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Implementing Computerized and Digitally Mobile Home Automation System towards Electric Appliance Control and Security System

Zeeshan Ahmed[1,3,4,*], Mujtaba Ali[2,4], Saman Majeed[1]

[1]University of Wuerzburg, Wuerzburg Germany.
[2]DEKA Research and Development, Manchester USA.
[3]Vienna University of Technology, Vienna Austria
[4]University of Central Punjab, Lahore Pakistan.

zeeshan.ahmed@uni.wuerzburg.de, saman.majeed@uni-wuerzburg.de

Abstract. In this research paper we address the importance of home automation system as compared to the old and traditional living systems. We present our own idea leading to a concept towards the practical implementation of a home automation and security system. Going into the details of this research, we present designed hardware and software architectures which then implemented in the form a real time prototype application i.e. Smart House. Discussed and implemented prototype application is capable of providing options for controlling house's electric appliances using computer and mobile. Furthermore it provides a house security system which is capable of not only tracking the interruption but also taking some intelligent immediate response actions.

Keywords: Artificial Intelligence, Automation, Hardware Engineering, Human Machine Interaction, Mobile Interface, Product Line Architecture, Software Engineering, Security.

1 INTRODUCTION

Computer Science (CS) is mainly the study of practicalities of information and computation for the implementation of applications with the use of different algorithms to model multifarious systems. Unlike other branches of Natural Sciences (Biology, Physics, Chemistry) CS is not that mature, experienced and old, as it has just recently completed its half century of academic existence in 2011. But at the same time, its speed of technological progress and worldwide acceptance is a much faster than any other field of the World which is ultimately not less than a revolution of 21st Century, so far. Likewise other scientific fields, CS has many sub fields e.g. System Design and Engineering, Theoretical CS, Operating System, Programming Languages, Software Engineering, Artificial Intelligence, World Wide Web, CS Graphics, Image Processing, Machine Informatics, Machine Learning, Semantic Web, Game Programming, Knowledge Engineering, Security, Virtual Product Development, Human Machine Interaction, Natural Language

Processing and Product Data Management and Bioinformatics etc. Many software systems have been developed and contributing in different fields of life e.g. data mining systems implementing mathematical algorithms [24], biological data management system [32], product data management systems with intelligent graphical user interface [25],[29] and natural language processing based search [26], [31], product line applications towards performance measurement and metrics based Analysis [27], agent and knowledge based semantic web based applications [28],[30], robots and multi agent systems etc. Still there are lots of areas, domains and sub fields that need to be improved and progressed. The field in the focus of this research paper is one them i.e. *Electronic home automation system design and engineering [1]*.

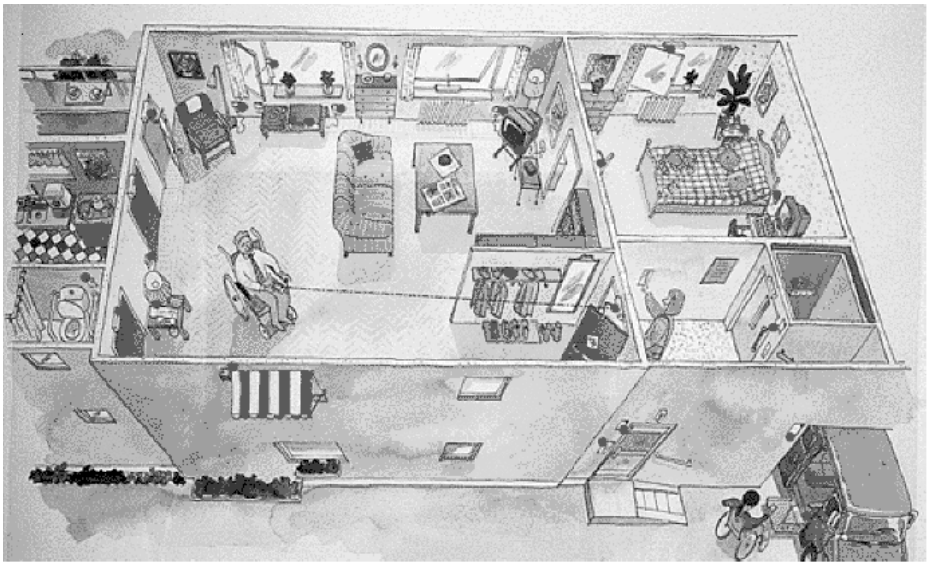

Figure.1. Traditional Living System; this is an abstract pictorial presentation of the traditional living of system of developing countries and old living concept of developed countries, where most of the time a person has to do the things by his own (manually), and to make things bit automatic a person has to take help of some additional things e.g. strings etc.

