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Review: Context Aware Tools for Smart Home Development

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Abstract

Context-aware computing is the concept of leveraging information about the end user to improve the quality of the interaction. Emerging context-enriched services will use location, presence, social attributes, and other environmental information to anticipate an end user's immediate needs, offering more-sophisticated, situation-aware and usable functions. Smart homes connect all the devices and appliances in your home so they can communicate with each other and with you. Context-awareness can be applied to Smart Home technology. In this paper, we review the context-aware tools for Smart Home System Development.

Keywords: *context-aware computing, smart home, situation-aware*

1. Introduction

Context awareness originated as a term from ubiquitous computing or as so-called pervasive computing which sought to deal with linking changes in the environment with computer systems, which are otherwise static. [1] Smart homes or buildings are usually a new one that is equipped with special structured wiring to enable occupants to remotely control or program an array of automated home electronic devices by entering a single command. Context awareness plays a big role in developing and maintaining a Smart Home. On the following parts of this paper, we discuss Context Awareness, Smart Home, and the Context aware tools used in Smart Home Development.

2. Context Awareness

Context awareness refers to the idea that computers can both sense, and react based on their environment. Devices may have information about the circumstances under which they are able to operate and based on rules, or an intelligent stimulus, react accordingly. Context aware devices may also try to make assumptions about the user's current situation. [1]

While the computer science community has initially perceived the context as a matter of user location, in the last few years this notion has been considered not simply as a state, but part of a process in which users are involved; thus, sophisticated and general context models have been proposed, to support context-aware applications which use them to adapt interfaces, tailor the set of application-relevant data, increase the precision of information retrieval, discover services, make the user interaction implicit, or build smart environments. A context aware mobile phone may know that it is currently in the meeting room, and that the user has sat down. The phone may conclude that the user is currently in a meeting and reject any unimportant calls. [2]

Context aware systems are concerned with the acquisition of context, the abstraction and understanding of context, and application behavior based on the recognized context. As the user's activity and location are crucial for many applications, context awareness has been focused more deeply in the research fields of location awareness and activity recognition.

2.1. Context Aware Computing

Context-aware computing refers to a general class of mobile systems that can sense their physical environment, like their context of use, and adapt their behavior accordingly. Such systems are a component of a ubiquitous computing or pervasive computing environment. Three important aspects of context are: where you are; who you are with; and what resources are nearby.

Although location is a primary capability, location-aware does not necessarily capture things of interest that are mobile or changing. Context-aware in contrast is used more generally to include nearby people, devices, lighting, noise level, network availability, and even the social situation; e.g., whether you are with your family or a friend from school. [3]

3. Smart Home Systems

A smart home or building is a home or building, usually a new one that is equipped with special structured wiring to enable occupants to remotely control or program an array of automated home electronic devices by entering a single command. For example, a homeowner on vacation can use a Touchtone phone to arm a home security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks.

The field of home automation is expanding rapidly as electronic technologies converge. The home network encompasses communications, entertainment, security, convenience, and information systems.

A technology known as Powerline Carrier Systems (PCS) is used to send coded signals along a home's existing electric wiring to programmable switches, or outlets. These signals convey commands that correspond to "addresses" or locations of specific devices, and that control how and when those devices operate. A PCS transmitter, for instance, can send a signal along a home's wiring, and a receiver plugged into any electric outlet in the home could receive that signal and operate the appliance to which it is attached.

One common protocol for PCS is known as X10, a signaling technique for remotely controlling any device plugged into an electrical power line. X10 signals, which involve short radio frequency (RF) bursts that represent digital information, enable communication between transmitters and receivers.

In Europe, technology to equip homes with smart devices centers on development of the European Installation Bus, or Instabus. This embedded control protocol for digital communication between smart devices consists of a two-wire bus line that is installed along with normal electrical wiring. The Instabus line links all appliances to a decentralized communication system and functions like a telephone line over which appliances can be controlled. The European Installation Bus Association is part of Konnex, an association that aims to standardize home and building networks in Europe.

