data streams; identifying the basic functionalities of the device (e.g., turn on and turn off) and related actuators; identifying the virtual actions that the device can perform through the virtual actuator; representing the devices in the VE; and syncing with the IoT middleware.

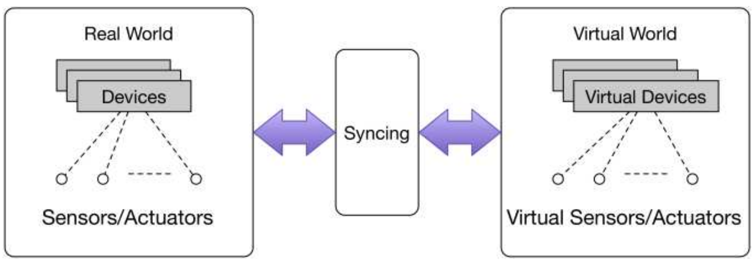

Figure 1: a) Modeling framework. b) FutureHAUS kitchen and living room.

A case study, Virginia Tech's FutureHAUS (http://www.vtfuturehaus.org) prototype (Figure 1b) was used to test the proposed approach. The components can be accessed and controlled through a whole-house interface which manages and monitors appliance performance and energy use. The initial architectural model was used to construct the corresponding VE that was then refined based on the user feedback. Two FutureHAUS modules, the kitchen and the living room, were designed and constructed through this process. The kitchen and living room are "wired" with IoT-based electronic actuators and sensors that make using the living space easy, more accessible and energy efficient. The case study was exhibited at the Kitchen and Bath Show (January 2015, Las Vegas, the kitchen module) and 2015 American Institute of Architects Convention (May 2015, Atlanta, the kitchen and the living room modules). The results are currently being used to construct the next module, the bathroom.

The goal is to integrate smart technologies into a prefabricated system while elevating the human experience of all household activities: shopping, cooking, and socializing. One of the main challenges is how to quickly develop sufficiently accurate physical models of individual appliances and other devices. We are extending our work to construct and model the other parts (modules) of the house. The ongoing work proceeds in several directions, including preparing user studies and exploring additional application domains, such as manufacturing systems, and training.

REFERENCES

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