Ubiquitous Home Simulation Using Augmented Reality

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Abstract: - Computing paradigm is moving toward ubiquitous computing in which devices, software agents, and services are all expected to seamlessly integrate and cooperate in support of human objectives. Augmented reality (AR) can naturally complement ubiquitous computing by providing an intuitive and collaborative interface to a three-dimensional information space embedded within physical reality. This paper presents a context-aware immersive framework for simulating ubiquitous home using augmented reality, which can simulate a rich set of ubiquitous services in a mixed ubiquitous home.

Key-Words: - augmented reality, context awareness, mixed reality, ubiquitous computing, ubiquitous home simulation

1 Introduction

Ubiquitous computing is a vision of our future computing lifestyle in which computer systems seamlessly integrate into our everyday lives, providing services and information in anywhere and anytime fashion [1,7,10]. Context-aware and ubiquitous systems are computer systems that can provide relevant services and information to users by exploiting contexts. By contexts, we mean information about locations, software agents, users, devices, and their relationships [3].

Augmented reality (AR), another type of virtual reality, is considered as an excellent user interface for ubiquitous computing applications, because it allows intuitive information browsing of location-referenced information [9]. In an AR environment, the user's perception of the real world is enhanced by computer-generated entities such as 3D virtual objects. Interaction with these entities occurs in real-time providing convincing feedback to the user and giving the impression of natural interactionThus, AR is considered naturally complementing ubiquitous computing by providing an intuitive and collaborative interface to a three-dimensional information space embedded within physical reality. Correspondingly, the human-computer interfaces and interaction metaphors originating from AR research have proven advantageous in a variety of real-world ubiquitous application scenarios such as simulation of virtual manufacturing [4], AR-enabled 3D collaboration [2], convergence of context awareness with augmented reality [8], and mobile augmented reality [11].

Although context-aware and ubiquitous computing is very popular in various research areas, a more sophisticated research is still needed, which should combine context-aware computing with more natural and intuitive interfaces like augmented reality for simulating ubiquitous services and supporting immersive interactions. Note that the need for such requirements is increasing rapidly so that a neutral framework or middleware should also be provided to support visualization and simulation of various ubiquitous applications.

This paper presents a context-aware immersive framework using augmented reality for supporting the simulation of various services and immersive interactions in ubiquitous home. The framework offers a software framework to acquire, interpret and disseminate context information. Further, it utilizes augmented reality for simulating relevant and immersive interactions in ubiquitous home design and evaluation by embedding virtual models onto physical models considering contexts. Moreover, human interactions based on AR not only feedback to existing contexts, but also generate new contexts, which can realize bi-augmentation between physical and virtual spaces. The remainder of the paper is organized as follows. Section 2 overviews the proposed system. Section 3 presents how to maintain contexts and apply them to augmented reality in ubiquitous home environments. Finally, Section 4 concludes with some remarks.

2 System Overview

The primary objective of this research is to propose a generic framework that supports the simulation of ubiquitous home in mixed reality-based environments as shown in Fig. 1. The framework has been built on the three layers: 1) U-interface layer, 2) U-context layer, and 3) AR interaction layer. The U-context layer maintains contexts from various resources such as devices, people, environment, etc. Further, the U-context broker facilitates reasoning and execution of those contexts. The U-context layer is based on CAMUS (Context-Aware Middleware for URC System) which is a middleware for supporting the context-awareness of ubiquitous services such as devices, sensors, and sobots (software robots) [6]. The U-interface layer supports bi-interactions between physical devices (or software components) and the U-context layer. Thus, all the devices can be easily registered, searched, and executed by the CAMUS-enabled broker. The AR interaction layer provides more realistic and human-oriented services using an AR technique. It is linked to the U-interface and U-context layers for context acquisition and reasoning, and graphical information gathering and synchronization. Thus, the three layered framework can support various kinds of ubiquitous services and interactions such as context-aware adaptation to the environment and human-centered AR-enabled interactions and simulations.

