

Natural Language Processing based Context Sensitive, Content Specific Architecture & its Speech based Implementation for Smart Home Applications

M.B.Chandak*

*Shri Ramdeobaba Kamla Nehru Engineering College, Nagpur - INDIA
chandakmb@gmail.com*

Dr.Rajiv Dharaskar

*G.H.Raisoni College of Engineering, Nagpur - INDIA
rvdharaskar@rediffmail.com*

Abstract

The one of the upcoming research stream of Computer Science and Engineering is Natural Language Processing (NLP), which is widely being used in design of Interfaces for Human-Computer Interaction. One of the basic applications of NLP, is design of “Smart Homes”, in which; based on user input certain actions can be performed either locally inside the house or globally outside the house. The smart homes designed are either based on remote input provided to the system from one place in the house or limited to only certain type of actions which the system can handle. The current state of art of the Smart Home design methodologies, does not includes the design of customized systems capable of handling inputs from different gender i.e., in different pitches, similarly the methodologies does not provides facilities to handle input in different language. The systems existing are not capable of understanding the context of situation and determining actions based on context.

The paper describes a Smart Home application which can be used by elderly people living alone in the home to serve their basic needs, which specifically includes security issues. The system is initially based on generic architecture, and can be further customized to user needs. The main component of the generic architecture is ability to fix a certain language or set of languages in which the input will be provided to the system. This enables the user to interact with the system in multiple languages, thus the specific instruction set is not limited to one language. The interface designed is based on speech input, can handle multiple languages and is not gender specific. The system designed is also “Context Specific”, to understand the context of current state in which input is given to the system and perform the necessary action. The context understanding feature makes the system more specific to understand the urgency of action to be performed based on input. The system can deployed for a building incorporating a wireless sensor network, and provide a high quality, efficient context-sensitive data transmission facility.

Keywords: *Smart Homes, Natural Language Processing, Prosody detection, Context specific, Sensor networks, Data transfer.*

1. Introduction.

The technology has played major role in improving quality of life. The smart home application aims at the integration of technology and services in the household environment

for the improvement of the quality of life, safety and security as well as the communication possibilities with the outside world [3]. This aspect plays important role when the elderly peoples are living alone in the house. With sufficient support of technology, even in the old age the persons can remain in their well known living environment and maintain the social relations with their known ones as well as keep their independence [1,2]. The smart home applications can compensate the deficits encountered with advancing age such as decrease in physical strength, hearing and visual ability with suitable technical aids and systems.

The system deals with the development of local and global communication networks in the personal environment and its applications. The major focus is on use of new communication facilities such as videophones, ip-phones, emergency call system and speech communication devices [8]. Further the system is also capable of controlling household technologies and environmental factors such as light, temperature and air humidity with the main aim to achieve an optimum adaption of the needs of older peoples.

The paper majorly describes the design methodologies, findings and results for user interfaces with integrated speech processing modules. The system designed has basic facility to recognize the speech input so as to authenticate the user [6]. The speech interface handles the user registration process; recognize the voice & pitch of voice, language in which the command is provided. The applications and acceptance aspect of relevant technical solutions are also discussed.

In order to handle context in which the command is issued to the system, the architecture of the system has been designed to provide context-sensitive services in a smart building environment. The speed of data transfer is increased by handling data in wireless environment using wireless protocols [5].

The paper is divided in various sections. In section 2 the architecture of Smart Home Application System is described. In section 3 the implementation details of the architecture are described. In section 4 the voice controlled user interface is described and in section 5 its implementation is described. In section 6, the various issues regarding design of speech interface is discussed. In section 7, conclusion and in section 8, references are discussed.

2. Architecture of Smart Home Application System

The architecture of Smart Home Application System is based on controlling both local services of house and as well as global services required in general. The architecture is self sufficient to understand the type of service and necessary action to be performed for the service. Since the entire system and application is meant for old age peoples, who are not very much acquainted with the technological aspect of the system, while designing the architecture the user ability to handle to system is main point considered [4].

