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Smart Space Design Framework

Jayashri A. Bangali, Arvind D. Shaligram

Abstract: Smart space is usually an environment of any building, University campus, outdoor areas that are enabled for interfacing the objects or systems and ubiquitous interaction with the users or visitors. A smart space enhances users experience in the space and provides an environment to perform his everyday activities more easily. However, creating such smart spaces or environments is really a challenge, as the human needs are changing all the time. To cope-up with the available technology and user's requirements is a difficult task.

This paper proposes the design framework of Smart Space based on various aspects such as physical space, its architecture, context, cognitive psychology, technology etc. The methodology of designing a smart space is also explained with the help of flowchart and it is illustrated by a set of system prototypes especially designed for the corridor of a building.

Keywords: Smart Space, Design Framework, cognitive psychology

I. Introduction

Smart spaces primarily consist of automation systems and smart services. Basically there are two classes of smart spaces, one is known as fixed smart space and other class is smart space for mobile user. The fixed smart space provides intelligent features that adapt to the requirements of the user. The research of fixed smart space has focused on developing technology and method to support building automation or home automation such as intelligent light control, security systems, kitchen appliances etc. Another class of systems deals with the needs of mobile users which are related to the delivery of smart services irrespective of user's location and the devices that are accessible to him/her. This approach mainly includes the use of wireless technology and further smart phone facilities. A number of projects and prototypes are reported which are based on the fixed smart spaces [1-4] and smart spaces for mobile users [5] [6]. The papers [5] and [6] had presented a system which gives security alert by sending SMS to the user. Here, the service is provided to the mobile user through GSM network which is location independent.

Jayashri A. Bangali
Kaveri College of Science and Commerce
India

Arvind D. Shaligram
Department of Electronic Science, Savitribai Phule Pune University
India

II. Related work

The conceptual framework is presented in [7] identifies the design principles of ubiquitous smart spaces. The author suggests a set of methods that are essential to realize the human-computer interaction design process. The methods support the formulation of design solutions for integrating new technologies in ubiquitous smart spaces. The physical prototype has been implemented in the interactive workspace, including RFID entry, an interactive door, a wall-sized display, smart floor, tangible models, and LED-mounted hand gesture recognition. A world model for ubiquitous computing environments is presented in paper [8] for context-aware services, e.g., location-aware and personalized information services, in ubiquitous computing environments. It also has several advantages such as it can be used to model not only stationary but also moving spaces (e.g., cars). The issues related to the design framework of smart spaces are reported in few papers. The paper [9] presents that there is need of development of an interdisciplinary design framework that articulates various viewpoints on ubiquitous computing technologies, while emphasizing the potential applications of smart spaces to transform our built environments. .Helal S states the same problem and suggests that creating a smart space is restricted by the set of concepts available at the time of its development. However they faced the problem of better technology becoming available [10]. The paper [11] [12] states the research challenges in smart space application. According to them the real problem is most of the state-of-the-art solutions never cross the research laboratory door step. Many high quality software platforms which have been used to develop smart space applications are not easily available.

III. Smart Space Design Framework

The design of smart spaces requires collaborative efforts in integrating the physical environment, technologies and creates user experiences in a broader human-centric design. To design a smart space, it is necessary to understand the patterns of occupants or users of that space. The design of a smart space is basically based on three factors: 1) Patterns of everyday life of user 2) Technological infrastructure 3) Physical space. Patterns of everyday life include types of occupants, their usage timings and their requirements from the space. Technological infrastructure must support the user requirement and make their pattern of life comfortable. Physical space is basically concerned with the sensors, actuators and network facilities.

A smart space is usually thought of a classroom, meeting room, corridors, conference room etc where people come together to share information or knowledge. These spaces are physical spaces which can be consists of many sensors and actuators to make it smart. This smart space has human centric view which provides an easy interaction with services and resources within it. This interaction is made with the help of sensors and adequate model of control which actually automate the space. The design framework of smart space includes various parameters such as energy efficiency, cost, comfort, security, availability of technology which is shown in figure 1. One dimension of the smart space depicts physical space ranging from a room, corridor, building and it includes user's requirements and study of space. Second dimension denotes living requirements such as comfort, security, energy efficiency, cost etc. The third dimension is linked with sensors and technology used for the smart space.