Technologies like "*Home Automation Systems*" are still under considerations and have not been developed up to the level of ultimate maturity. The Smart House is supposed to be a house whose electric appliances can be remotely controlled (while residing with inside or outside the house) using computer, remote control, mobile or voice recognition systems etc. But due to the lack of integration in available tools, technologies and limited relevant hardware availability, it is very difficult to produce a system which can be controlled fully as desired. The motivation behind this research was to propose, design and implement a home automation system i.e. Smart House; a computerized and digitally mobile home automation system towards electric appliance control and security system. Using

developed system, a house's electric appliances can be controlled via computer and mobile manually, automatically or by scheduling operations e.g. automatically turning on or off switches at particular date and time. Furthermore it requires the proposition and implementation of a security system for not only tracking the interruption but also intelligently taking immediate responses.

This proposition can lead to many benefits in terms of its usage by saving time, improving security and reducing electricity usage by limiting the unnecessary use of electric appliances e.g. some lights are turned on every night and need to be turned off early morning which can be scheduled. It can also be very beneficial, in case if the user is a special/disabled person, then he or she can control the electric appliances without going to the every switch by foot. Due to its mobile use, it could be very use full for busy persons or those who normally forget things e.g. if some person left for his job early morning then he can later using his mobile can check might he has forgotten to close some lights etc. Furthermore, if the records of all electric appliances (on and off timings etc.) are saved and maintained in some particular system (database), then even user can verify the electricity bill as well.

The main objectives of this research and development were

- To construct a complete automated home which can control major electric components via computer and mobile.
- System should not only provide complete manual control of electric devices but also provide the accessibility of scheduling (date and time) devices using the computer and mobile devices.
- The record of all the activities e.g. Time of on and off of the house's electric devices (switches) should also be stored and maintained in database.
- The graphical user interface should be flexible and friendly so then a normal local user can easily understand, use and adopt the system.
- A phone dialer should also be provided to make manual and automatic phone calls, the main purpose of this phone dialer would be to automatically make phone calls to the concerned person when some security disturbance happens.
- The mailbox should also be provided to manually and automatically check and send emails, the main purpose of this mailbox would be to automatically send information to concerned person's email when some security disturbance happens and most important data needs to be saved.
- User authentication system should also be there to secure software usage; to avoid illegal manipulation of the system remotely; as only the administrator should have the complete control of house including all provided options.

Residing within the scope of this research, availability of limited resources in terms of man power and budgets, keeping eyes on above mentioned benefits and objectives with a narrow focus, a research was conducted in the field of home automation system and security implementation. This research was started with the construction of conceptual designs and prototype model implementation (see section 2), later the hardware (see section 3) and software designs (see section 4) were constructed and implemented. A comprehensive hardware and software based prototype application was developed which was consisting of different modules capable of not only successfully working as stand alone applications but also in the

form of an integrated product line application. Implemented prototype has been successfully tested and validated during unit and integration testing. During this research we have found some limitations and prerequisites with respect to the user point of view (see section 5), which could be resolved in future.

2 CONCEPTUAL DESING AND PROTOTYPE MODEL

Before starting the construction of implementation designs of proposed prototype, conceptual designs are made and presented in Figure 2. The house is supposed be constructed following three layer architecture i.e. *External Layer, Internal Layer and Deep Internal Layer*. External Layer of prototype as shown in Figure 2(a), is the outer layer of the house (like almost every house), Internal Layer as shown in Figure 2(b) carries the internal structure of this prototype consisting of 6 Rooms, a lobby and some other parts but equipped with electric appliances (bulbs in this case). As shown in Figure 2(c), Deep Internal Layer is like a basement containing implemented hardware (powerhouse with electricity and designed hardware). The designed conceptual model is implemented successfully in the form of a real time prototype house (made of wood) as shown in Figure 2(d).

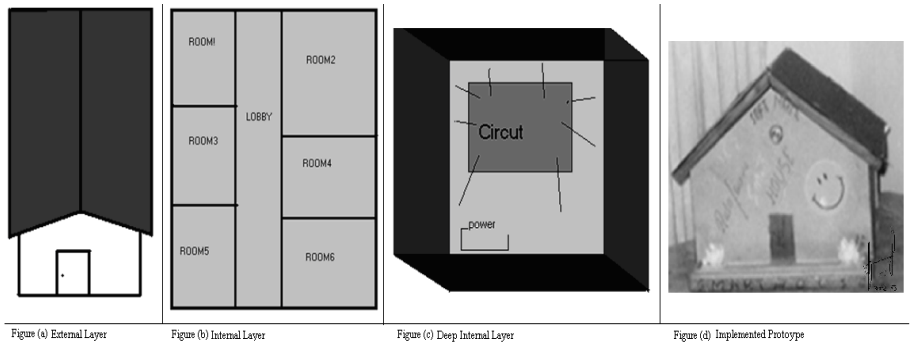

Figure. 2. Conceptual Designs and Implemented Prototype Model. Figure (a) is the Conceptual External Layer, Figure (b) is the Conceptual Internal Layer, Figure (c) is the Deep Internal Layer and Figure (d) is the implemented prototype of the all three conceptual layers.

