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AN INFRASTRUCTURE FOR EXPERIENCE CENTERED AGILE PROTOTYPING OF AMBIENT INTELLIGENCE

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ABSTRACT

As ubiquitous computing, particularly smart environments, become more feasible early assessment of alternative solutions will be required before costly deployment. We propose the use of prototyping frameworks that will allow the simulation of alternatives. This work presents APEX, a development framework that combines a 3D Application Server with a Petri nets modeling tool. This new way of prototyping helps the developer understand how the user might experience the system. The proposal is that prototyping is supported by three different layers: a simulation layer (using the 3D Application Server); a modeling layer (using the Petri nets modeling tool) and a physical layer (using external devices and real users). Using a prototyping approach, APEX makes it possible to move between these layers to analyze different features, from user experience to user behavior through exhaustive analysis of the ubiquitous system. The multi layer approach makes it possible to express user behavior in the modeling layer, providing a way to reduce the real number of users needed while at the same time testing specific user behaviors and performing exhaustive analysis.

INTRODUCTION

Prototyping ubiquitous computing environments has the potential to reduce development cost by allowing early assessment of alternative design solutions. We are particularly interested in ubiquitous computing environments that are designed to enhance physical environments by using “spaces” augmented with sensors and dynamic objects (e.g. public displays, personal devices). These dynamic objects react to both explicit and implicit interactions, and to context changes, to provide services to users in the environment.

THE APEX FRAMEWORK

The APEX framework is designed to support prototyping through three stages:

1. A 3D simulation of the environment is created in a “virtual world” using a web based 3D application server (OpenSimulator[1]). The animation of the 3D simulation is based on the behavioral models produced in the second stage.

2. The behavior of ubiquitous computing devices (sensors, screens, etc.) is modeled rigorously using CPN (Colored Petri Nets) [1].

3. External (physical) devices can be connected to the virtual world via Bluetooth as the prototype development progresses. Users can interact (both explicitly and implicitly) with the environment’s prototype by controlling avatars located in the virtual world. They can use the avatars or can act as users directly by manipulating physical handheld devices. Using the model based simulation it is possible both to analyze the system rigorously using the model and to observe user reaction to the system.

These three stages correspond to the three layers of behavioral representation supported by the APEX prototyping environment (from more abstract to more concrete): behavior expressed as CPNs in the behavioral model (the modeling layer); programmed/encoded in the 3D simulation (the simulation layer); as an external “device” connected to the simulation (the physical layer).
Each layer supports a specific type of evaluation: analysis of the model (in the modeling layer); observation of virtual objects’ behavior, and user reaction to them, within a virtual world (in the simulation layer); observation of real objects (for

[1] http://opensimulator.org/wiki/Main Page

example, actual smart phones) connected to the virtual world, and users reaction to them (in the physical layer).

The behavior of users within the environment can be captured by actual users interacting with the simulation at physical layer and used as a basis for analyzing underlying models. The representation and simulation of users is accomplished by avatars at the simulation layer. User behavior is captured more abstractly as tokens at the modeling layer. Open simulations, i.e. simulations where actual users interact can be used to run user testing sessions to acquire user feedback. This feedback data may be collected and later "mechanically" analyzed (e.g., by comparing it to expected behavior [2]). User behavior (as captured through the control of avatars) can also be expressed at other layers: programmed directly in the virtual environment, or modeled via CPN as a basis for "closed" simulation in the model. These closed simulations are generated from synthetic users. The behavior of these synthetic users is programmed (without actual users controlling them). The value of this approach is that the number of users needed to drive the simulation is reduced. This can be useful in situations where more than one user interacts in the environment.

We are particularly interested in closed simulation. One of the goals of using a language with a rigorously defined semantics (in this case, CPN) has been to enable the formal analysis of the designs. Although exercising the prototype with actual users provides valuable feedback about user experience, it is not exhaustive in terms of all the possible interactions between the numerous components of the ubiquitous environment. Expressing all the elements and users of the system at the modeling layer, forces the system to be deterministic, and enables it to be run "disconnected" from both the simulation and the physical layers. In turn, this enables an exhaustive analysis of the environment's possible behaviors. This closed simulation can also be used as a basis for model-based testing.

CONCLUSION AND FUTURE WORK

Flexible and extensible rapid prototyping frameworks try to make complex system development easier and more efficient. APEX framework aims to ubiquitous computing environments development thought a prototyping in layers. This framework makes it possible to explore different aspects of the environment, from user experience to user behavior through exhaustive analysis. Environments involving virtual, physical or mixed elements can be prototyped depending on the available resources. The framework makes it possible to explore easily a variety of different desired aspects. The possible movement between layers to analyze different features of the ubiquitous environments as well as the possibility to test the environment with a reduced number of real users are possible. APEX enables reasoning, formal modeling and analysis as well as providing valuable feedback about ubiquitous environments user experience.

The problem that remains to be solved will focus on the connection of isolated sensors, i.e. not integrated in the mobile devices. Further development will involve creation of a tool which will enable the semi automatic selection of input values to be used in the test of the prototyped environment. The link of APEX to a CAVE (Cave Automatic Virtual Environment) enabling a more immersive experience of the prototyping, making it easier to create the sense of "being there" is planned as future work.

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