# Towards Universal Access to Home Monitoring for Assisted Living Environment

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**Abstract.** The improvement of the conditions of daily life at home and work, promoted by the socio-economic progression, best quality private living environments and the immense development in healthcare and biomedical technologies has extended the average age of life beyond 70. According to recent surveys this "population aging" phenomenon will contribute to reach the record number of 1 billion people over 60 years on earth by the year 2020. Due to a variety of reasons such as convenience or a need for security and privacy these elderly people generally prefer to avail healthcare facilities at their home. This is time to break through the physical boundaries of hospitals and bring healthcare facilities to the homes. Wireless and internet-based healthcare devices can play a vital role in this regard given that reliable, individualized systems with user-friendly interfaces are developed to enable elderly people feel comfortable with making use of novel technology. This paper presents a remote home monitoring application called Living Assistant that could be utilized to continuously monitor and control a wide range of electronic appliances and ambient parameters. Basically it has been designed to function as a healthcare aide for elderly patients suffering from restricted mobility or other chronic diseases. The advanced ways of user interfaces presented in this paper are simple, generic and universally applicable. With little customization the application can be used to accommodate other user groups as well.

**Keywords:** Universal access, Home monitoring, Smart home, Assisted living, Living Assistant, Elderly people, Technology-enhanced learning, TinyOS.

## 1 Introduction

During the last decade, the size of elderly population has shown noteworthy growth, especially in the developed countries. Carrying out daily tasks at home becomes difficult or impossible for elderly persons with restricted mobility capabilities. Besides, movement in (out)-doors requires a third-party's assistance [30, 31]. Yet, these elderly people clearly prefer independent living to institutionalization [28, 29]. At same time, they exhibit ever-increasing tendency towards leading an isolated life away from their offspring. In this context, conceiving technologies for increasing their

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autonomy, so as to enable them to self-manage their life is of utmost importance. Furthermore, a safe, convenient, sound and healthy living environment is the prerequisite for a good house for the elderly people with special needs.

Alongside the overwhelming spread of computer and internet technology the volume of the market for mobile handheld devices (cell phone, PDA, smart phone etc.) is significantly increasing. In addition, recent advances in sensor networks and wireless mobile technologies, such as Bluetooth, WiFi, Zigbee [1] etc. has resolved the complicacies of developing applications constrained by the mobility of users. A wide variety of sensors are becoming inexpensive and readily available. With the objective of improving quality of lifestyle of modern people, current research works deal with the development of digital home monitoring system using wireless sensors. Despite the breakthroughs in the technological aspects, the relatively slow adoption of such systems indicates that there are certain factors restricting their acceptance and use [28, 29]. For example, most available home-care systems monitor the health of individuals suffering from chronic diseases such as heart disease, lung disorders, diabetes, etc. Most of them are costly and include health monitoring equipments which are difficult to use. Less attention has been paid to monitoring and maintaining the personal wellness of the elderly people to enable them to live a normal life. In this paper, we present the design and implementation of an affordable solution to provide remote home monitoring that allows users to monitor and control elements of their home from a remote device. Our proposed solution, Living Assistant (LA), allows individuals to monitor and control electronic appliances in their homes while they are away using remote devices such as cell phones, PDAs, and laptop computers. We have conducted necessary research to explore the field of home monitoring and developed a concept that would serve as an efficient universal home monitoring system. We have built a prototype of the LA that allows remote control of electric appliances via a webpage, electronic switch, and Zigbee-enabled Tmote-brand sensors [23, 27]. The website and server prototype enable the users to control the system remotely.

Major objective of our application is to provide the means for improving the quality of life of elderly people at home by developing generic technologies for managing their domestic ambient environment, home automation systems with the aim to increase their autonomy and safety. In order to accomplish this goal LA aims at providing universal access [18] to a set of electronic devices and couple of ambient parameters. Such omnipresent access to information technology plays an extremely important part in the context of technology-enhanced learning (TEL) [22]. Our system proposes an enhanced interface technology which is customizable and adaptable to be used in any context. The advanced ways of user interfaces presented in this paper are simple, generic and universally applicable. Therefore, it should be easy for educators to adopt the system and apply it in their own contexts.