A survey of adaption of Smart Home Environment was conducted amongst old people to understand about their opinion regarding use of smart homes, concluded in following points:

- i) Apprehensions of not being able to handle the technology
- ii) Difficulties in recognizing the benefits of the technology

Thus the successful introduction of Smart Home Applications depends upon how good one manages to incorporate older peoples' needs and requirements. Therefore this issue requires

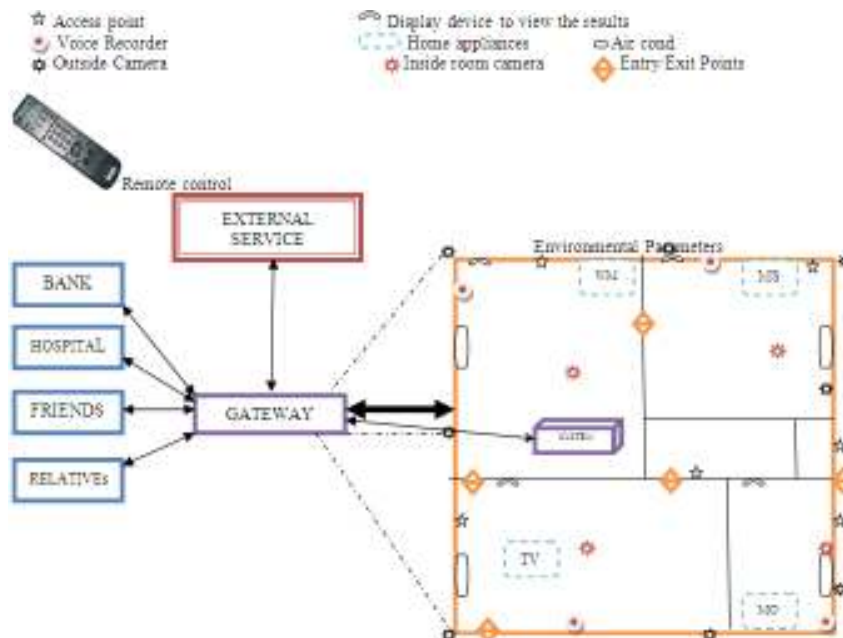
thorough examination from social science perspective. Hence the design should be convincing in terms of efficiency, reliability and handiness, which will need high level of ergonomics, design and constructive perfection.

The necessary prerequisite for Smart Home Application architecture is development of network and transmission media in personal environment. The major need is to integrate all the components of the architecture. The components are of two types: active components represented by actors using the system and passive components represented by networking equipment (switches, sensor, router). These components are integrated with the help of single bus system. The components are connected using transmission media in the form of twisted pair cables (CAT6), wireless environment (access points and antenna's) and electric supply power lines.

Following are the major issues in architecture of Smart Home Applications

- 1) Integration: The components of the system should be integrated to operate on one platform. There are two different types of components in the system, wired and wireless. The basic need is to operate these components with single interface.
- 2) Visual display: The result of the system should be displayed on visual display. This display should be clear and high resolution. The display will provide the details of operation requested or continuous pictures if system is customized for security purpose. Similarly if certain services outside house are to be performed, then the display should provide result of operation performed. For example if certain banking transaction is requested, then display will show the result of transaction.
- 3) Remote input device: This device is user interface to the system. With this device the user can access the various services provided by the application. The device is capable of interfacing home service, outside home services and security issues depending upon the user requirement.

Block diagram of architecture of Smart Home Application System



3. Implementation Details.

As shown in the block diagram following are main part of the system. The following section describes brief details of implementation of the system and integration of various components.

- 1) Access point: The access point is located in various rooms of the house. These access points are internally connected using single CAT6 cable and then finally connected to the main switch through which the signal is sent to control the local service or global service.

The access points are also interfaced with camera present inside and outside the house. The continuous picture is captured by camera is stored in main system. The picture is transmitted to main system using closest access point present in the house. The cameras installed have night vision and will capture the movement both in day and night.

- 2) Application: The application is capable of controlling two types of services: local and global. One of the main features of application is to understand the context of current situation and make certain decisions. For example consider following situations:
 - a. Burglary: Due to continuous analysis of conversation happening in the house, the application is capable of making its own decisions. Similarly the contexts of conversation, pitch of conversation, person voice are some of the main components to make intelligent decision. If at late night a conversion is recorded which may contain a keywords like “money” or “gold” or “keys” etc, then the voice (person not registered with the system) of conversation is checked if not regular, similarly if pitch of conversation is not regular then using automatic dialing system, a call is made to nearest police station, and a recorded message regarding urgent help is transmitted through telephone.
 - b. Single command locking: Using one single command the entire house can be locked at the time of moving out of the house. This will also involve shutting down of all the electrical appliances like lights, television system, microwave etc. At the same time all the remote locks installed at doors and windows will be locked.
 - c. Emergency Health Services: The contact number of the service provider is made available to the system at the time of installation. With single push button the already recorded message is transmitted to the service provider. The system is also self intelligent in order to understand the current state of home and deliver the message to service provider.
- 3) Display interface for the system: It is a TFT monitor which acts as virtual terminal to control various devices present in the house. The devices present in the house must have Bluetooth interface. The system can generate a menu showing all the devices interfaced and methodology to control the devices. For example if it required to switch off the washing machine, then interface can provide the facility, similarly if it is required to open the curtains of the window, then it is possible using the interface.
- 4) Methodology of message transmission: The system is implemented on high speed server machine with power backup and internet facility for 24x7x365. The machine

supports both wireless and wired connectivity. The authentication is provided by user name and password.

