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OSGi-based services architecture for Cyber-Physical Home Control Systems

Chin-Feng Lai [a,*], Yi-Wei Ma [a], Sung-Yen Chang [a], Han-Chieh Chao [b], Yueh-Min Huang [a]

[a] National Cheng Kung University, Taiwan
[b] National Ilan University, Taiwan

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ABSTRACT

With the development of digital home appliances, the vision of a digital home can be realized, and users can control home appliances by remote control through the home network. However, current home networks have a variety of transmission control information media, such as WLAN, Zigbee, ECHONET, and LonWorks, resulting in an issue of interoperability of different network protocols. To solve this problem, this study proposes a OSGi-based service architecture for Cyber-Physical Home Control Systems, which supports service-oriented control methods. Users can control appliances in the physical environment by intuitive operation through a virtual home on the network. When the state or location of any appliance in the physical environment changes, the virtual context can enact timely changes, accordingly.

1. Introduction

With the growing number of remote control equipment in homes, users need to operate different remote controls, and have increased demands on desktop and laptop computers. Therefore, technologies for the control of computer equipment and digital appliances in home network environments keep developing [1]. Many studies have focused on how to link devices of different protocols, integrate the protocols, and further control the equipment; however, most methods use a 2D user interface for control. With each addition of new equipment and given the complex interface, the system fails to be user-friendly [2,3].

In order to build a user-friendly, service-oriented Cyber-Physical Home Control System [4,5], this study attempts to use signals and events in a virtual context for both the control of home appliances and the detection of their current positions [6,7]. The services and states of the home appliances are displayed on a webpage, allowing users to have a sense of being at home when physically away, as shown in Fig. 1. To achieve virtual reality control, this study uses three technologies, including Object location, Electronics control, and a Dynamic virtual environment, to integrate a link to virtual reality and the physical world. Object location is composed of two parts of bundles: (1) a Zigbee location bundle and (2) an object-tracking bundle [8]. This study uses two systems because the positioning in a 3D space is relatively difficult and adopts a method of double judgment to ensure accuracy. In planning, this study first determines the major areas on plane and uses the positioning system to determine the planar coordinates and the zone of the detected objects located in the 3D space. Then, a camera is placed accordingly to capture an image of the object to judge its height. Regarding electronics control, to realize more features of virtual context, this study uses relays, Zigbee, infrared, and other electrical control signals to give the commands that control the home appliances in a dynamic virtual environment [9,10]. With access to the Internet, users can control physical objects by webpage interface, and achieve the goal of integrating virtual and physical environments [11,12].

The remainder of this paper is organized as follows. Section 2 introduces the Cyber-Physical Systems and AXJX3D technologies. Section 3 presents the framework of the Cyber-Physical Home Control Systems, as well as object location, electronics control, and the dynamic virtual environment. Section 4 presents the experiment and results. Section 5 gives the conclusions.

2. Related work

2.1. Cyber-Physical Systems

A Cyber-Physical System (CPS) is a system featuring a tight combination of coordinated computational and physical elements. Today, the pre-cursor generation of Cyber-Physical Systems can be found in areas as diverse as aerospace, automotive, chemical processes, civil infrastructure, energy, healthcare, manufacturing, transportation, entertainment, and consumer appliances, and are often referred to as embedded systems. In embedded systems, the emphasis tends to be more on the computational elements, and less on the link between the computational and physical elements [13].

Unlike traditional embedded systems, a full-fledged CPS is typically designed as a network of interactive elements rather than

* Corresponding author. Tel.: +886 956012312.
E-mail address: cinfon@gmail.com (C.-F. Lai).

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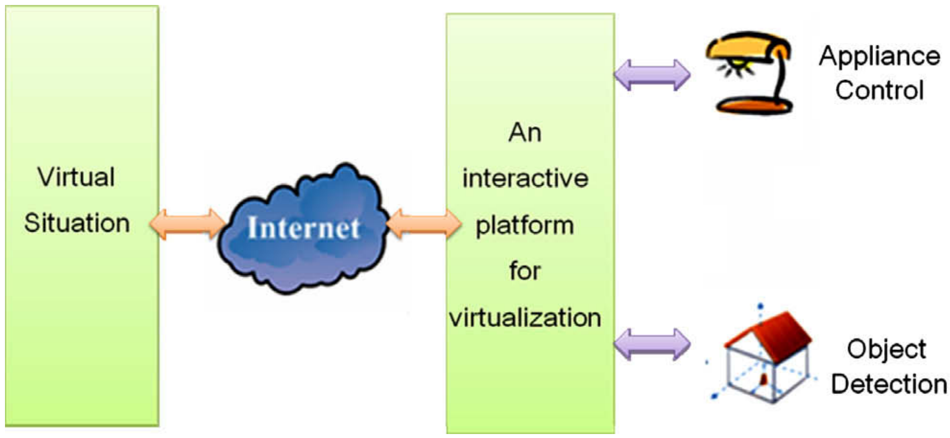