The overall designed conceptual architecture and real time work flow of this complete project is shown in Figure 3. As presented, the concept is to implement a complete home automation system using which a user can control its house's electric appliances directly via computer and via World Wide Web using mobile device.

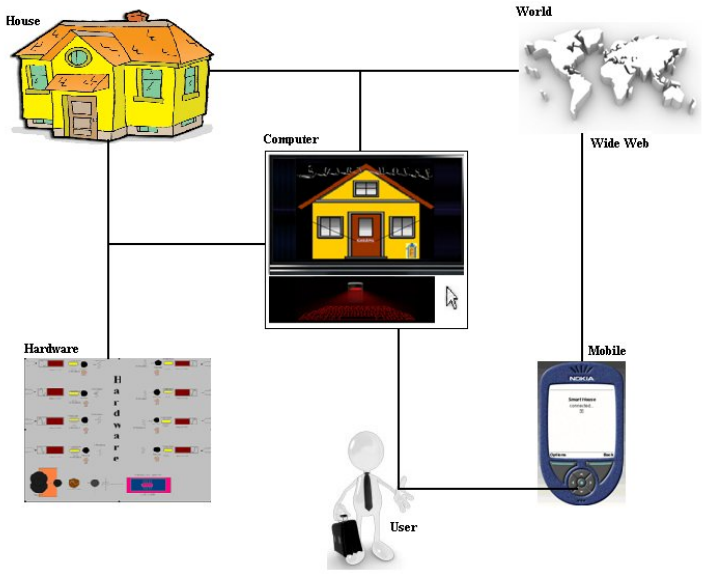

Figure. 3. Designed Conceptual Architectures and Real Time Work flow of Smart House consisting of a user, computer with installed needed software, mobile with some needed services from any telecommunication company, world wide web (internet), house and implanted in use hardware.

3 HARWARE DESIGN AND IMPLEMENTATION

The designed hardware consists of two main circuits i.e., *Output Control Circuit and Input Control Circuit*. Output Control Circuit is designed and implemented to control the electric appliances using computer and mobile devices. This circuit connects to the computer through data cable using Input Output (I/O) Port [2]. Output Control circuit consists of following different components .i.e., *eight Relays, eight Transistors, eight Crystal diodes, eight 1K Resistances, eight 4.7K Resistances, eight LEDs, one 2.5 volts Capacitor, one Bridge (AC to DC Converter), one Connector and one Parallel port*, as shown in Figure 4.

- *Relays* [3]; the output circuit is mainly based on 8 relays (12V, 5A). Rely is an electrically operated switch and its function is to switch between two terminals. The electric connection of each room is connected to each relay. Operating voltage of each relay is 12 volts (DC), capable of switching current of 220 volts 5A (AC). Furthermore relays perform both forward and reverse biasing, handled with the help of a transistor. During forward biasing it connects to terminal (1) and during reverse biasing it connects to terminal (2).
- *Transistors* [4] (C945) is to control biasing (maximum operating voltage of a transistor is (1-1.5V or 0.3A) therefore resistances are connected across the transistor).

- *Crystals Diodes* [5], [6] are used for purifying the biased current flowing toward relays.
- *Resistances* [7] are to drop flow of current up to extent of resistance. Two types of resistances are used in this circuit i.e. 1k and 4.7k.1k resistance is connected across LED and combination of (4.7k and 1k) resistance is connected across transistor.