Figure 1. Smart Home Technology Automation

Echelon Corp., the creator of the LonWorks system, is helping drive adoption of an open interoperability standard among vendors in the control networks industry. LonWorks is an open standard for network automation and control for the building, transportation, industrial and home markets. The American National Standards Institute (ANSI) has adopted the protocol underlying LonWorks control networks as an industry standard. The LonMark Interoperability Association is made up of more than 200 controls companies mission working on standard to integrate multi-vendor systems based on LonWorks networks. [4]

3.1. Smart Home Software and Technology

Smart home technology was developed in 1975, when a company in Scotland developed X10. X10 allows compatible products to talk to each other over the already existing electrical wires of a home. All the appliances and devices are receivers, and the means of controlling the system, such as remote controls or keypads, are transmitters. If you want to turn off a lamp in another room, the transmitter will issue a message in numerical code that includes the following:

- An alert to the system that it's issuing a command,
- An identifying unit number for the device that should receive the command and
- A code that contains the actual command, such as "turn off."

All of this is designed to happen in less than a second, but X10 does have some limitations. Communicating over electrical lines is not always reliable because the lines get "noisy" from powering other devices. An X10 device could interpret electronic interference as a command

and react, or it might not receive the command at all. While X10 devices are still around, other technologies have emerged to compete for your home networking dollar.

Instead of going through the power lines, some systems use radio waves to communicate, which is also how WiFi and cell phone signals operate. However, home automation networks don't need all the juice of a WiFi network because automation commands are short messages. The two most prominent radio networks in home automation are ZigBee and Z-Wave. Both of these technologies are mesh networks, meaning there's more than one way for the message to get to its destination.

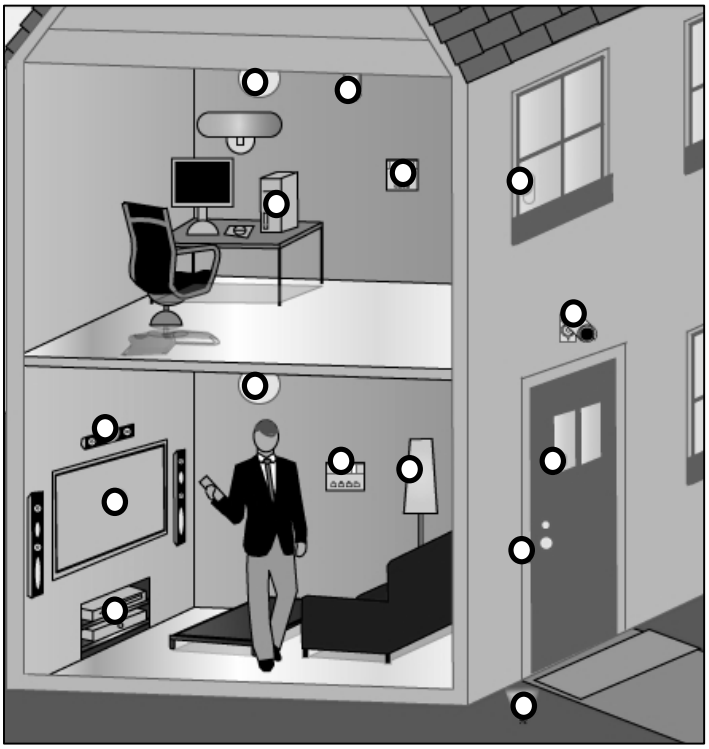

Figure 2. The dots represent devices that could be connected to your smart home network.

Z-Wave uses a Source Routing Algorithm to determine the fastest route for messages. Each Z-Wave device is embedded with a code, and when the device is plugged into the system, the network controller recognizes the code, determines its location and adds it to the network. When a command comes through, the controller uses the algorithm to determine how the message should be sent. Because this routing can take up a lot of memory on a network, Z-Wave has developed a hierarchy between devices: Some controllers initiate messages, and some are "slaves," which means they can only carry and respond to messages.

ZigBee's name illustrates the mesh networking concept because messages from the transmitter zigzag like bees, looking for the best path to the receiver. While Z-Wave uses a proprietary technology for operating its system, ZigBee's platform is based on the standard set by the Institute for Electrical and Electronics Engineers (IEEE) for wireless personal

networks. This means any company can build a ZigBee-compatible product without paying licensing fees for the technology behind it, which may eventually give ZigBee an advantage in the marketplace. Like Z-Wave, ZigBee has fully functional devices (or those that route the message) and reduced function devices (or those that don't).

Using a wireless network provides more flexibility for placing devices, but like electrical lines, they might have interference. Insteon offers a way for your home network to communicate over both electrical wires and radio waves, making it a dual mesh network. If the message isn't getting through on one platform, it will try the other. Instead of routing the message, an Insteon device will broadcast the message, and all devices pick up the message and broadcast it until the command is performed. The devices act like peers, as opposed to one serving as an instigator and another as a receptor. This means that the more Insteon devices that are installed on a network, the stronger the message will be.