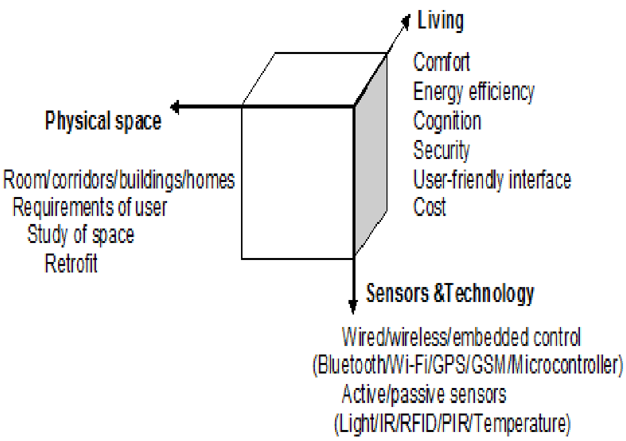

Figure 1 Design Framework of Smart Space

Various aspects have to be considered in designing the smart spaces which can be divided into four functionalities: Cognition, Security, Energy efficiency, Comfort and Context. The cognition in smart spaces is related to the presence of the user in space at a particular location and providing smart services to the user. Security is the most important parameter and it is the need of any user or family as well as the house or a building. Depending upon the user, his needs and surrounding environment, the smart services can be provided which make the user's stay comfortable in the space. Context of any space basically classified two types; physical context and user context. Physical context include physical parameters of the space along with the location and time that every user is concern. Context based system basically captures the context or information of the space and change accordingly. Along with all these parameters, energy efficiency, cost and availability of technologies have to take into account while designing the smart spaces.

IV. Methodology for designing a Smart Space

This paper proposes the methodology of designing a smart space. The design flow of smart space can be explained with the help of flow chart as shown in figure 2.

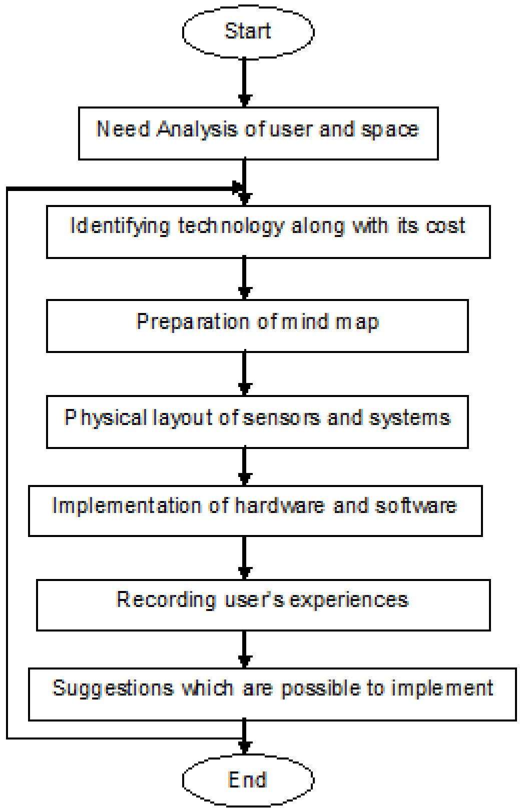

Figure 2 Flow chart of Design flow of smart space

The figure 2 shows the design flow of smart space which itself explains the various design steps of smart space. The design steps are : Need Analysis, Identifying Technology, Mind map of the space, Physical layout, User experience.

V. Illustration of proposed design framework

To illustrate the proposed design framework, a smart space in corridor of a building is designed. Before designing smart space and smart space automation systems for the corridor, physical structure of the corridor and types of users are studied.