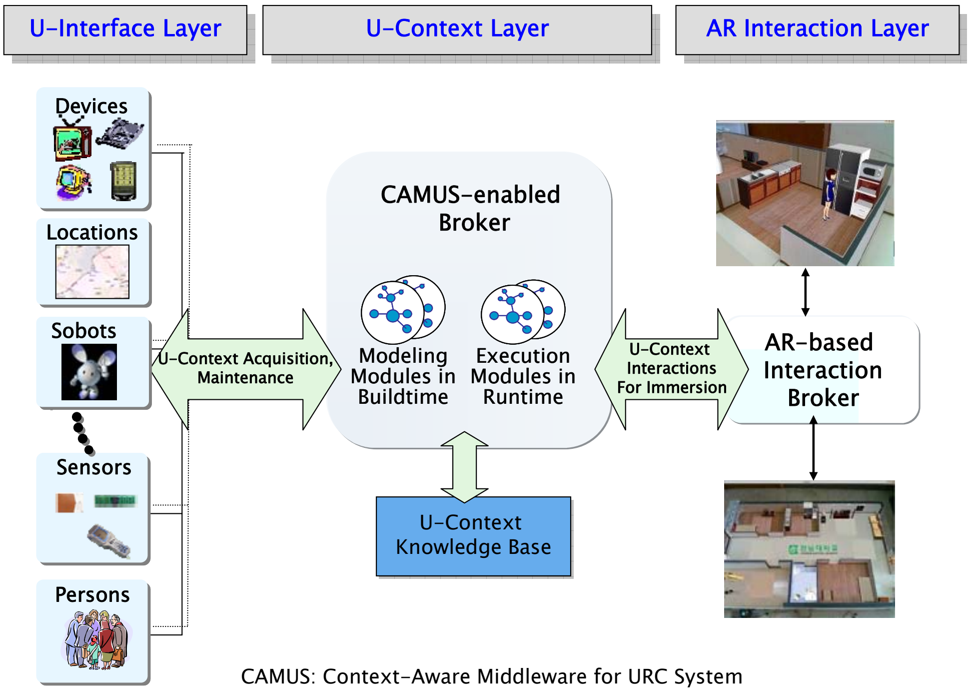

Fig. 1 CAMUS-enabled ubiquitous service framework

3 Context-Aware Simulation Using Augmented Reality

This section explains how contexts are managed and reasoned to provide more relevant and ubiquitous services. It also discusses how to utilize augmented reality for executing context-aware interactions in ubiquitous home.

3.1 CAMUS-based Context Management

The CAMUS-based middleware consists of two parts as shown in Fig. 2: 1) build-time components for ubiquitous space modeling and 2) runtime components for task execution [6]. The build-time components are used for registering and managing physical sensors, ubiquitous services, environments, users, and tasks. For example, the sensor modeler offers means for mapping sensors of the physical space into sensor services of the cyber space, extracting context information from the sensors and supplying the information to the task engine. The task modeler supports the modeling of context information specific to a task and the description of the rules necessary to perform the task. Then, the built tasks are executed by the runtime components. Among the runtime components, the task manager plays the main role in executing tasks. It initiates individual tasks and manages on-going task processes. The task engine executes the actual tasks considering the situation. It has an inference engine to process facts and rules supplied by a task. In CAMUS, we applied JESS as an inference engine [5].