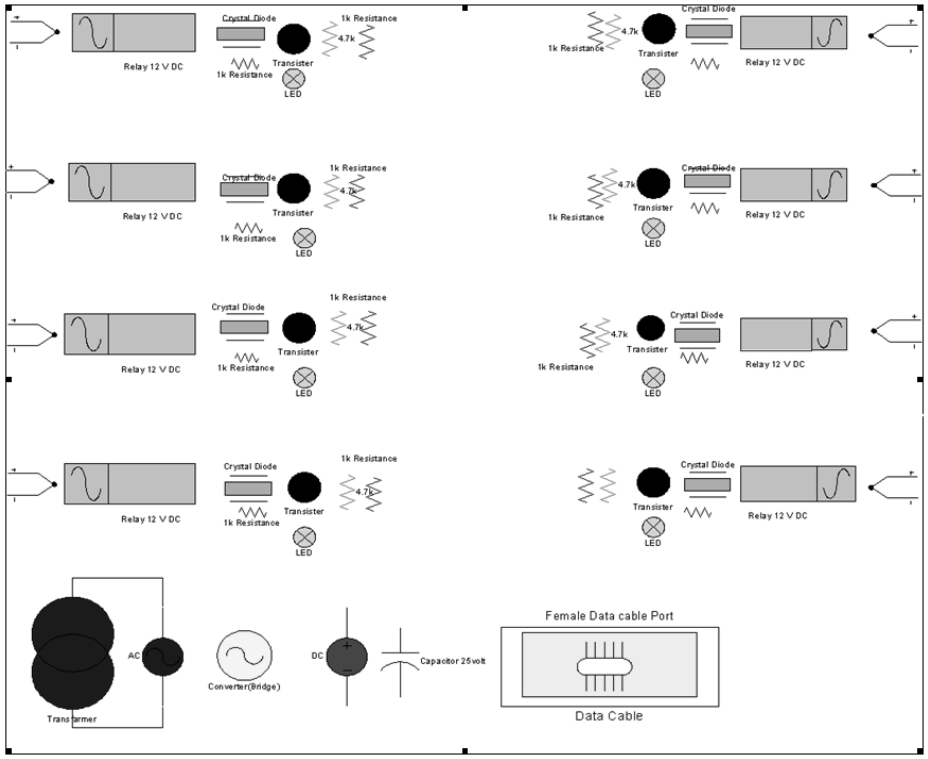

Figure. 4. Output Control Circuit; Design is consisting of eight Relays, eight Transistors, eight Crystal diodes, eight 1K Resistances, eight 4.7K Resistances, eight LEDs, one 2.5 volts Capacitor, one Bridge (AC to DC Converter), one Connector and one Parallel port.

- *Capacitors* [8] are to store the charge and maintain constant flow of current (Capacitor rated here is as 25V 2200 MICRO FARAD).
- *Bridge* [9] is to convert (AC) voltage into (DC) voltage (a combination of four diodes).
- *Connector* is used to connect (AC) transformer (12V, 1A) to the circuit.
- *Light Emitting Diode* (LED) [10] is to produce light and to verify the signal.

Parallel Port [11, 12] is a 25 holes port used to connect it to the computer system via parallel port. It is mainly divided into three parts .i.e., *Port A, Port B and Port C.* Port A consists of selection lines D0 – D7 (from connectors hole number 2 to 9).

Port B consists of ERROR, SLCT, PE, ACK, BUSY Lines (from hole number 15, 13, 12, 10, 11 respectively) and Port C consists of AUTOFND, INIT, SLCTIN lines (from hole number 14, 16, 17).

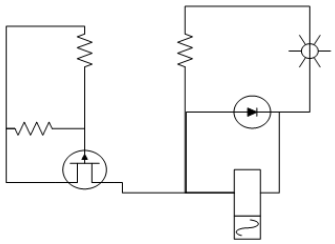

Figure. 5. Output Control Circuit; Flow of Current.

The flow of the current to relay is controlled by the circuit (designed). The circuit is designed using the combination of a transistor (C945), a crystal diode, three resistances (1k, 1k and 4.7k respectively), where as LED is used to indicate the activeness of relay, as shown in Figure 5. The work flow of whole circuit starts with the availability of electric current to all components on the board. Later then signal from computer via data able comes to the board and move towards respective relay and turn on or off the switch, and then connected electric device to the respective switch will also be turned on or off (depending upon the signal). Bit 0 is for off and bit 1 is for on.

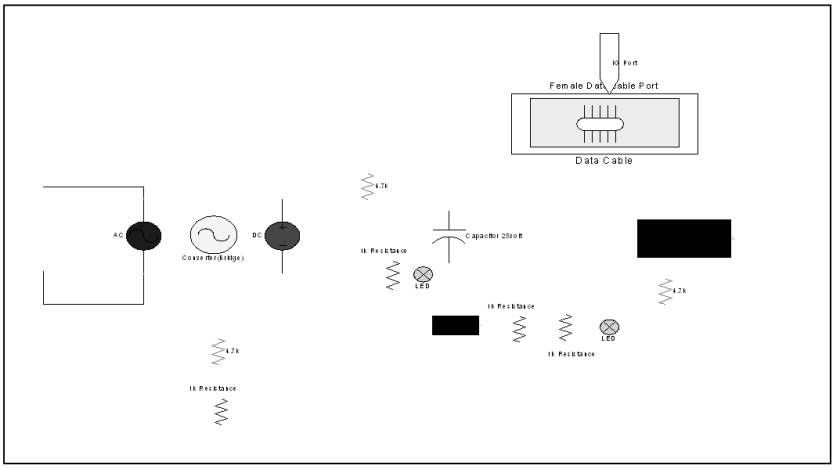

Figure. 6. Input Control Circuit; Design is consisting of Transistor C945, Resistances, Capacitor (25V 2200 MICRO FARAD), Bridge, Connector (12V, 1A), One Integrated circuit, LEDs and Parallel port.