3.2. Setting Up a Smart Home

X10, Insteon, ZigBee and Z-Wave just provide the technology for smart home communication. Manufacturers have made alliances with these systems to create the products that use the technology. Here are some examples of smart home products and their functions.

- Cameras will track your home's exterior even if it's pitch-black outside.
- Plug your tabletop lamp into a dimmer instead of the wall socket, and you can brighten and dim at the push of a button.
- A video door phone provides more than a doorbell -- you get a picture of who's at the door.
- Motion sensors will send an alert when there's motion around your house, and they can even tell the difference between pets and burglars.
- Door handles can open with scanned fingerprints or a four-digit code, eliminating the need to fumble for house keys.
- Audio systems distribute the music from your stereo to any room with connected speakers.
- Channel modulators take any video signal -- from a security camera to your favorite television station -- and make it viewable on every television in the house.
- Remote controls, keypads and tabletop controllers are the means of activating the smart home applications. Devices also come with built-in web servers that allow you to access their information online.

This keypad will send a message to your lamp.-These products are available at home improvement stores, electronics stores, from technicians or o-nline. Before buying, check to see what technology is associated with the product. Products using the same technology should work together despite different manufacturers, but joining up an X10 and a Z-Wave product requires a bridging device.

In designing a smart home, you can do as much or as little home automation as you want. You could begin with a lighting starter kit and add on security devices later. If you want to start with a bigger system, it's a good idea to design carefully how the home will work,

particularly if rewiring or renovation will be required. In addition, you'll want to place strategically the nodes of the wireless networks so that they have a good routing range.

The cost of a smart home varies depending on how smart the home is. One builder estimates that his clients spend between $10,000 and $250,000 for sophisticated systems. If you build the smart home gradually, starting with a basic lighting system, it might only be a few hundred dollars. A more sophisticated system will be tens of thousands of dollars, and elements of home theater systems raise the cost of a system about 50 percent. [5]

3.3. Benefits of Smart Home

Smart homes obviously have the ability to make life easier and more convenient. Home networking can also provide peace of mind. Whether you're at work or on vacation, the smart home will alert you to what's going on, and security systems can be built to provide an immense amount of help in an emergency. For example, not only would a resident be woken with notification of a fire alarm, the smart home would also unlock doors, dial the fire department and light the path to safety.

Smart homes also provide some energy efficiency savings. Because systems like Z-Wave and ZigBee put some devices at a reduced level of functionality, they can go to "sleep" and wake up when commands are given. Electric bills go down when lights are automatically turned off when a person leaves the room, and rooms can be heated or cooled based on who's there at any given moment. One smart homeowner boasted her heating bill was about one-third less than a same-sized normal home. Some devices can track how much energy each appliance is using and command it to use less.

Smart home technology promises tremendous benefits for an elderly person living alone. Smart homes could notify the resident when it was time to take medicine, alert the hospital if the resident fell and track how much the resident was eating. If the elderly person was a little forgetful, the smart home would perform tasks such as shutting off the water before a tub overflowed or turning off the oven if the cook had wandered away. It also allows adult children who might live elsewhere to participate in the care of their aging parent. Easy-to-control automated systems would provide similar benefits to those with disabilities or a limited range of movement.

4. Context Aware for Smart Home Technologies

Context awareness plays a big role in developing and maintaining a Smart Home. The following are researches and development of tools and technologies utilizing Context Awareness in developing a Smart Home.

4.1. Context-Sensitive Rule-based Architecture for a Smart Home Environment

The system can be instantiated for an application context that deals with a particular building with certain types of sensors, and where particular services are offered. The definition of the context elements (such as location, sensor values, time, user schedule) and the services that can be invoked by a rule can be done by the system administrator using XML specifications. [6]

An event-driven architecture, where various contexts and services can be registered in a standard manner supports this generality. The actual rules defining which services a user requires for a given contextual environment can also be defined using XML but are more easily done by the user on the mobile device using an automatically generated interface. [6]

4.2. An Aware Community

The Aware Community will enable us to move the paradigm of an aware and assistive home to the development of an aware and assistive community infrastructure by incorporating devices and methods into a small urban community of homes, recreation facilities, retail and service providers, on city streets with vehicular traffic and public transportation.[7]