Our application provides advanced ways of user interfaces which are simple, generic and universally applicable. These interfaces can be used to build customized and sophisticated healthcare tools as well. Inclusion of a number of biosensors will facilitate that. The existing prototype is easily extensible to accomplish that purpose. Such a system would be useful for healthcare professionals in real time monitoring of fall detection, sleep monitoring, pulse monitoring etc. of an elderly patient.

The rest of the paper is organized as follows. Section 2 presents several scenarios where our application provides the perfect solution. Characteristics and functionalities

are discussed in Section 3 and Section 4 respectively. We discuss our application in detail in Section 5. Usability of our proposed system in TEL is presented in Section 6. Section 7 focuses on the related works and finally we conclude in Section 8.

## 2 Motivation

***Scenario 1:*** Mr. Jones goes out for a walk in the evening as usual to do some light exercise. When he reached the nearby park, he could remember that he forgot to switch off the electric oven at his home. He gets worried as there was nobody at home to turn it off immediately to get rid of any mishap. In such situation, he uses the Living Assistant application from his PDA as he is a subscribed user. After logging on to the server Mr. Jones instantly gets access to the home monitoring system which displays status of the electrical devices. Then using the system he switches off the oven and be assured that it is turned off properly. At the age of above 65, many people like Mr. Jones suffer from such memory loss and frequently forget to properly handle the electronic devices of their daily life. They find the LA as a handy tool.

***Scenario 2:*** Mr. Hughes, another elderly customer, is on his way to home after meeting some of his relatives. It is about half an hour's journey. When he starts driving, he asks his Living Assistant running in his PDA for the scheduled report which shows that temperature is running low at his home and reminds him to set the heating system on. Mr. Hughes turns on the heating system and sets it at a specific temperature. By the time he reaches home, he finds it at the desired temperature. Thus our system assists him in daily life activity and helps bring down electrical cost (utility bills) by reducing power consumption as well.

***Scenario 3:*** Mr. Hughes cannot attend his elderly parents regularly as they live quite far from his house. However, using the LA he can extend the level of attention paid to his parents as it allows him to monitor their living conditions frequently. Every night he makes sure that the living rooms are at proper temperature and lights are switched off. Sometimes his father falls asleep while reading books and keeps lights on. Mr. Glenn can easily switch off the light remotely using LA.

Situations like these require the need for applications that can assist elderly people to monitor and control electronic devices and certain ambient parameters as well. The Living Assistant application will provide its users with such enhanced facilities.

## 3 Characteristics of Living Assistant

The Living Assistant application aims at improving the lifestyle of modern people by allowing them interacting with their home ambience more conveniently. Proper handling of a number of challenging issues is essential for perfect accomplishment of this purpose. These are:

***Safety of the User:*** As the application deals with remote handling of electrical appliances, ensuring safety of the environment is of utmost importance. The process of distant regulation of a device should be safe enough for the home environment such

that it does not cause electrical shocks, short-circuits, fires etc. Besides, immediate actions should be taken regarding any malfunctioning behavior of a device to safeguard major mishaps.

***Accuracy and Precision:*** The actions taken by a user from a remote place should be taken care of accurately with highest attainable precision. Lack of accuracy may allow the devices operate in a way not intended by the user and it may endanger the home environment. Likewise, operating conditions of the devices should be controlled precisely to attain a task done smoothly.

***Device Diversity:*** Modern home environment comprises wide variety of electrical devices. These devices may differ in their operating conditions such as driving power, voltage, current etc. The application should be adaptable to such diversity. In particular, the controlling hardware (switch) should be capable of driving on appliances that operate at a wide range of electrical power, voltage, current etc.

***Responsiveness:*** Actions taken by a remote user should be responded within a reasonable period of time. Slow response time degrade user's perception about the system.

***Portability:*** The hardware unit consisting of a switch and set of sensors acts as the data collection unit of the application. In order to widen the usage of our system it is necessary that the hardware unit is lightweight and occupies less space to fit in different locations throughout a home or office environment. Such portability will facilitate multi-purpose uses of the same hardware unit distributed with the application package.

