International Journal of Smart Home
Vol.3, No.4, October, 2009

Networking Mobile Devices and Computers in an Intelligent Home

Lior Zoref[1], David Bregman[2], and Dov Dori[1]

[1]*William Davidson Faculty of Industrial Engineering and Management*
Technion - Israel Institute of Technology.Haifa, Israel
[2]*School of Business Administration, The College of Management, Academic Studies,*
7 Rabin Blvd., P.O.B 25073, Rishon LeZion, Israel 75190.
dudibreg@colman.ac.il

Abstract

This paper presents the prototype of a universal model for implementing the smart home. In this model, computers and various digital devices form a single network that operates at a high level of intelligence to provide and manage common services. The universal model includes a standard framework that will enable hardware and software vendors to develop consumer electronic (CE) devices that connect easily to the smart home network. An eHome server stores and controls data while various information technologies connect home devices and appliances to the network's PC. A set of definitions is formulated for the user interface (UI), operations and management (OM) and artificial intelligence (AI) modules. For each component, a set of standard properties and interfaces was defined to create a seamless experience. The main contribution of this model is that it offers a possible solution to many of the hardware and software design issues in the eHome environment.

Keywords: *Smart-home, Standardization, Universal Model, OPM*

1. Introduction

As computers become ubiquitous in the home, the question arises as to how they can be used to improve our standard of living. Can computers help us become more efficient in the home? How can computers help provide the basis for a new means of communication and entertainment in the home? Researchers have investigated the possibilities of the connected home [1], [2], [3], but the technologies also need to be explored in the context of the home as an intelligent environment, in which people use computers to enhance their day- to- day home experience. Technology is becoming ever more pervasive in households around the world and the PC; in particular, once owned by a small number of early adopters is now a common feature in homes around the world. In the USA, for example, PCs are to be found in more than 80% of the homes[1]. In addition to PCs, we see that such "smart" devices as security cameras, remote controlled lighting, and mobile phones are very popular and a common feature in many homes. With the introduction of such technologies as Bluetooth, as well as RF and new power line standards, smart devices are becoming increasingly connected. As interconnectivity increases, we can expect to see greater coordination among devices. The first signs of this trend are already evident in such specialized devices as MP3 players that can transmit over telephone lines to a stereo system in another room.

Today, the main challenge is to create a simple and seamless software connection between all new devices, and to ensure that the devices work well together in generating a new set of functional scenarios for users. At present, digital devices are performing separate tasks. For example, a digital camera takes pictures and a webcam captures video on a PC. Since they are standalone devices, one

[1] World Development Indicators (http://www.worldbank.org)

cannot view images from the webcam on the digital camera screen. And yet, if it were possible, there are considerable advantages to observing a webcam scenario on one's digital camera. Consider, for example, the benefits of monitoring infants in other rooms in the house.

Another useful scenario is light control in the home. At present lights are connected to a central control unit. But why not connect them to the various monitors that are now to be found in most houses (such as a PC monitor, alarm system monitor, television monitor, etc.)?

An environment in which several smart devices are connected together is termed an intelligent environment [4] or ubiquitous computing. Most existing research focuses on technologies that facilitate intelligent environments such as speech-enabled computing, wireless computing, etc. There is comparatively less research on how these devices can be easily connected and form part of a standard home network. While it is important to develop new devices, it is also necessary to ensure their interconnectivity so as to provide users with the possibility of maximizing the potential of these devices. Our research is based on a universal implementation model for the smart home [5].

The proposed smart-home architecture, described in detail in [5], comprises four modules (Figure 1):

- Central Management Units (CMU)
- User Interface (UI)
- Home Equipment and Appliances Interface (HEAI)
- External Communication Interface (ECI)

Figure 1. The smart home model architecture

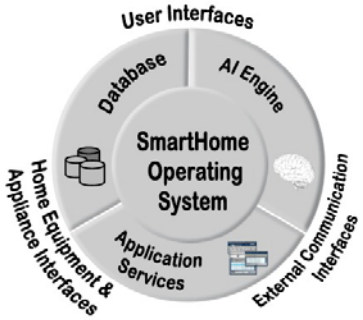

Figure 2. CMU components

The CMU components (Figure 2):

- Operating System (SHOS - Smart Home Operating System)
- The Smart-Home Database (SHDB)
- AI (Artificial Intelligence) Engine or Home Intelligence (HI)

Application Services (AS)

2. The model implementation

2.1. Research goal

This research explores the reality of a fully networked home based on the proposed universal model for a smart home. The universal model will make it possible to easily integrate many devices in the home using standard protocols and a standard user interface (UI). These standards will provide hardware and software vendors the opportunity to work within a single framework to connect devices in the eHome. A central concept in the model is "home intelligence" (HI), a set of AI applications that monitor and react to complex scenarios. For example, a smart home might learn the typical behavior of a home and issue an alert when someone is badly injured.