The McKIZ Aware Community is located on a ten acre site in the Third Ward of McKeesport as shown in the site plan. The Blueroof Smart Cottage/R&D Center, YWCA Community Center, Salvation Army and two active churches are located in the McKIZ and will remain. Blueroof will build a number of new structures to include 15-20 single family houses, a small grocery store and a new building for the Blueroof Tech Center. There are 22 existing HUD houses (five of which are accessible) that have infrastructure in place to accommodate sensors and other technology.[7]

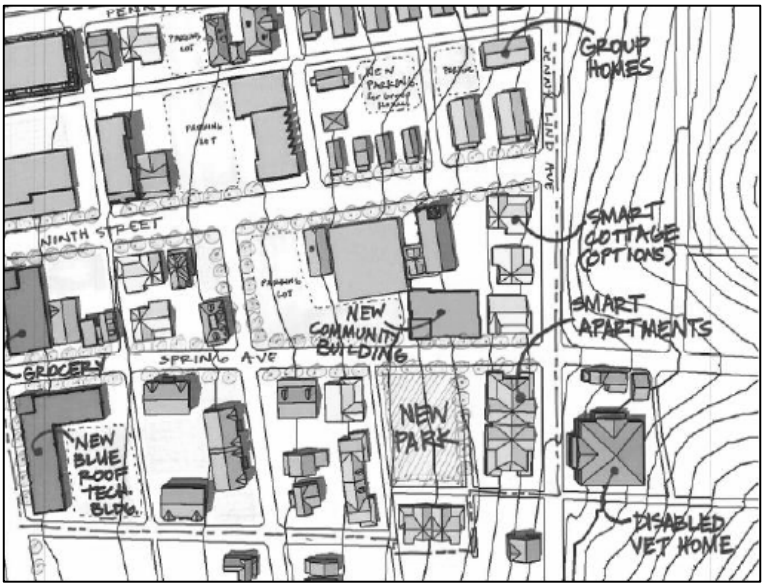

Figure 3. The aware community site plan.

4.3. CAMUS based Context-Awareness for Pervasive Home Environments

CAMUS is to provide a framework for the development and execution of context-aware applications for network-based robots. URC is a new concept for a network-based service robot. It allows the robot to extend its functions and services by utilizing external sensor networks and remote computing servers. In the URC, CAMUS plays the important role of the

software infrastructure that expands the robot functions and services, improves the context-awareness in the pervasive computing environment, and enhances the robot's intelligence. [8]

The following figure shows the system architecture of CAMUS. CAMUS is composed of four parts: CAMUS-MS (CAMUS Main Server), SAM (Service Agent Manager), SA (Service Agent) and Planet.

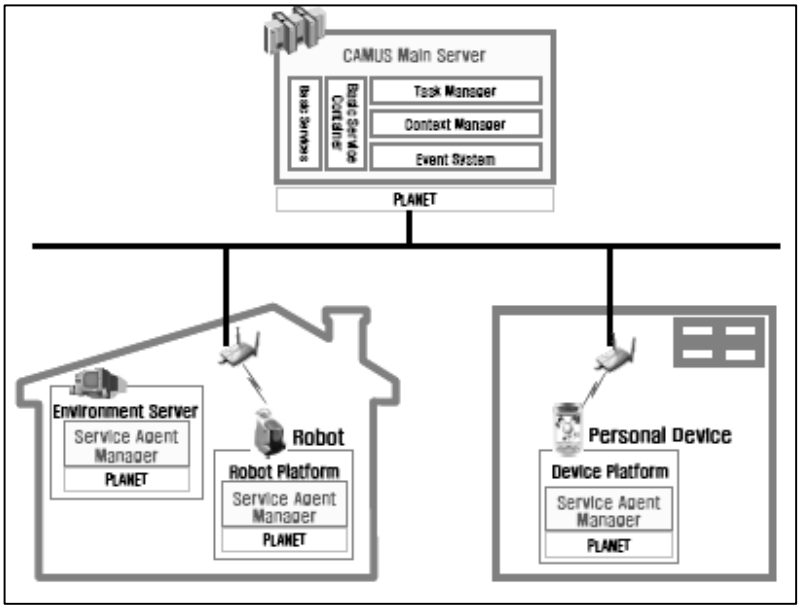

Figure 4. CAMUS System Architecture

CAMUS-MS is a framework which collects contexts from SA and uses the contextual information. In addition, it supports a variety of functions for context-aware application development. In particular, CAMUS-MS controls all information about user context including user preference used in contents recommendations and environmental contexts, then sends events by context's changes to applications and helps applications to perform suitable actions for the context. There is another point that is important for the CAMUS-MS: it offers a service framework that can connect to the basic service agent of a robot controller and a variety of software, such as voice recognition, image recognition, and motion detection. In the next section, we describe the detailed components of CAMUS-MS. [8]