***Customizability:*** Different users may choose different combinations of electrical devices to put under continuous monitoring and regulation. Preference of a specific user may also vary depending on the weather parameters like temperature, humidity of surrounding environment of her residence. Users should have options to set alert level for the devices to be monitored. In order to provide all these facilities the application should be customizable.

***Energy Efficiency:*** The need for continuous monitoring keeps the Living Assistant application (hardware and software units) running all the time. So, it should consume low electrical power. It is better if the controlling switch and the sensors are supplied power from the server PC to eliminate usage of external power source.

***Security, Authenticity and Integrity of Data:*** In order to avoid false data all tiny sensors must be authenticated before data can be treated as reliable. Security and reliability of the data are highly dependent on the authentication mechanism. There should be integrity among all these data and by checking this integrity the system will be able to detect any anomalous situation such as faulty/malfunctioning device, erroneous information from any source.

***Universal and Ceaseless Access:*** The entire system must provide uninterrupted connectivity between the remote PC or handheld device of the users and the home monitoring system.

***User-friendly Multimodal Interface and Minimal Interaction:*** Entire user interface must be simple, self-explanatory and easy to learn and use. The system with its focus on e-learning and training should provide multimodal interfaces which enable the inclusion of a number of human senses. The data should be displayed in a way that requires minimal interaction on the user's part.

## 4 Functionalities

***Home Monitoring:*** Continuously monitoring the statuses of electrical devices and certain environmental parameters of the home is the basic task of LA. A number of mote sensors are placed in the rooms to collect data regarding temperature, humidity, light, sound, smoke etc. There is a special purpose switch which works with a device selection unit to monitor and control on/off state or operating level of any electrical device. Data from the sensors and the switch are sent to a server connected to the internet.

***Data Display through Multimodal Interface:*** An authorized user can log on to the website at anytime, from any place and using a PC, laptop or PDA. The server module of LA displays status of home appliances/devices, doors, windows and values of selected ambient parameters graphically. The system interacts with the user through an interface having iconic representations of appliances/devices, doors, windows, rooms etc. The multimodal interface is customizable based on user's preference. It requires minimal typed input from the user and is easy to learn and use.

***Ubiquitous Access:*** One of the major goals of the LA is to ensure universal access to home monitoring system. It is accessible from any phone, PDA or computer connected to the internet. There is no constraint on the software or hardware platform of the client.

***Scheduled Reports and Emergency Alarms:*** LA can schedule reports on home status at periodic times with specified intervals. Besides, fixed thresholds can be set up to check for an emergency situation (according to gathered data) and generate an alarm. The authorized users can also be immediately notified and can take measures before it is too late.

## 5 Living Assistant: Design and Development

The major steps of developing our entire application start with creating an interface on the web that mobile devices can access at anytime from any place and to have a TMote sensor-based monitoring system that can control the flow of electricity to home electric appliances. Finally we enable the web interface to send signals to the TMote monitoring system, effectively allowing the user to monitor and control electric appliances at home while they are away. The entire system comprises a hardware unit and a software unit. Major part of the hardware unit is an analog control switch which controls the electronic device connected to it. There is a TMote which works as

wireless data transceiver to transfer data to and from the server. The overall hardware interface will resemble the picture of Fig. 1. As shown in this figure any other electronic device can be attached to the switch and using a device selection unit a specific device can easily be chosen.

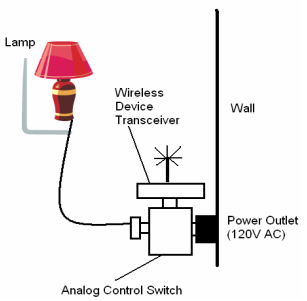


**Fig. 1.** Hardware Unit

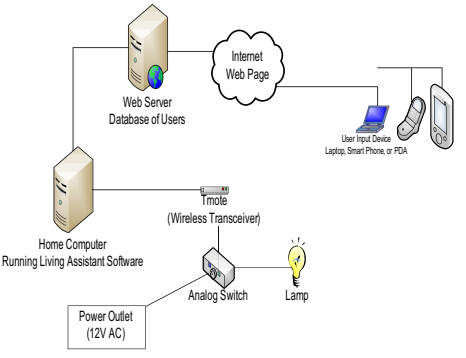


**Fig. 2.** Software Unit

Fig. 2 presents the architecture of the software unit of LA. Major components are TMote sensors, a home computer and a web server. Status of a device connected to the analog switch is stored in the home computer. A user accesses this data by logging on to the website through internet.