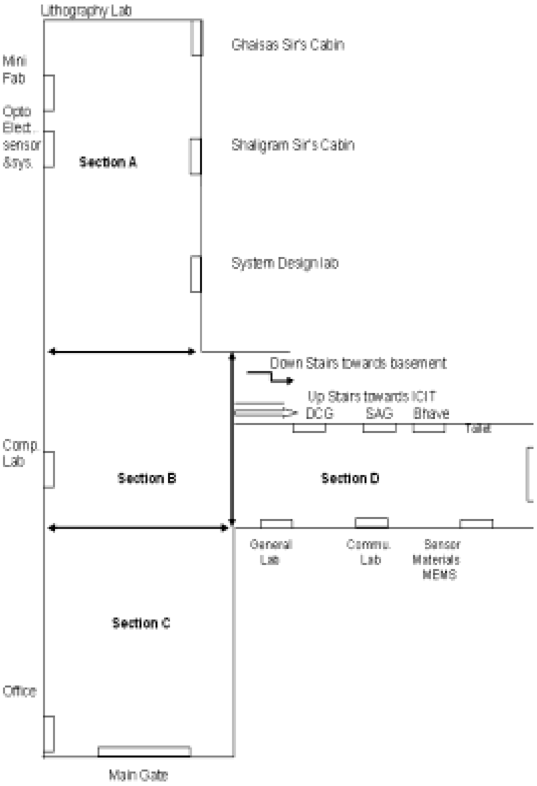

Figure 3 Physical structure of corridor

The study also includes types of occupants, their needs and their working timings. In the present research work, the corridor of Department of Electronic Science, University of Pune, India is considered as an experimental area. The physical structure of the corridor is shown in figure 3. This corridor is divided into four sections; section A, B, C and section D. The mind map of the smart corridor is given in figure 5 which shows various systems and smart services that can be provided to the users. The physical layout of the smart corridor is shown in figure 4. The figure is actually a sensor layout of the smart corridor which shows the locations of the sensors, microcontrollers and the systems in the corridor. Light sensors are denoted by 'L' and 8 light sensors are installed in various sections of the corridor. Temperature sensors are marked as 'T'. Eight temperature sensors are installed in the corridor at different locations. Four passive infrared sensors (PIR) are fixed in each section of the corridor which can detect the movement of an intruder. Interactive notice boards are designed for the students and they are fixed in each section of the corridor which is named as N.B. A navigation system is designed whose master (M) controller is installed at the main entrance and slaves (S) are installed in each cabin.

As per the design of a smart corridor, system prototypes developed for smart corridor are: 1) Energy efficient lighting control system 2) Wireless Light, security system and heating-cooling control system 3) Smart services: a) Navigation System b) Smart Notice Board.

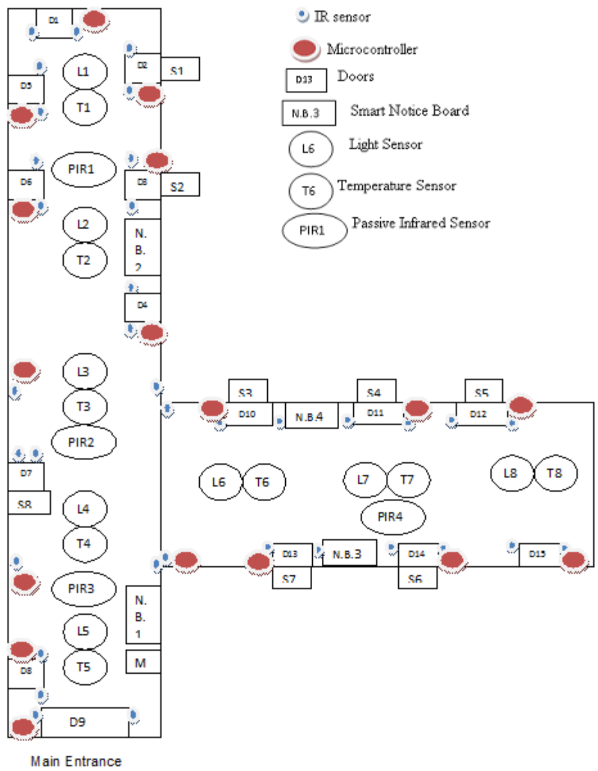

Figure 4 Physical layout of Smart Corridor

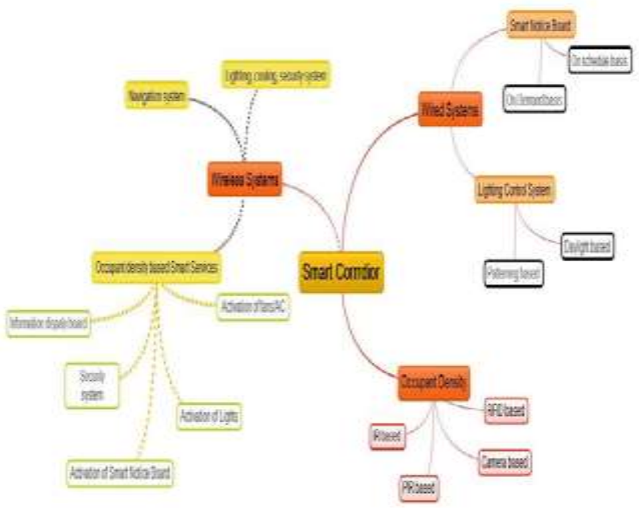

Figure 5 Mind map of Smart Corridor

VI. Development of System Prototypes:

The system prototypes developed for smart corridor are explained in the following section:

1) Lighting control system:

It is basically used to save energy consumption by applying various control techniques. The Lighting control system is based on context and energy efficiency of an indoor lighting installation for corridors which mainly includes use of daylight [13]. The system is designed using 89S52 microcontroller.