- 5) Cameras inside and outside the house: These cameras are capable of capturing image and send it to the service real time. The servers can check the images and generate the message or signal as per the requirement. For example if during night hours some suspicious movement is recorded by outside camera the server can raise the alarm.

There are wide ranges of applications for which Smart Home Technology can be used. Following are the key areas:

- i. Safety and Protection:
 - Protection against burglary, theft and attacks
 - Protection against fire, flooding and gas leakage
 - Video Surveillance (entrance and around the building)
 - Medical Emergencies and alarms
- ii. Comfort
 - Temperature, lighting and humidity
- iii. Telecommunication
 - Telephone with additional functions like IP Telephone, videophone
 - Interactive TV
 - Communication with neighbors and in-house communication
- iv. Environment
 - Energy Saving systems
 - Reduction in environmental burdens

The table – 1 describes the facilities and functions which can be implemented on remote control to implement local and global services.

Safety and Security	Comfort and Assistance	Measure, Display and operate	Communication
Emergency call system to medical service provider or security provider	Lighting control	Trouble detector	Video communication
Switch off if danger	Sunblind and shutter control	Measure environmental data	Speech communication
Front door observation	Air condition controller	Smoke and fire detector	Internet service
Window observation	Remote control and test	Water and Gas detector	Interactive service
Simulation of presence	Automatic door opener	Banking transaction	Network service
Video observation	Speech controlled tele guidance	Temperature measure	
Movement detector during night hours	Speech output in devices	Measure and transfer exhausted data (water and gas)	

It is therefore important to understand which applications the user is interested in implementation and which applications will be operated using remote control. Instead of remote control, the functionality can be implemented using voice controlled user interface. This interface will reduce the overhead of remembering the key control and sequence to implement the particular operation [5].

4. Voice Controlled User Interface:

The use of voice controlled user interface is justified from the following table-2 which describes the deficiencies in old age peoples. These deficiencies can be overcome using voice enabled user interfaces.

Table-2 deficiencies in old age peoples

Action/Impairment	Vision	Hearing	Speech	Intellect	Mobility
Locate, access and identify the equipments or commands	Difficult	-	-	Limited problem	Limited problem
Lift, hold or use the devices and switches	-	-	-	Limited problem	Very difficult
Use dial, numeric pad or keyboard	Limited problem	-	-	Difficult	Very difficult
Read and write (keyboard)	-	-	-	Very difficult	Very difficult
Use, touch and read screen	Very difficult			Difficult	Limited problem
Receive and understand visual information	Very difficult	-	-	Difficult	-
Receive and understand audio information	Very difficult	-	-	Difficult	-
Use spoken information	-	Difficult	Very difficult	Limited problem	

The speech communication is natural and familiar concept in contrast to keyboard or mouse communication. For use of keyboard and mouse, it is sometimes necessary that old age peoples should be trained and additional learning process is necessary. Also the expenditure for use of speech interface is low and old age peoples with hand & limbs disability can be also handle the system [7].

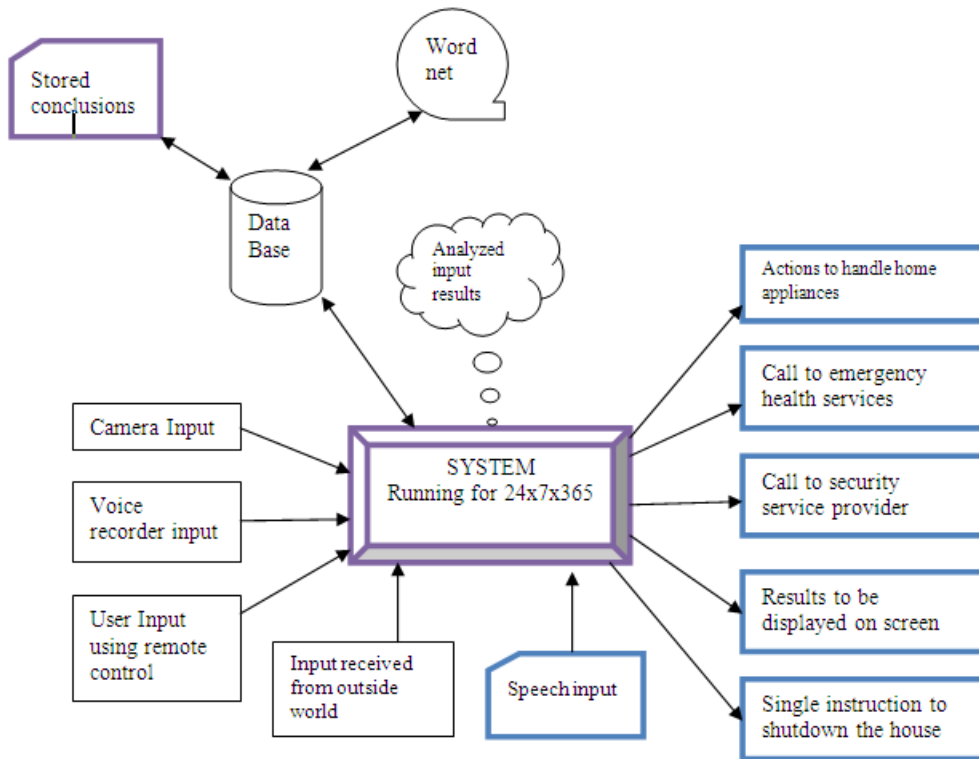
5. Implementation of Speech Enabled Voice Interface

