Smart Architectural Surface: Modularized Platform for Polymorphic Functional Changes and Multimodal Interactions

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Abstract

Smart Architectural Surface is a highly integrated planar construct for diversified smart home services with networked smart cell units equipped with various sensing, cognition, and actuation capabilities that would allow run-time polymorphism as the basis for functional changes for various event-driven operation scenarios. The SAS system can demonstrate the outcomes of collective intelligence that are mediated by various multi-modal interactions. Current SAS prototype is capable of polymorphous functional changes for dynamically adjustable electronic wallpaper, location/distance-aware video conferencing, personalized information browser, and automatic responses to various unintended events. Future applications would harness machine learning and machine vision techniques.

Key Words: Planar Construct, Smart Home Services, Sensing, Cognition, Actuation, Smart Cell, Multi-modal Interaction, Polymorphous Changes.

1. Introduction

Most smart home related systems keep adding more objects into home environment, which is not always the best approach considering the ever-increasing cost and maintenance efforts in addition to the complexity of networking those objects to make them work together. Here we introduce such system that is capable of providing a highly adaptive and interactive environment by using minimum resources. We developed a new breed of smart architectural component which is capable of dealing with polymorphic functional changes based on the detected or interpreted user requests through multi-modal interactions. Smart Architectural Surfaces (SAS) uses smart cells to construct highly interactive and responsive architectural surfaces to accommodate diverse multimedia and communication services which have been normally provided by a collection of dedicated devices and equipment in our ordinary residential environment.

2. Related Research

NCSA's Scientific Visualization group currently operates a rear-projection-based large tiled display that has been developed for high resolution visualizations. This system enables simultaneously displaying images from multiple sources using multiple projectors and all projectors are connected to multiple Linux PCs to drive the wall [1]. On the other hand, Hello.Wall as a wall-sized ambient display, is mainly for an informative art. The interaction is enabled through hand carried ViewPorts, WaveLan, and RFID technology [2]. The visual codes provided by this system are dynamically changeable depending on the distance of a person from the surface that is made up with multiple cells having a cluster of LEDs and a short-range transponder. These and other existing interactive surface technologies [3] are primarily focused on visualization, therefore the use scenarios of these systems are relatively simple and limited.

3. System Objectives

SAS is an innovative framework for building highly integrated and interactive smart surfaces primarily based upon a self-regulating network of smart cells that form the surfaces. Each cell is equipped with networked communication, sensing, computation, and actuation capabilities. SAS cells coordinate their operations in order to provide complex sensing and actuation applications. SAS would allow various multi-modal interactions and semi-immersive experiences for the users. SAS can be dynamically constructed from its components, namely SAS cell units. As is illustrated in Figure 1, SAS is also able to flexibly change its functional states based on the interpreted contextual information or explicit user requests. In any instance, software control of those sensing, computational, and actuation devices in SAS cell units could provide hardware-independent smart home services that normally require various electronic devices such as TV, radio, home theater, internet browser, computer, video phone, indoor climate monitor, game box, and semi-immersive CAVE for experiencing Virtual Reality [4].

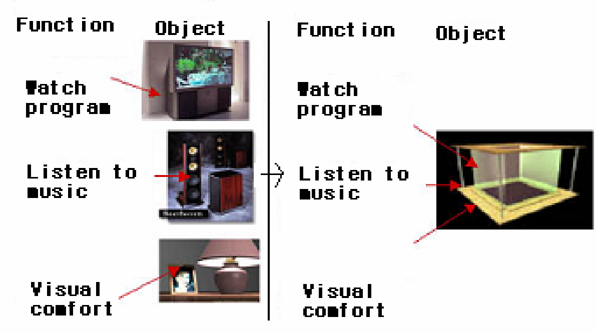

Fig. 1 Polymorphism that decouples conventional function-object mappings

4. Hardware Architecture

A SAS system is a collection of about 1 sq ft sized grid component namely SAS cell. Each SAS cell is equipped with IEEE 802.11b Wireless LAN card to communicate with neighboring cells or remote computers. The sensors installed in each SAS cell could be categorized into two groups: Environmental Sensors include thermometer, humidity sensor, and photometer. Activity Sensors installed in each cell are camera, microphone, ultra-sonic proximity sensor, and IR sensor. Current SAS system has a PC level computing power (1GHz). For display, each SAS cell has 15 inch XGA resolution LCD screen to deliver visual outputs. Each cell is also equipped with speakers for sound and voice outputs plus a LED for status signaling. Figure 2 illustrates the physical appearance of a single SAS cell.