Input Control Circuit is designed to provide and control security of the house. Conceptually and practically a thief detector (can be laser or infrared ray etc.) is supposed to be connected to this circuit. The job of this designed circuit is to receive sent signal from thief detector and forward to the computer. This circuit is also connected to the computer via data cable. The designed circuit consists of following components .i.e., *Transistor C945, Resistances, Capacitor (25V 2200 MICRO FARAD), Bridge, Connector (12V, 1A), One Integrated circuit, LEDs and Parallel port*, as shown in Figure 6. The flow of Input Control Circuit, likewise Output Control Circuit, starts with the availability of electric current to all attached electric component in the board. The main job starts, when a signal comes from the attached thief detecting device (when some interruption occurs). After converting analog signal to digital signal, a digital notification is sent to the computer for further action using attached data cable via parallel port.

4 SOFTWARE DESIGN AND IMPLEMENTATION

Looking at the project size and level of complexity in software design and implementation, it was very difficult to achieve the goals of this research and development in one step. Keeping this in mind, the software architecture of the project was designed following the concepts of Product Line Architectures (PLA), as the implementation was divided into a number of modules i.e., *Output bit controlling, Receiving input, Phone, Mail Box, Data base and Mobile Interface.* Each module is capable of working as a standalone application as well as integrating with each other to form a PLA based application i.e. Smart House. Major tools and technologies were used in the design construction and software development i.e. Microsoft Visual Studio 6 [13], C++/C [14], Nokia Mobile Tool Kit 3.1 [15], Java Standard Development Kit and Run Time Environment [16], Kawa [17], Tomcat [18], Wireless Markup Language (WML) [19], Circuit Maker [20], Unified Modeling Language and Rational Rose [21].

The designed main graphical user interface is shown in Figure 7, the concept of graphical user interface was to design a house, whose, after knocking the main door (in software) you will get different options i.e. *Control, Detector, Main Box, Phone, Records and Quit Me*. Control option is to enable graphical user interface for Output Bit Control, Detector is to start process of thief detection by enabling Receiving Input module. Mail box provides options for personal manual and automatic email send and receive operations. Phone is the interface as a dialer for making manual and automatic phone calls. Records provides the graphical user interface as a Database Management System integrated with designed database for keeping and maintaining records of all operations.

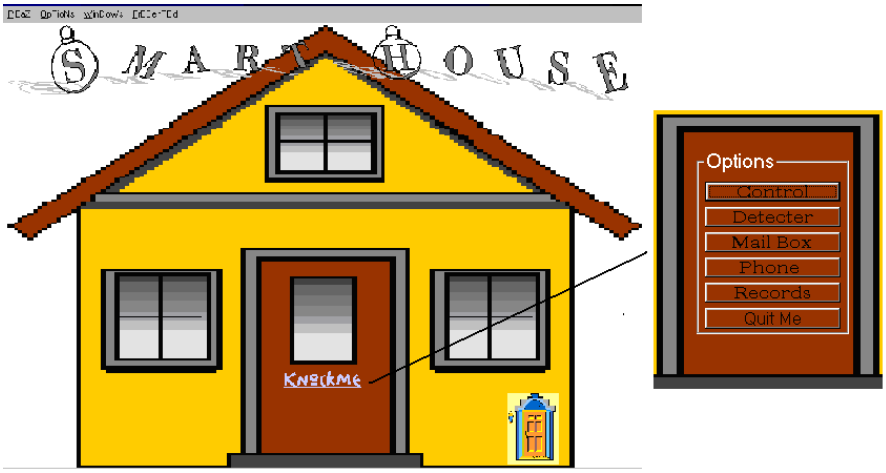

Figure.7. Main graphical user interface of Smart House; developed using visual basic programming language providing call to different operational modules of the application i.e. *Control, Detector, Mail Box, Phone, Records and Quit Me*.

Output bit controlling module is the first module and the job this module is to send signal for switching (on or off) to the Output Control circuit using Data Cable [22] attached at Parallel Port of in use computer. This is a back end module developed using C programming language.

Figure. 8. Work Flow of Output Control Module.