Following block diagram shows the methodology to implement the speech enabled voice interfaces. The system designed is able to understand the context with the help of database available. The database contains the list of words and their meaning. The database is designed

with the help of “wordnet” a free tool providing information about English Language. This will allow the user to use the different words with same meaning to perform particular action. For example if action is “stop” then use can also use the words like “halt”, “shut”, “end”, “break”, “switch off” etc [6]. This facility improves the vocabulary set of the commands. The “wordnet” is also used to determine the sense of word, which helps in understanding the “emotion” going on in the conversation. With this information, it is possible to find out the urgency involved in the action to be taken for the service requested. If some keywords which are related to heated arguments are found in the conversation say at the late night hours, then some urgent action is required and it is essential to inform security officers.

The context of conversation is by first recording the conversation and then finding out the keywords involved in the conversation. A database of keyword with emotion involved in the words is used to find out the context. For example if the conversation is in between burglar and house owner, then keywords like “give me” “fast” “gold” “money” can be used to understand the context and generate necessary actions [11]. The fact can be further confirmed by checking the time at which the conversation is taking place. The system can also keep record of incidences and action taken against incidences. If similar incidence happens again then instead of processing the incidence and generating the action, the recording can be used to confirm the desire action. It is possible to map two incidences which have some specific similarity to single desired action [12]. This has been proved mathematically, but the mathematical calculation of mapping incidence is not presented in the paper.

Block Diagram for Speech Enabled Voice Interface



6. Strategies for better user interface based on speech recognition

In order to successfully handle the speech based system the main component is successful recognition of user input. The other components are: System environment, User speech and recognition system [9].

The user input is influence by: [12]

- Methodology to speech, speech pronunciation and speech input discipline
- The language used for speech communication
- Methodology to control the speech devices

The speech recognition model depends upon

- Speech models
- Signal processing algorithms
- Speech training algorithms
- Speech comparator and speech classifier
- Ability to relate the words to closest meanings (stop = halt, break, shut etc)

The environment factors are

- Disturbance due to environmental noises
- Hardware and Software disturbances
- Ergonomics properties

7. Conclusion

The smart home applications greatly improve the life style of older peoples with the help of technology. The improvement is significantly in the areas like security, safety, communication and comfort [14]. The major requirement is implementation of these facilities should be such that they can be easily used with extremely high reliability. In case of system failure, there should be alternate method to carry out the main functions manually, such as closing of door, adjusting temperature, handling electrical appliances of home etc. The emergency services must be operational even if there is break down in electricity [8]. The design should be “for all”, this will increase the number of Smart Home customers considerably and would have high impact on the cost of the systems.

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Authors



M.B.Chandak, received his B.E. degree in Computer Technology with merit position in 1991, and M.E. degree in Computer Science and Engineering 2003. He is presently pursuing Ph.D in Natural Language Processing with Machine Translation as main sub field. His research interest includes Natural Language Processing, Distributed database systems, Designing computer algorithms and mathematical tools for NLP. He is associate member of IEEE and the IEEE computer society.



Dr.Rajiv Dharaskar has obtained Ph.D degree in Computer Science and Engineering. His research interest includes Web Technologies, Multimedia programming, Expert Systems, Virus Programming, E-learning Softwares, System Utilities etc. He has total 23 years of teaching experience. He has published 08 research papers in reputed journals. He is reviewer of many International Journals and Conferences. He is associate member of IEEE and the IEEE computer society.