Fig. 1. Cyber-Physical System architecture.

standalone devices. The expectation is that in the future ongoing advances in science and engineering will improve the link between computational and physical elements, significantly increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of Cyber-Physical Systems. The advances will broaden the potential of Cyber-Physical Systems in several dimensions, including intervention (e.g., collision avoidance); precision (e.g., robotic surgery and nano-level manufacturing); operations in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration); coordination (e.g., air traffic control, war fighting); efficiency (e.g., zero-net energy buildings); and augmentation of human capabilities (e.g., healthcare monitoring and delivery).

2.2. AJAX3D

AJAX3D is a combination of AJAX technology and X3D to achieve X3D control of a webpage through AJAX technology [14,15]. AJAX stands for "Asynchronous JavaScript and XML", and is a webpage development technology to create interactive webpage applications [16]. The major technologies are as follows:

- Use XHTML + CSS to represent information.
- Use JavaScript to operate DOM (Document Object Model) for dynamic displays and interaction.
- Use XML and XSLT for data exchange and relevant operations.
- Use XMLHttpRequest object and Web servers for asynchronous data exchange.
- Use JavaScript to bundle items.
- Use SOAP to transmit descriptions and parameters of methods in the XML format.

X3D is a new set of standards for Extensible 3D [17,18], developed by the Web3D organization. XML is used as the extension of VRML97. In the spring of 2000, Web3D organization completed the transformation from VRML to X3D. X3D is compatible with MPEG-4 and XML, and can provide all the functions of VRML97. X3D is defined as an interoperable, extensible, cross-platform network with 3D standards. Regarding the implementation structure, the X3D design is based on the composite layer to enable it to meet technical services of different quality demands, selectiveness, and compatibility with VRML97. For example, layer 1 is defined as compatible with VRML97, and the norms of this layer can be fully compatible with VRML97. Therefore, standard objects, fonts, and action models of VRML97 can be used. However, layer 2 includes objects foreign to VRML97, and the action models have better performance, as well as setting details, being compatible with VRML97 where possible. Fig. 2 illustrates the software structure of X3D.

AJAX is not a single technology, but a full integration of XML [19,20], JavaScript, DOM, CSS, and XSLT webpage technologies. At present, AJAX technology is widely supported in webpage browsers, including Mozilla Firefox, Internet Explorer, and Opera. As a result, AJAX3D is able to provide a 3D virtual environment with relatively high interactivity on networks.

3. System architecture

Fig. 3 shows the entire architecture of the Cyber-Physical Home Control System. The Cyber-Physical Home Control System proposed in this paper contains three layers: (1) the Physical Layer: the protocols and profiles for users control of home appliances; (2) the Service Layer: the conversion and management of Physical Layer signals and Application Layer services, through device drivers in the OSGi Bundle, control signals are in packet formats, which conform to the specific protocols of the home appliances of the Physical Layer; (3) the Application Layer: all the services provided by physical equipment can be converted to the OSGi service model for users, through the Service Layer. Details of the various components of the system architecture proposed in this paper are described in the following sections.

3.1. Control Service

First, operator system provides the API (Application Program Interface) of Device Driver that could be used to operate the physical devices in Physical Layer to upper layer. Furthermore, OSGi Device Service Bundle could use Device Drivers through JNI (Java Native Interface) or OSGi Framework and transfer Device Drivers to several Basic Services by the Bundle format. At the same time, Control Service constructed the required Basic Services from ones is used to provide the operator and control of the physical devices to Dynamic Virtual Environment of Application Layer.

3.2. Object location service

The object positioning system is divided into two sections: (1) the Zigbee Location Bundle: determines planar coordinates to judge the approximate coordinates of X, Y, and corresponding zones; (2) Object Tracing Bundle: used to capture object location and judge height and approximate regional coordinates through captured images. Due to the relative difficulty in 3D locating, this