The front end of this module is developed in Visual Basic programming language, as shown in Figure 8, which takes input from user at run time and sends respective input to the C program which operates attached hardware to the computer. The complete procedure of controlling hardware is divided into two steps .i.e., *Manual Output Control and Schedule Output Control*. Manual Output Control is to control hardware (attached with house's electric appliances) manually using the computer (with mouse and keyboard) as shown in Figure 9(a) and Schedule Output Control interface is to schedule hardware controls using computer e.g. user can assign time and date to turn on or off switches, as shown in Figure 9(b).

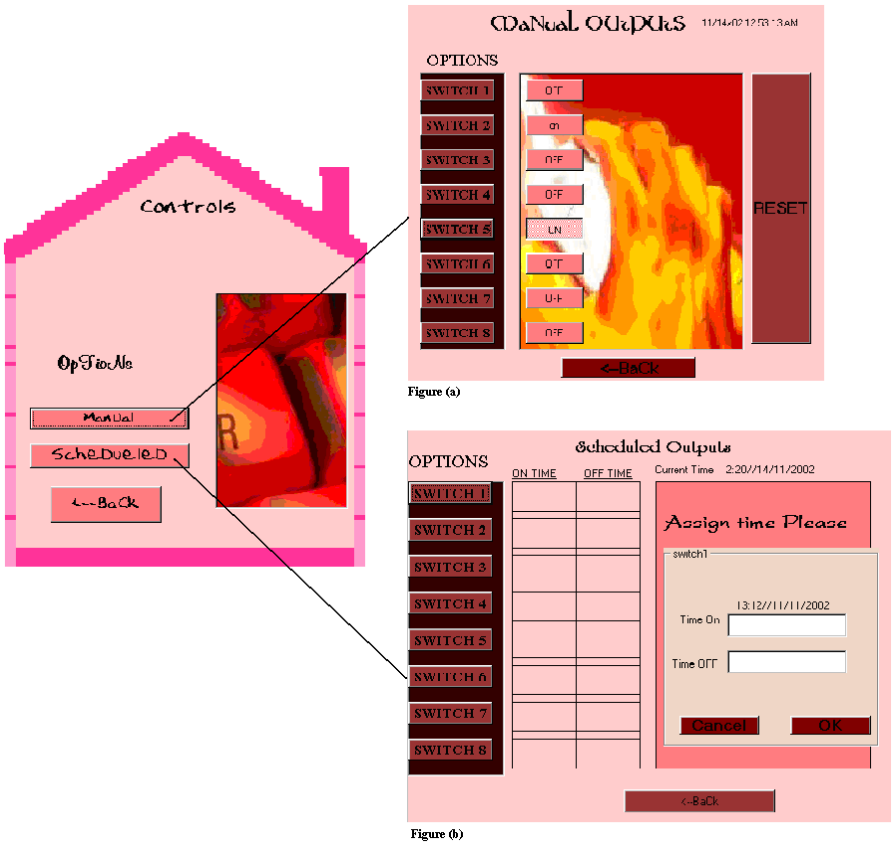

Figure.9. Output Control Module; Figure (a) presents manual output control and Figure (b) presents scheduled output control module.

Receiving input is the second and very important module of the project. The job of this module is to take input signal from an external device (designed hardware e.g. Infrared [23] based thief detector) as shown in Figure 10.

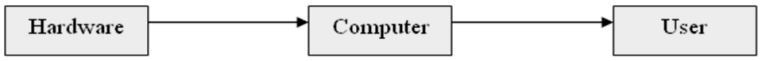

Figure.10. Work Flow of Receive Input Module.

It receives signal from the external hardware via data cable, calls interrupt, starts (output) alarming condition, enable automatic phone dialer and makes call to inform security disturbance. Then enables mail box and send automatically compiled email with security disturbance information e.g. time, device information (if there more than one devices are connected), image of effective place (if camera is attached and properly working). Then again try keep working and searching

signal again. The graphical user interface of receive input module, as shown in Figure 11, is designed using Microsoft Visual Basic and back module which communicates with hardware is programmed using C programming language. As it is not possible to directly transfer data from 16 bit C program to 32 bit program (developed using visual basic), a batch 'dot bat' file was created with path information.