***Prototype Description:*** The prototype version of LA is built using Visual Studio 2008, nesC, TinyOS [28] and JDK 1.6. Using HTML with JavaScript for our web architecture ensures that our system functions on most devices and still allows active interaction with the client monitoring and control software. We use switching relays and a single plug interface for our electrical hardware to promote easy and inexpensive prototype development and construction. The web page accessed by the user through a PDA, Smart Phone, or Computer with internet connection, is programmed using HTML and JavaScript. The HTML acts as a wrapper to display the content to the user while the JavaScript is used to pull information from the user (input) as well as give output to the user. The user input is sent to an APACHE web server which hosts a database of customers as well as command information which is relayed to a Home Computer running Living Assistant Software. The Living Assistant system sends information to a TMote sensor to carry out a user specified task. The diagram below shows the user interface of the system.

***Evaluation:*** The user experience and opinion of the Living Assistant application has been examined by means of cognitive walkthrough among people from various age groups. The survey included 24 people of three different age groups with a questionnaire about the features of the application. The questionnaire contained questions about the usability of the prototype and the overall importance of certain concepts related to LA. Fig. 4 exhibits the results of the survey. The category being considered in Fig. 4(a) primarily covers data confidentiality and privacy issues along with the user friendliness and responsiveness of the application.

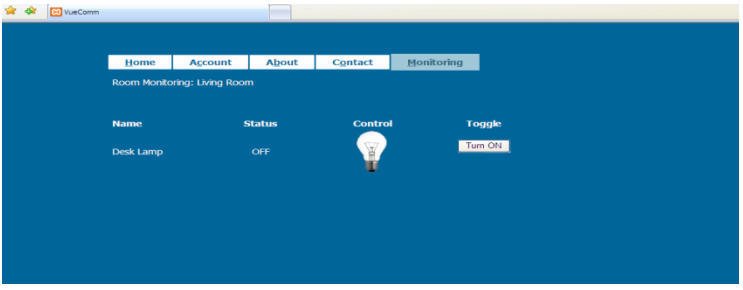


**Fig. 3.** Software Interface of the Living Assistant Application

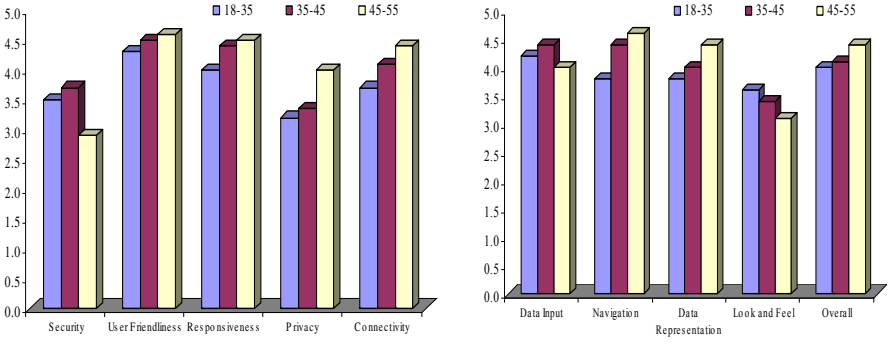


**Fig. 4.** Survey data collected on the Living Assistant application

From the graph it is evident that a user friendly interface is the most important and users seem to be less worried about security, especially in the higher age group. The usability category, as shown in Fig. 4(b), reveals that the prototype requires enhancement in navigation, data representation and visual style.