2.2. Events

Events describe and define the behavior of the intelligent home. The event publishing definition is a set of functions and properties that defines events that might be useful in the eHome environment. Events might be related to security, health, convenience or any other practical issue. The event publishing model will enable centralized management and monitoring of all events, leveraging main alerts and obtaining input from several devices at the same time. For example, an alert could be initiated if, when the front door is locked and the house is presumably empty, a window is being opened. The events are implemented as software modules either by pre-programming or by the **eHome_HI** module's AI learning and reasoning capabilities.

An event is defined as a set of properties and functions (the object-oriented approach):

- Event Name: a description of the event name
- Input Devices: devices inside the eHome that trigger an event
- Event Triggers: functions that return TRUE when a trigger is invoked
- Output Operation: another function with the desired output operation
- Output Alert: As stated in the previous section, the eHome Main Alerts defines the UI for main alerts. If an event requires an alert, Output Alert describes the alert.

2. 3. Implementation considerations and the model prototype

The implementation of the Smart Home prototype includes detailed database design, server-side functions and sample devices. In order to ensure standardization, the implementation architecture uses standard Web-services as the communications standard between devices and the eHome server. The Web-services definition might be used as the standard for connecting devices to the eHome environment. For each Web-service, there is an XML standard definition which could be implemented by device manufacturers.

A prototype of a connected home model can be found at http://www.liorzehome.com The application design is based on Object-Process Methodology (OPM) [6] - developed using Visual Studio 2005, SQL Server 2005, .NET architecture and OPCAD. The link "Web Services" links to the implemented Web-services using the simple OPDs (Object-Process diagrams) described in this research. Clicking on each diagram element invokes the relevant Web-service for testing purposes.

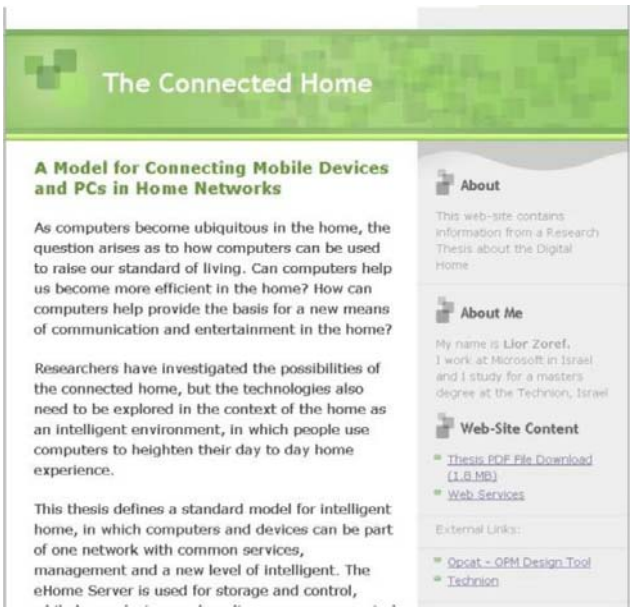

Figure 3. The prototype of the connected home model - http://www.liorzehome.com

2.4. Object-Process Methodology

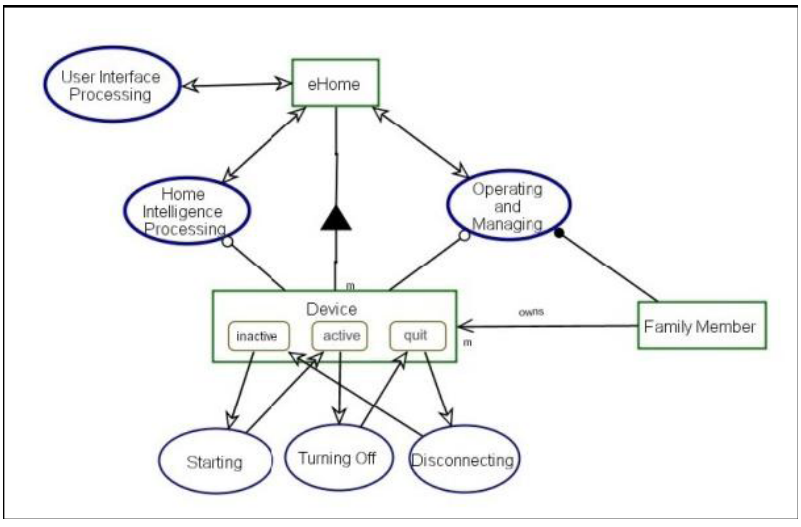

Figure 4. Object-Process Diagram (OPD) of eHome_CMU (Central Management Unit)