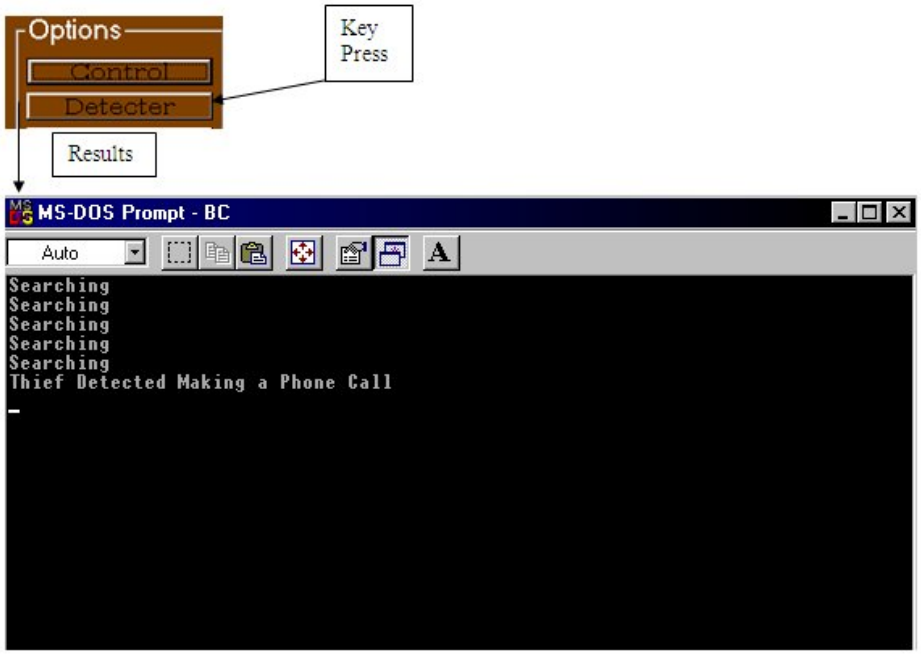

Figure.11. Receive Input; Module was enabled using Visual Basic interface and then back end program developed using C programming language starts looking for interrupt and when interrupt occurs, it takes immediate actions.

As the major focus of this manuscript was to present major home automation modules (Output and Input Control Modules), so without going into the further details, here, we will briefly present all other developed modules of the software project. Phone Module is a dialer to make phone calls manually and automatically according to the situation and requirements, as you have seen in Figure 11, when a thief is detected it automatically makes a phone call to user's phone or mobile number. The main graphical user interface of this module is presented in Figure 12, developed using Microsoft Visual basic with the inclusion of Telephone Application Programming Interface (TAPI). The main function of the manual output window is to make call at provided number by user and main function of automatic phone dialer is to save user provided phone number which can be contacted in case of emergency. Due to the security reasons storage of numbers in database using automatic phone dialer is divided into two categories i.e. *Dynamic and Fixed Phone Numbers*. Dynamic Phone Numbers are those numbers which will be dialed (one

after another, changes number automatically after three blink ring tones in answer) in case of disturbance and Fixed Phone Number is that which will only be dialed in case none of the dynamic numbers work e.g. if there are three users of the system (dynamic numbers) and at the time of emergency none of them is available then call will automatically be transferred to secondly preferred person (police etc.).

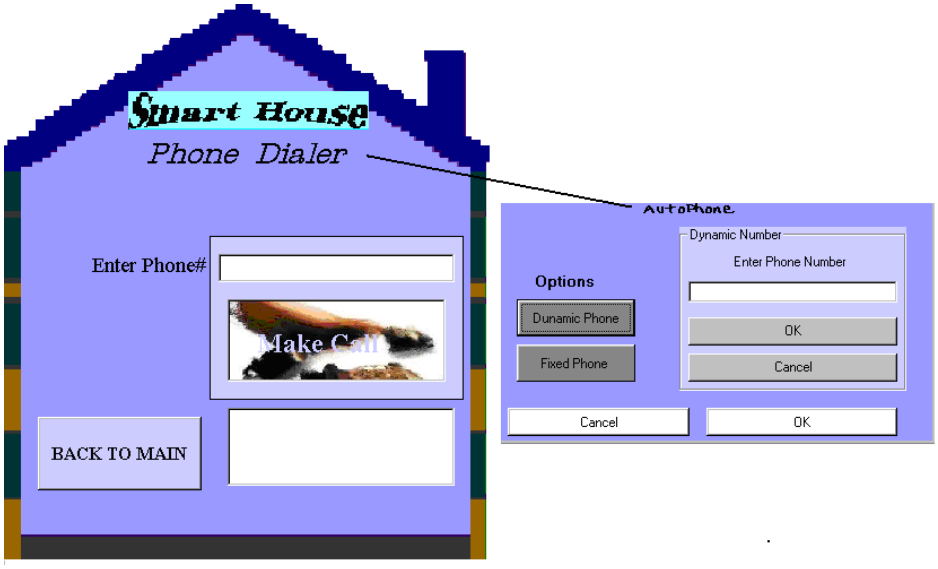

Figure.12. Phone Dialer; Manual and Automatic

The main job of implemented Mail box module is divided into two modules i.e. *Send Mail and Check Mail*. Send mail is to send email and vice versa check email is to show received emails (its job is limited). The main purpose of making this module is not to just receive or send email like many other applications but to generate an automatic email in the time of emergency, as discussed in earlier in this paper. This module is 4also developed using Microsoft Visual Basic. Database is designed to store and mange records of user's logging, usage of different modules, making automatic and manual calls, send and receive emails, turning on and off switches (manual and automatic both) and thief detection.