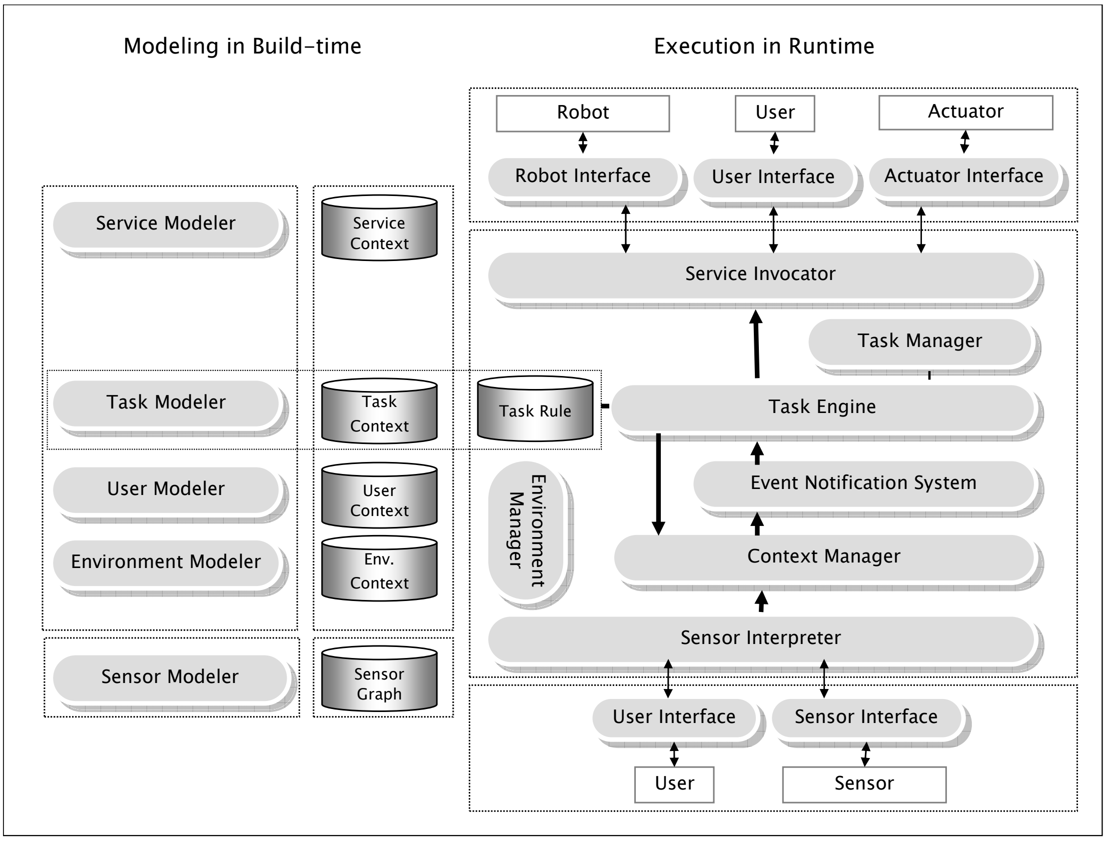

Fig. 2 Build-time and runtime components of CAMUS

3.2 AR-based Simulation

The AR-based interaction broker consists of 4 major modules as shown in Fig. 3: U-context binding module, U-interface binding module, tracking module, and rendering module [8]. Internally, the tracking module and rendering module support AR applications. The tracking module is based on a marker-based tracking technique, also supporting multi-marker tracking capabilities. In this research, ARToolkit has been utilized [2].

The rendering module embeds the 3D virtual reality of service and context information onto the physical reality image synchronized by the tracking module. Externally, the U-Context binding module and U-Interface binding module are used to communicate with the U-Context layer and U-Interface layer for context and service information retrieval and synchronization. The U-Interface binding module receives virtual models from the U-Interface broker, then, applies various interactions, and finally feedbacks the interactions to the U-Interface broker, which can modify the original model or generate new models. Similarly, the U-Context binding module gets context information from the U-Context layer and then embeds the contexts to AR. Further, it also feedbacks new contexts generated from AR interactions to the U-Context layer. Moreover, the U-Context broker queries and reasons about contexts, and sends the derived contexts to the U-Context interface module, which again applies them to AR.

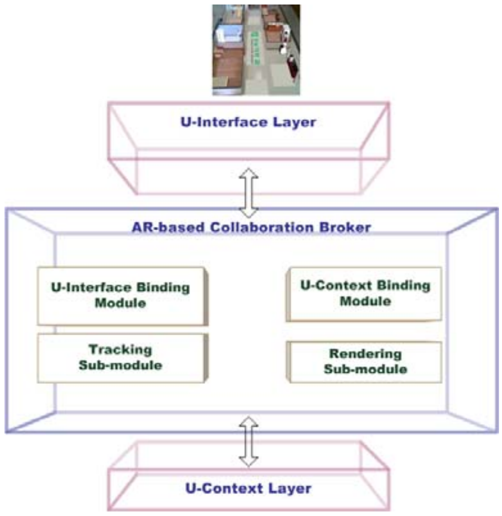

Fig. 3 Modules of the AR interaction layer

Fig. 4 shows how the proposed approach can be applied to visualize and simulate a ubiquitous home. Typically, in many research works, a ubiquitous home has been built, equipped with many ubiquitous devices, and tested by applying a variety of context aware software components to them. However, we can expect that, in a preliminary research, it would be quite difficult to modify and simulate dynamic objects and devices in the real environment, which limits realistic context-aware experiments. Further, re-building and modification of the home is cost expensive.

On the other hand, by combining the AR technique with the real environment, we realized that AR could be very effectively utilized by dynamically embedding virtual models into the physical environment, which can simulate real environments, although all kinds of ubiquitous devices are not equipped with. Further, modification of the environment by introducing new dynamic objects and their interactions is easy, which is very effective in the early stage of testing and proving. To experiment this and verify the effectiveness, we constructed a miniaturized ubiquitous home as shown in Fig. 4. Considering the implemented results, we realized that ubiquitous environments can be much more realistic, interactive, and immersive if the AR technique can be fully utilized.

(a) (b) (c)

Fig. 4. Simulation of ubiquitous services in ubiquitous home

5 Conclusion

This paper has presented how to simulate and visualize ubiquitous home in mixed reality-based environments by supporting the convergence of context-awareness and augmented reality. The framework provides a common data model for different types of context information from external sensors, applications and users in the environment. It also offers the software framework to acquire, interpret and disseminate context information. Further, it utilizes augmented reality for simulating virtual ubiquitous home and immersive interactions by embedding virtual models onto physical models considering contexts, which can realize bi-augmentation between physical and virtual spaces. In conclusion, the convergence can be very effectively utilized for: 1) seamless interaction between real and virtual environments, 2) providing context-awareness, 3) presenting spatial cues for various kinds of interactions such as ubiquitous home and collaboration, and 4) providing the ability to transit smoothly between reality and virtuality.

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