A wireless lighting control system designed for a corridor uses photosensors to detect light intensity and passive infrared (PIR) sensors to detect an intruder at night. The temperature sensor senses the temperature and control air conditioner or fans of the corridor. The system has two nodes; analog sensor node and temperature node. The systems is based on wireless sensor node (WSN) and it uses LabView.

A smart space service is defined as a service to a person or user or occupant in a smart space. Services include mechanism for interacting with users and with the physical environment. As the space under consideration is corridor of an educational building, notice boards are vital part of the corridor. Students, staff members and visitors are the main users of this space, so smart services include navigation system and smart notice board.

A) Navigation system

To assist visitors in finding the way to a particular place in building, a prototype of navigation system is developed [15]. The idea behind the development of navigation system is that any visitor can find the way of any cabin or office or laboratory in the building at the entry gate of a building. The system is wireless and it uses Zigbee modules and PIC microcontroller. The block diagram of the system is shown in figure 8. There is one master microcontroller (M) which is installed at entrance of the main gate and eight slaves (S) which are installed in each cabin or office or laboratory as shown in figure 4.

B) Smart Notice Board

The developed smart notice board is a display (LCD screen) which is connected to a laptop or tab. It uses MATLAB program to display the notices. The notices can be available to the students 'On demand' by using RFID cards or 'On schedule' recovery basis [16]. The notices are displayed on the smart notice board 'On schedule' basis. Depending on the date and time, notices related to the students are displayed. For example, M.Sc.Part-I students had a lecture at 10 a.m. and they finish their lectures at 2 p.m., the recess is from 2-2.30p.m. and they finish their practicals at 5.30 p.m. Then the notices related to M.Sc.Part-I students are displayed from 9.30-10.30a.m., from 1.30-2.30 and from 5-6 p.m. Also notices having higher priority are displayed or highlighted number of times.

VII. Results and Discussions

To illustrate the proposed design framework of smart spaces, physical prototypes are developed for smart corridor. The first step in the design of smart space is the need analysis of user and the space. Based on the need analysis of users, requirements of the space, lighting control systems are designed and developed for corridor.

After studying illumination levels in all sections of the corridor (section A, B, C and D) and considering the comfort level of occupants, it was concluded that minimum light intensity required in the corridor is about 70 lux. In section A, B, and D, very less daylight reaches as these sections are interior part of the building. However, in section C sufficient daylight is present because entrance door of the department is open during day time which is in section C. So, accordingly patterning of luminaires in the corridor is designed.

The energy saving calculations of lighting control system is performed on the basis of patterning of luminaires and assumption of available daylight according to the seasonal changes. Assuming, three seasons (summer, winter and rainy) of the year and considering one pattern of lumuniares for 21st March and for 22nd calculations were carried out. The detail calculation of energy saving due to seasonal changes is reported in [13]. The energy saving due to the developed lighting control system is 84% and. Due to the patterning of luminaires, about 70% energy is saved [14].

To make use of available daylight in the corridor, light dependent resistors are used in the wireless lighting control system. In the developed system, eight light dependent resistors are mounted in the corridor which senses available light in the space and accordingly operates the lights. The PIR sensor will detect the movement at night and if it detects the movement, lights will be turned ON and buzzer will sound. Four temperature sensors (thermocouples) are installed in four sections of the corridor (as shown in figure 4) which actually controls fans or air-conditioner of that space.

The designing aspects such as energy saving, user-friendly interface, cost and availability of the technology are also considered in designing the lighting control system. The main advantage of the microcontroller based lighting control system is its user-friendly interface and low cost. The system is retrofitted in the workspace and users are satisfied with the system. The second system developed for smart corridor has all the benefits of wireless technology. It controls lights and temperature of the corridor and gives indication of an intruder. This system is used to study lighting distribution in the space and to observe occupancy pattern of the space since all the data captured by the sensors is stored in the file.

As per the requirements of the space and users, smart services are also offered to the users in smart corridor. As the corridor under consideration is a part of an educational building, the role of notice boards becomes important. So, smart notice board is developed which displays notices related to the students 'On Schedule' and 'On Demand' basis. The system is eco-friendly and convenient for the students. The second smart service provided in the smart corridor is the navigation system to assist the visitors in finding the pathway in the building. As the system is wireless, it is easily expandable to any number of nodes which can be placed at different locations in the building.

The navigation systems are mostly based on GPS technology. Nowadays navigation facility is also provided in the smart phones. However, the main problem with such systems is of the connectivity of the network which is rarely available in an interior part of the building. The developed system overcomes this drawback.