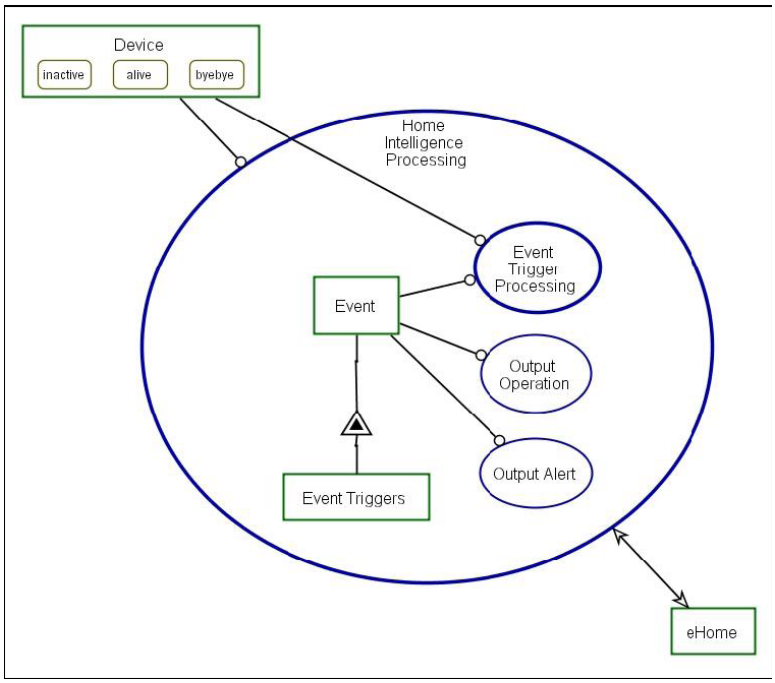

Figure 5. OPD of eHome_HI (Home Intelligence)

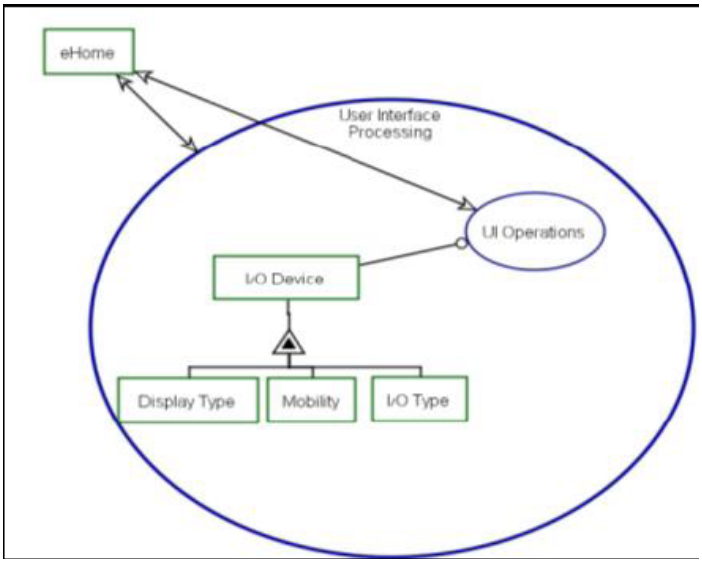

Figure 6. OPD of eHome_UI (User Interface)

Object-Process Methodology (OPM) [6] is a comprehensive novel approach to systems engineering. Integrating function, structure and behavior in a single, unifying model, OPM significantly extends the system modeling capabilities of current object-oriented methods. Founded on a precise generic ontology and combining graphics with natural language, OPM is applicable to virtually any business,

engineering or science domain. Relieved from technical issues, system architects can use OPM to engage in the creative design of complex systems. Figures 4, 5, and 6 use OPCAT, a software product that supports OPM-based conceptual modeling (www.opcat.com) to describe the functionality of some components of the smart home.

2.5. Scenarios

Following are some scenarios that describe the functionality and behavior of the smart home in different situations:

2.5.1. Personal Health Scenarios: Table 1 presents a range of typical healthcare scenarios in relation to various inputs and outputs.

Table 1. Healthcare scenarios

Event Name	Input Devices	Event Triggers	Output Operation	Output Alerts
Sleep alerts	Video camera in the bedroom. For babies: a 'Baby Sense' sensor.	If a person has a breathing problem or has stopped breathing.	Activate eHome alarm and possibly communicate this to an external contact.	eHome alarm.
Medicine reminders	Medicine database	Every time a person needs to take medicine, an event is triggered	None	A reminder is displayed in the eHome main alerts.
Body temperature (IR)	Thermo-Camera	If the body temperature rises above a defined level	None	An alert is displayed in the eHome main alerts.