Last but not the least module of Smart House is its Mobile Interface, developed using Nokia tool kit. The aim of the implementation of this module was to provide access to the user to its house's electric appliances using mobile. As shown in Figure 13, developed mobile interface is consists of several options i.e. *User Authentication (as shown in Figure 11 (b)), Check Status Options (as shown in Figure 11 (c)) and Alter Status (as shown in Figure 11 (d))*. User Authentication is to validate user, Check Status is to view the current status of switches (attached electric devices with computer) and Alter Status is to switch off or on of the attached devices.

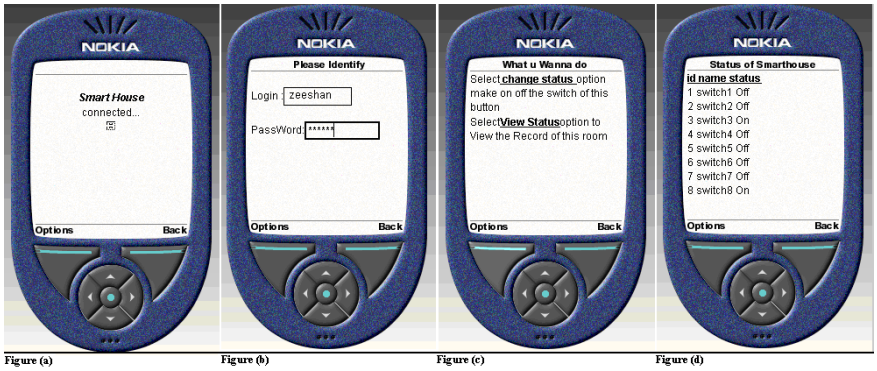

Figure.13 Nokia Tool Kit; Graphical User Interface of Smart House

The software and hardware has been successfully tested using two kinds of testing approaches so far i.e. Unit test and Integration test. Unit test is performed to check each module at individual basis as standalone application and integration test is to check each module in integrated form.

5. LIMITATIONS

As this is an academic research project with limited resources (time, man power, finance), there are some user end prerequisites and project limitations (based on third party elements) available in this project, which are

1. User has to buy a real IP address for the web server.
2. User has to get mobile service facilitating web browsing.
3. User has to buy a SMTP server for electronic mailing (email) facilities.
4. User can only access eight switches at the moment.
5. User must have the computer with at least profile motioned in Table 1.

Table.1. System Requirements

Hardware Components	Minimum Specifications
Central processing unit (CPU)	133 MHz
Video Graphics Array (VGA) Card	4 MB
Hard drive space	1MB
Port	Parallel Port

Operating System	Windows 98
Random-access memory (RAM)	16 Mb

6. CONCLUSIONS

Targeting the challenges of proposition of a home automation system capable of controlling house's electric appliances and providing efficient security system, a thorough research has been conducted in fields of Home Automation System, Hardware Engineering, Software Engineering, Machine Human Interaction, Mobile Programming, Wireless Application Protocols, Produce Line Architectures, Software Testing and Database Management System. Taking help from observed information from conducted research in respective fields and using personal research and development experiences, we have proposed an approach i.e. Smart House [33]. In this research paper we have briefly discussed some constructed conceptual and implementation designs along with the presentation of some of its implemented modules. Concluding the research and development efforts, we can say that our proposed approach and implemented software and hardware system can add some good values to the field of Home Automation System Design and Development.

7. FUTURE RECOMMENDATIONS

As mentioned earlier in section 1 of this research paper, home automaton systems are needs to be matured. There are a lot of things which can be improved by enhancing the scope of this project e.g. SMS facility can be added in security system, VXML structure can be used with WAP, hardware can be enhanced by multiplexing switches, macros can be used instead of a computer machine, graphical user interface can be redeveloped using some platform independent language etc.

AUTHORS CONTRIBUTIONS

Mr. Zeeshan Ahmed (*Software Research Engineer*) is the main and corresponding author of this research paper and initially the developer of this project (for both hardware and software), as this research project (Smart House) was proposed and started by the Zeeshan as an academic (unfunded and personal) project at Punjab Institute of Computer Science, University of Central Punjab Pakistan. Later the scope of this research project was extended and co-author Mr. Mujtaba Ali (*Software Consultant*) joined this research and heavily contributed in the Mobile Interface design, development and integration. Continuing the theoretical part of this research, co-author Mrs. Saman Majeed (*Doctoral Scientist*) contributed as a potential writer and reviewer to this research paper.

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