## 6 Usability of LA in Technology-Enhanced Learning

In this section we discuss how our proposed application facilitates technology-enhanced learning. Technology-enhanced learning aims at supporting a learner-centered mode by offering several means of engaging the participants-both learners and educators more actively [22]. In the context of learner-centered orientation and technology support, experiential learning is encouraged as this style is more strongly self initiated and self organized. The experiential learning style can substantially be supported by the use of our proposed application as it enables provision of personalized learning objects in the area of versatile collection of electronic devices. Our application provides various advanced options for computer mediated communication as well.

Features of LA are inclusive in the sense that there are no constraints regarding potential teachers, learners and organizations. They can be used in and adapted to any educational context. LA interfaces are adaptable and extensible by their very nature. They describe generic interactions that have been abstracted from application-specific

or organization-specific implementations. LA interfaces are easy to use given the learning process is sufficiently transparent, emphatic towards the learners familiar with basic underlying pedagogical concepts. User involvement is inherent in technology-enhanced learning [22]. During the entire development process of the application we ensured user involvement by gathering their perceptions and feedbacks in relation to our proposed system.

## 7 Related Works

Telemedicine and remote monitoring of patients at home are gaining higher urgency and importance [3, 4]. In [2], the in-house movements of elderly people are monitored by placing infrared sensors in each room of their homes. While such a method may not be as obviously intrusive as using cameras, still it intrudes into the privacy of the person. Ahamed et al. discusses the challenges of developing Wellness Assistant (WA) [10], software which can be used by people with obesity, diabetes, or high blood pressure, conditions which need constant monitoring. In [13] they provide the details of another application 'Healthcare Aide'. A similar software called Wellness Monitor (WM) is presented in [11] which facilitates continuous follow-up of cancer patients. In [3] the new possibilities for home care and monitoring are described using wireless micro sensors. Regular patient monitoring using personal area networks of wireless intelligent sensors is reported in [4]. The development of care support system to monitor the overall health of residents who need constant care has been reported in [5]. The Home Heartbeat [6] is commercial product developed by Eaton [6] with assistance from MAYA design [7]. Home Heartbeat uses wireless sensors to determine if windows or doors are open, which devices/appliances are on, if there is water in the basement, and so forth. Gaddam et al. proposed the development of a wireless sensors based home monitoring system especially for elder people [8]. All these systems have the purpose of monitoring a patient remotely or taking care of elderly people. These systems do not facilitate universal access as they target a particular user group. Most of these systems are not even affordable by common people.

The relationship between services, spaces and users in the context of a smart home is analyzed in [9]. Then they propose a framework as well as a corresponding algorithm to model their interaction. [14] presents an omnipresent customizable service which can be used by different types of users from different fields such as education, healthcare, marketing, or business, at any time, and at any place. In [15] Mileo et al. describe an intelligent home environment in which modern wireless sensor network technologies allow constant monitoring of a patient in a context-aware setting. Some recent works in relation to ambient assisted living is reported in [16] which refers to electronic environments that are sensitive and responsive to the presence of people and provide assistive propositions for maintaining an independent lifestyle. Similar works presented in [17] aims at producing technological and media support to help elderly people to stay at their homes longer. This paper is about challenges of technological and media innovations concerning quality of life of elderly people. These works propose advanced interface mechanisms and other techniques to assist lifestyle but the approaches are too specific to be used in technology-enhanced learning. In [19, 20, 21] the issue of technology-enhanced learning is addressed and several advanced techniques are proposed for enhancing collaborative learning.

## 8 Conclusion

This paper has presented a remote home monitoring application called Living Assistant intended to facilitate the monitoring and controlling of a set of electronic devices at any time from any place. Although the application is basically designed to function as a healthcare aide for elderly patients suffering from restricted mobility or other chronic diseases, the software and hardware units are developed to be open, flexible and customizable for different user groups and adaptable to allow for a variety of electrical devices and many different types of sensors to monitor countless conditions regarding home ambience. We have built an analog control switch and a software module for interfacing with the system. The system enables users to access the system universally. Couple of significant challenging research issues like privacy, reliability and multimodal user interface capable of covering all human senses are at the focus of our future work. Features of the system proposed in this paper adequately match with the ultimate goal of technology-enhanced learning which is to bring clear benefits and increased value for the end users.

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