Table 2. Security scenarios

Event Name	Input Devices	Event Triggers	Output Operation	Output Alerts
Entrance control	Video camera at the entrance	When someone appears at the entrance	None	An alert is displayed in the eHome main alerts.
Physical intruder detection	Motion detectors, video cameras	Different triggers are defined according to the time of day and whether or not a family member is inside the house.	Release gas against intruder, contact family members or a security call center	An alert is displayed in the eHome main alerts.
Network intruder detection	Intrusion detection software	Network intrusion detected	Disconnect network	An alert is displayed in the eHome main alerts
Car control	Car motion detector	Broken window or door opened without a remote control	Lock door, contact car owner	An alert is displayed in the eHome main alerts
Pet GPS monitoring	Pet GPS WiFi control	When the pet is outside a defined area without permission	Contact owner	An alert is displayed in the eHome main alerts

2.5.2 Security scenarios: Table 2 presents a variety or range of home security scenarios that the eHome and eHome_HI will be capable of handling. In dealing with these events, the

eHome functions like a smart alarm system. Sensors such as video cameras are used by the eHome_HI to analyze video input and trigger appropriate responses.

2.5.3. Home entertainment and home automation scenarios

Table 3. Home entertainment scenarios

Event Name	Input Devices	Event Triggers	Output Operation	Output Alerts
New digital photo	Digital camera	When a digital camera is connected and has new pictures	Sync pictures to home server	An alert is displayed in the eHome main alerts
eHome movie scenario	Light control	When a family member touch a specific control	Turning lights into movie mode, turn on TV, turn on sound system	None

Table 4. Home automation scenarios

Event Name	Input Devices	Event Triggers	Output Operation	Output Alerts
eHome lock	Front door	Unlocked (might be iris recognition device)	Door unlocked, lights, curtains (depending on time of day), alarm on	None
eHome open	Front door	Door locked and empty house	Door locked, lights turned off, curtains lowered, alarm off	None
Temperature Control	In-house temperature controls	Temperature range setting	Turn on/off heating / cooling devices	None
Grocery shopping list	Smart Refrigerator	Grocery inventory below a pre-defined level	Update shopping list	None
Bath control	eHome server	Secure phone call / email / http request	Fill bath with hot water	None
Digital art and pictures	eHome control panel	User request	Change all pictures inside the home to a specific theme	None

3. Conclusion

The next decade in computing will undoubtedly revolutionize our personal lives and enhance our digital lifestyle more than many anticipate today. As new digital devices become affordable, the main challenge for the industry is how to connect these devices and create value by providing access to many new and exciting possibilities and scenarios. A standard model is required if we wish to take full advantage of all the different devices. The prototype presented in this paper, demonstrates the basic concepts needed to create a single digital environment inside the home. As a first step, the model can set the framework for a standards committee such as those sponsored by the IEEE (Institute of Electrical and Electronics Engineers). This would open the way for hardware and software vendors to create a complete solution for smart homes. Future research is required to explore more advanced intelligent home scenarios such as personal health. The digital revolution is already underway, but the potential benefits for daily life are only just beginning to be understood.

References

[1] Brumitt, B. and Cadiz, Jonathan J., "Let There Be Light": Examining Interfaces for Homes of the Future. Proceedings of IFIP INTERACT01: Human-Computer Interaction, 2001, Tokyo, Japan.

[2] S.S. Intille, K. Larson. Designing and Evaluating Supportive Technology for Homes. Proceedings of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics 2003, IEEE Press.
[3] Kirchhof M. and Norbisrath U., Configuration and Deployment in eHome-Systems, Proceedings of the 2006 conference of the Center for Advanced Studies on Collaborative research, Toronto, Canada, 2006.
[4] Mozer, M. The Neural Network House: An Environment that Adapts to its Inhabitants. Proceedings of the AAAI Symposium on Intelligent Environments, 1998.
[5] Bregman and Korman, A Universal Implementation Model for the Smart Home, International Journal of Smart Home, Vol.3, No.3, July 2009
[6] Dori, D. Object-Process Methodology: A Holistic Systems Paradigm. Springer Verlag, Heidelberg, New York, 2002.

Authors

Lior Zoref, MSc, A senior marketing manager at Microsoft. Fields of research: smart home, social networks and social computing.

David Bregman, PhD, Senior Lecturer and Researcher, School of Business Administration, The College of Management, Israel. Fields of research: information technologies, simulation systems, elearning, medical informatics.

Dov Dori, Ph.D. Professor of Information and Systems Engineering at Technion, Israel Institute of Technology, Haifa, Israel. His research areas include model-based systems engineering, conceptual modeling, Objet-Process Methodology.