SAM is a program that manages and controls SAs within the environment. To do this, SAM is installed within various environments in a location, obtains information from a variety of sensors in the environment, sends the information to CAMUS-MS, receives instructions from CAMUS-MS, and controls the SA in the environment. Therefore, SAM can be installed in any location, such as rooms or offices, and also in a robot platform or PDA.[8]

SA executes the functions of legacy applications and sensors installed on physical places through communication with SAM and CAMUS-MS. SAs are the software module interfaces of devices and applications that interact with CAMUS-MS. Because SA exposures attribute and action with interfaces that are accessed by CAMUS-MS. For example, suppose that the

SA, which provides the information of the user's location, has interfaces o send the id and physical location for the user and the RFID sensor exists in the environment. [8]

4.4. A Context Aware Gateway

A home inhabitant could answer the incoming call by choosing his/her preferred SIP UA devices and post the outgoing presence information on an “as needed” basis (based on pre-defined context aware service criteria such as entity-to-entity relationships and current situations). An effective way to do this is to deploy an intelligent gateway to select/control communication sessions between home networks and the Internet. SIP Context Aware Gateway (SIP-CAG), serving as a SIP-based home application secretary, provides tremendous flexibility and capability in adapting to diverse environment situations. [9]

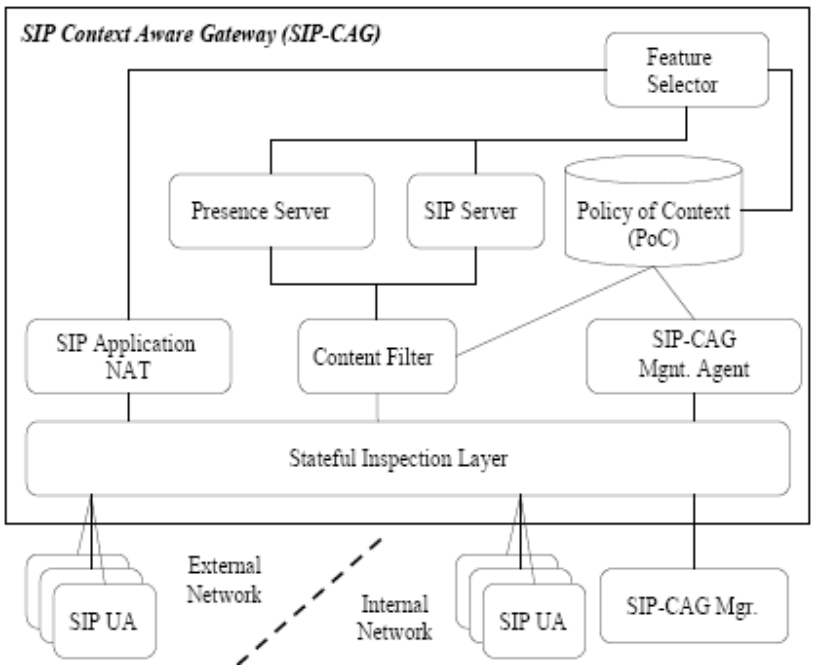

Figure 5. Architecture of SIP-CAG

SIP-CAG supports the SIP-based context aware applications based on the inhabitant’s motivations, behaviors and needs. The next figure shows the proposed SIP-CAG architecture that comprises the following major components: SIP Server and Presence Server, Stateful Inspection Layer (SIL), Content Filter (CF), SIP Application NAT (SAN), Feature Selector (FS), Policy of Context (PoC) and SIP-CAG Management Agent (SMA). Components are collaborated together to perform the context management. In the following paragraphs, we describe the function of each component in more detail.[9]

5. Conclusion

In developing and maintaining a Smart Home, Context awareness plays a big role. We discuss the context aware tools which can be implemented in Smart home. Although Smart

Home brings a lot of advantages, there are also challenges that comes with it. One of the challenges of installing a smart home system is balancing the complexity of the system against the usability of the system. When planning the system, it's important to consider a few factors:

- How large will the system be?
- What kinds of components are parts of the system? Are they basic, such a light dimmer, or more imposing, like an alarm system or a video camera?
- How intuitive will the system be to a non-user?
- How many people will be required to use the system?
- Who will know how to operate the system? Who will know how to maintain the system and address failures?
- How often will people who can only operate the system be left alone in the home?
- How easy is it to make changes to the interface?

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