The smart notice board is designed and developed after studying the user's requirements. The main advantage of the developed smart notice board is that it saves the cost of papers which are otherwise required to print the notices. The GUI developed in MATLAB is user-friendly and any non technical person can operate it. As notices usually are prepared by the non teaching staff after approval of the higher authority, it is the requirement of the system that it must be user-friendly and easy to operate. So, an executable file of developed GUI is prepared.

5. Conclusions

Today, designers and researchers are more focusing on the development of smart spaces in a specific domain. There has been no generalize method or design framework of a smart space that can be applicable to any smart space. In this paper, a conceptual design framework of smart space is proposed. Various aspects related to design framework of smart space is elaborated. The methodology of designing a smart space is illustrated in smart corridor. Based on requirements of the user and need of the space, smart services and systems are identified for smart corridor.

Most importantly, system prototypes are designed based on the proposed framework and they are implemented in the workspace. The proposed design framework and its implementation of prototypes have served as a logical base for design of a smart space.

References

[1] Abowd, G.D. and Mynatt, E.D.: Designing for the human experience in smart environments. In Cook, D.J. and Das, S.K., editors, Smart Environments: Technology, Protocols, and Applications,. Wiley, (2005), 153-174

[2] Coen, M., Phillips, B., Warshawsky, N., et al.: Meeting the computational needs of intelligent environments: The Metaglue system. In Proceedings of MANSE'99, Dublin, Ireland, (1999)

[3] Wang, X., Dong, J. S., Chin, C., Hettiarachchi, S., and Zhang, D.: Semantic Space: AnInfrastructure for Smart Spaces, IEEE Pervasive Computing, , 3(3) (2004) 32-39,

[4] Chen, Harry et al.: Intelligent Agents Meet Semantic Web in a Smart Meeting Room, Proceedings of the Third International Joint Conference on Autonomous Agents & MultiAgent Systems (AAMAS 2004), (2004)

[5] Syam Krishna1, J.Ravindra, "Design And Implementation Of Remote Home Security System Based On Wsns And Gsm Technology", Issn: 2250–3676 [Ijesat] International Journal Of Engineering Science & Advanced Technology Volume-2, Special Issue-1, 139 – 142

[6] Sadeque Reza Khan, Ahmed Al Mansur, Alvir Kabir, Shahid Jaman, Nahian Chowdhury," Design and Implementation of Low Cost Home Security System using GSM Network", International Journal of Scientific & Engineering Research Volume 3, Issue 3, March -2012 1 ISSN 2229-5518

[7] Taysheng Jeng," Toward A Ubiquitous Smart Space Design Framework**",** Journal Of Information Science And Engineering 25, 675-686 (2009)

[8] Ichiro Satoh," A World Model for Smart Spaces", National Institute of Informatics
2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo 101-8430, Japan

[9] T. Jeng, "Advanced ubiquitous media for interactive space: A framework," in Proceedings of Computer Aided Architectural Design Futures, 2005, pp. 341-350.

[10] Helal, S.: Programming pervasive spaces. IEEE Pervasive Computing 4(1) (2005) 84–87

[11]Cristiano di Flora, Jilles Van Gurp, and Christian Prehofer Nokia Research Center, Finland," Towards Effective Smart Space Application Development: Impediments and Research Challenges"

[12] S. Helal, W. Mann, H. El-Zabadani, J. King, Y. Kaddoura, and E. Jansen. The gator tech smart house: a programmable pervasive space. IEEE Computer, 38(3):50 – 60, March 2005.

[13] Jayashri Bangali, Arvind Shaligram "Energy Efficient Lighting Control system design for corridor illumination", International Journal of Science and Engineering Research, Vol-3 Issue -4, April 2012, ISSN no: ISSN 2229-5518

[14]Jayashri A. Bangali, Arvind D. Shaligram," Simulation and Development of Lighting Control system using Daylight for Corridor of a Building", International Journal of Innovative Research in Advanced Engineering, *ISSN: 2349-2163, Vol-1*, Issue-11, December 2014.

[15] Jayashri Bangali, Arvind Shaligram," "Development Of Smart Common Utility Corridor For An Educational Institution Building", International Journal Of Pure And Applied Research In Engineering And Technology, ISSN: 2319-507X 2014; Volume 2 (9): 327-335

[16] Jayashri Bangali, Arvind Shaligram," "Development of Interactive Smart Notice Board based on Matlab", Proceedings of National conference on Advances in Electronics and its Interdisciplinary Applications NCAEIA2014, organized by Department of Electronics, Fergusson college, 19-20 September 2014