Fig. 2 SAS Cell unit equipped with various transducers

5. Software Architecture

SAS system uses Windows 2000^{TM} for its operating system. Current SAS system consists of such software components as Sensor Module, Multimedia Player and Speech Module. Each component runs in a separate process and communicates with other components using a proprietary application protocol. The application protocol runs on top of TCP/IP over 802.11b WLAN. Current SAS implementation uses a client-server scheme to manage SAS operations. GC is the Global Coordinator and is responsible for anything to do with inter-cell coordination and managing the state of the whole system. GC delivers inter-cell messages to the destination cell and manages the FSM (Finite State Machine) of the SAS system as a whole. GC also gets reports from individual cells and performs necessary operations with them. In the meantime, LC stands for Local Coordinator. LC is primarily responsible for coordinating all different components within a cell. Every other component talks to LC and the internal structure of an individual cell is transparent to GC. LC delivers messages to/from the destination module and creates a new process or kill a process that is no longer in use. Figure 3 shows how GC and LC organize the necessary intra and inter-cell software controls.

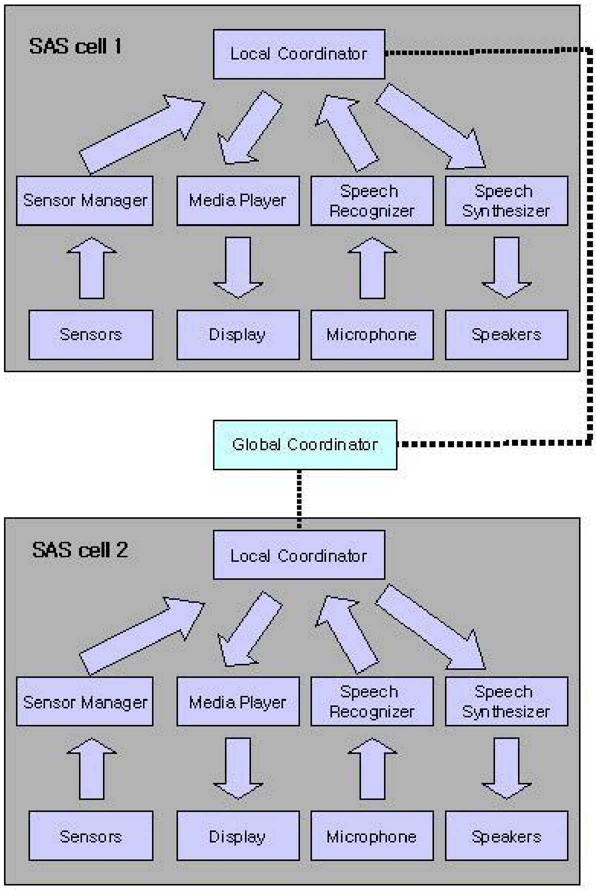

Fig. 3 SAS's software control structure

SAS uses a proprietary, ASCII-based application protocol to facilitate the communication and cooperation among cells within the system. In other words, SAS application protocol defines the way of sending and receiving messages among different components of the system.

SAS's User Data Message Format is as follows:

MSG,SOURCE_CELL,SOURCE_MODULE,TARGET_CELL,TARGET_MODULE,USER_DATA

CMD: type of Command sent from GC to SAS Cells. –i.e. SENS – measured Sensor values, REQ – Request from a SAS Cell to GC, MSG – Msg. sent from a SAS Cell to another

SOURCE_CELL: ID of the Cell that sends a Msg. -i.e. A1, B2. If the destination of Msg. is GC, the String "GC" is used.

SOURCE_MODULE: ID of the module in a SAS cell that actually sends a Msg. -i.e. PLAYER, VIDEOPHONE. If the destination of the Msg. is GC, the String "GC" is used.

TARGET_CELL: ID of the Cell that receives the actual Msg. -i.e. A1, B2. If the destination of the Msg. is GC, the String "GC" is used.

TARGET_MODULE: ID of the module in a SAS cell that receives the actual massage -i.e. PLAYER, VIDEOPHONE. If the destination of the Msg. is GC, the String "GC" is used.

USER_DATA: Msg. Data -i.e. GET-DIST, GET-NEAREST, ACT_VIDEOPHONE

6. System Operation Scenarios

Key applications currently being developed for the SAS system are Dynamic Wallpaper, Digital Calendar, Digital Mirror, and Context Aware Videophone. Dynamic Wallpaper uses the Multimedia Player developed on top of the DirectShow™ API. This application varies its SAS wall display contents depending on the various elements such as direct voice command, identified person, time of day, season of year, etc. Figure 4 demonstrates SAS's voice activated Dynamic Wallpaper application that is capable of freezing, and scaling up/down a video content across multiple cell units.

Fig. 4 SAS's Dynamic Wallpaper application

SAS wall can also deal with personalized information items such as weather, home shopping, or stock price. Digital Clock and Calendar are also built upon Macromedia Flash™ MX environment. Digital clock application especially uses an internal algorithm to calculate the angular positions of the needles that constitute an analogue clock. Figure 5 shows the Digital Clock and Calendar objects called up on the SAS surface.