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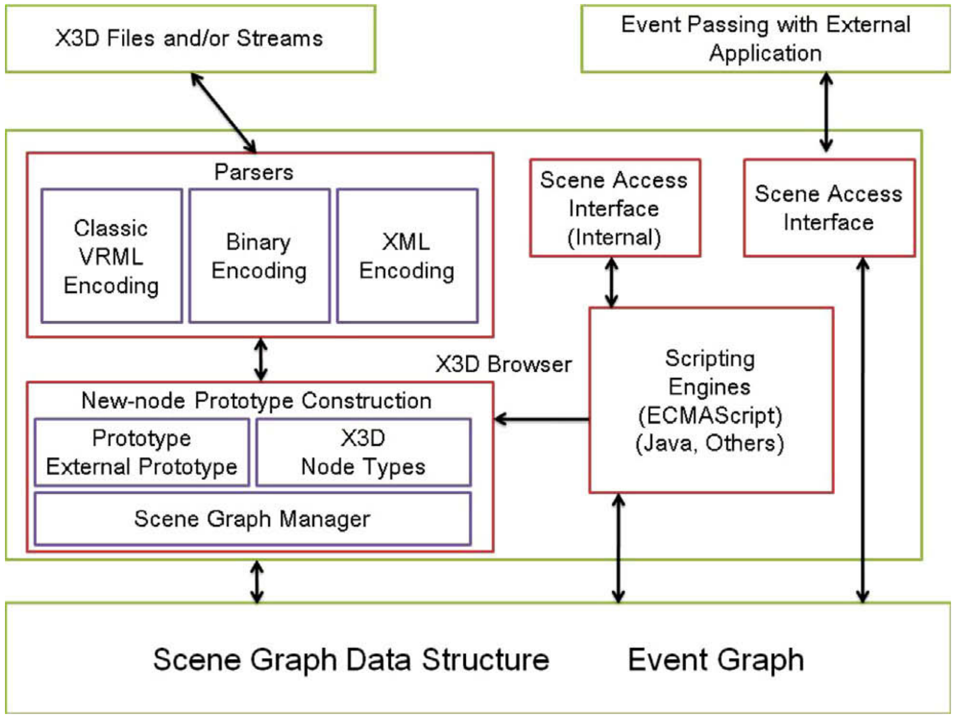

Fig. 2. X3D architecture.

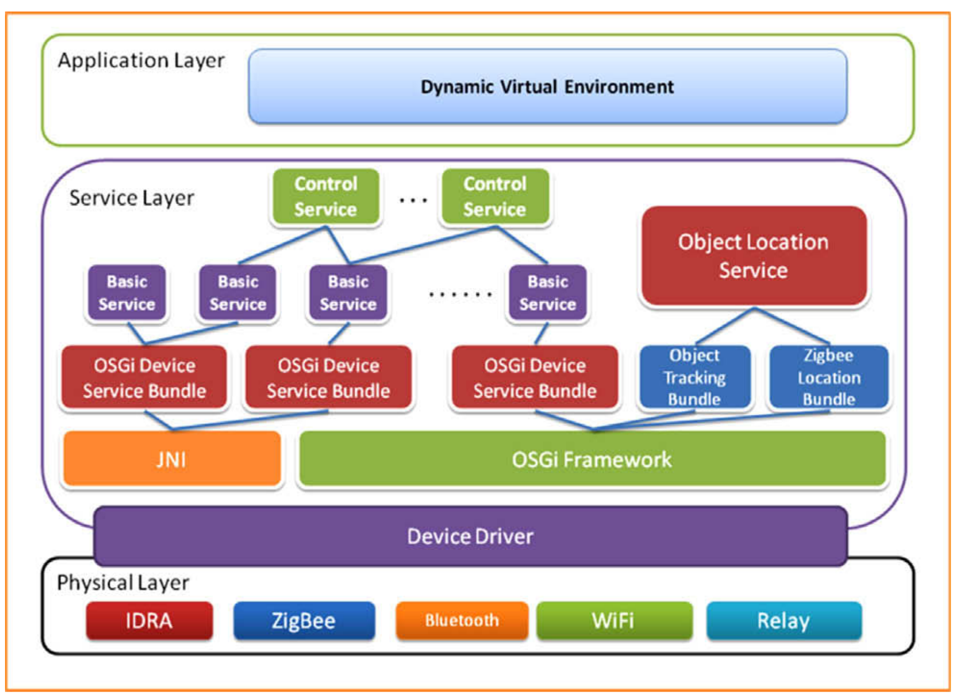

Fig. 3. Cyber-Physical Home Control System architecture.

study uses double confirmation of location and image recognition to improve accuracy.

3.3. Zigbee Location Bundle

In a wireless sensing network environment, the received signal strength indicator (RSSI) can be used to estimate the distance between any given sensors within communication distance. When the sender sends a signal to the receiving end, it leads to different signal attenuation, depending on different transmission distances. RSSI uses the relationship between signal attenuation and distance to estimate the distance between two sensors within the communication range. No special hardware equipment or additional resources are needed when using signal attenuation for distance estimation.

This method uses the RSSI data of a number of receivers to calculate possible locations. The data obtained are not the estimated data directly calculated according to the strength of the signals.

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