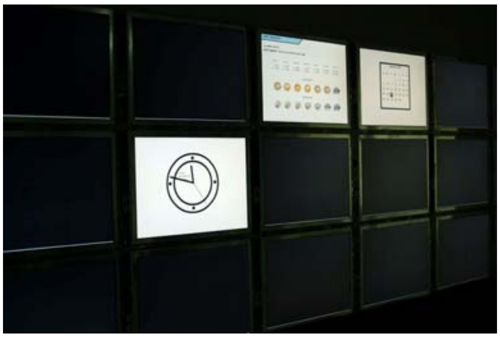

Fig. 5 Digital Clock and Calendar on the SAS surface

Real-time weather forecast data is patched from an internet site the URL of which is mapped with a voice command listed on the table containing the places of interest. The data from the selected website is in XML format and this XML format data is parsed after being stored as XML objects through Macromedia Flash™ MX environment. Parsed data is then graphically processed to yield such a snapshot image as is demonstrated in Figure 6. This graphical display of weather information is automatically updated when the source of XML data notifies a weather condition change event.

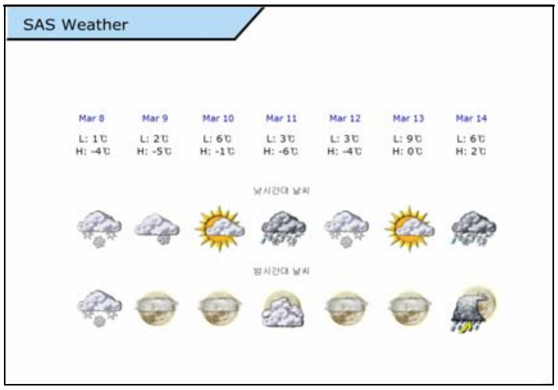

Fig. 6 SAS's real-time weather forecast display

Figure 7 shows a collective display using a cluster of SAS cell units. This type of application is especially important because of its applicability to a wide range of smart home services including TV, VCR, DVD, web-based video streaming as well as home theater. There are two on-going efforts for refining this application and those are reducing grid-shaped opaque bands that obstruct visual continuity and the other is audio/video synchronization across multiple SAS cell units [5].

Fig. 7 SAS's multi-cell activated movie playing

Figure 8 shows SAS's Digital Mirror application that uses multiple cameras which automatically detects human face and body in different angles. Original camera captured videos on all participating SAS cells are digitally processed to generate real-world mirror like view through a software-based manipulation. When one comes close to the Digital Mirror surface, a large image emerges out of the collection of fragmented pieces of images captured across multiple SAS cells.

Fig. 8 SAS's Digital Mirror using multiple cameras

As is illustrated in Figure 9, SAS operates a special type of Context-Aware Videophone application. The size and location of the videophone connection screen are adjustable based on the contextual information identified by the Global Coordinator with the data from an array of ultra-sonic proximity sensors imbedded in a cluster of SAS cells. GC sends signals to the LCs in a low of cells at some time interval. Each LC triggers its own ultrasonic sensor to generate ultrasonic pulse and waits temporarily to detect the reflected wave for distance measurement. Very brief sleep time is reserved before GC sends another signal to the cell adjacent to the activated one to avoid interference. Every time a specific sensor measures distance between the SAS surface and the closest object, it reports this value to the GC via LC it is coupled with. In this fashion, SAS system scans the objects in front of its own surface to identify the location of a user. Then, this location information is used for activating appropriate cell that is engaged in this application.

Fig. 9 Context Aware Videophone service

7. Conclusion

Instead of placing a host of devices and systems within a built environment in the way they eventually need to be networked and managed with complex and sophisticated methods, the SAS system tries to make this complexity unnecessary by using smart building blocks, namely SAS cells, to form highly interactive surfaces inside of a space. The focus of the future research is mainly to develop software applications utilizing SAS system's polymorphic structure. There are some technical challenges, for example, synchronizing multimedia outputs played upon a group of SAS cells is one such example. Another key issue for future effort is related to how a unique hardware like SAS that consists of multiple smart cell units can deal with complex and diversified smart home services in a natural way to provide a truly 'Sensible Environment'.

References

1. Wilhelmson, R., Baker, P., Stein, R., Heiland, R.,"Large Tiled Display Walls and Applications in Meteorology", Oceanography, and Hydrology, 18th International Conference on IIPS, Seattle, WA, USA. Jan. 2004.

2. Prante, T., Röcker, C., Streitz, N.A., Stenzel, R., Magerkurth, C., Alphen, D., Plewe, D.A.,"Hello.Wall –Beyond Ambient Displays", Peter Ljungstrand, Jason Brotherton (Eds.): Proc. Ubiquitous Computing (UBICOMP'03), Seattle, Washington, USA. 2003.

3. Low, K., Welch, G., Lastra, A., Fuchs, H.," Life-Sized Projector-Based Dioramas", VRST'01, November 2001, Alberta, Canada. 2001.

4. Pape, D., Neira, C., and Czernuszenko, M.,"CAVE User's Guide", Electronic Visualization Laboratory, University of Illinois at Chicago, Chicago, IL. 1997.

5. Cline, S. L., Du, J., Keany, B., Lakshman, K., Maciocco, C., Putzolu, D. M.,"DirectShow RTP Support for Adaptivity in Networked Multimedia Applications", IEEE Multimedia Systems '98, Austin, Texas, USA. 1998.