The Smart House Intelligent Management System

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Engineering

in

Information Engineering

at Massey University, Albany, New Zealand

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2004

Abstract

In October 2002, Massey University embarked on the Smart House Project. It was intended to be a test bed of different technologies that improve the safety and quality of life within the home.

This thesis presents the design and current status of the Smart House Intelligent Management System, a management system for processing the commands received in the Massey University Smart House. There will be two parts to this Management System: an Expert System which will be responsible for the supervision of the house, its rules and its devices, as well as a conversation module which will converse with the occupant/s of the Smart House. The system will receive voice or text commands from the user as input and process the information through performing database queries about the received command, to ascertain whether it is valid. Validity is dependent on the command's adhering to house rules, which have been set by the user beforehand. This Management System will communicate with three other modules: the Bluetooth Smart Watch, the Speech Recognition/Generation System and the Ethernet Switching System, which enables access to the house devices.

Acknowledgements

I would like to thank my project supervisor, Dr Chris Messom, for his guidance throughout the whole year.

I am also grateful to my colleagues Rafik Gadalla, Leon Kok and Vaitheki Yoganathan your patience and support throughout the whole year. Thank you for all the extra trips you took to uni and all the times you spent talking the problem through with me.

Thanks to my family for your support all the way through the year, even if you did not really understand what it was all about. Thanks heaps for the encouragement and concern.

And finally, I would like to thank God for giving me this opportunity.

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Chapter 1

Introduction

The home is central to the life of each individual. It provides shelter, one of a human being's basic needs. Apart from its role as a residence, it is also a place of familiarity, rest and a place where a person can be "at home." Within it, we find a place of safety and comfort. In the home is also performed all the necessary routine activities of everyday living. These have been defined into nine groups (Himanen & Himanen):

- Care and keeping fit
- Eating
- Hygiene and dressing
- Recreation, Communication and self-actualisation
- Sleeping and resting
- Gardening and maintenance
- Housework
- Personal business and mobility
- Storage.

A person's activities in life can be divided into three groups. These are domestication (which includes the activities above), the working life (how we generate income or what we do for a living) and other specialised activities (such as art, entertainment, or religious and spiritual services). All the activities mentioned above are focused on domestication or the routine actions of day-to-day life. These three groups of human activity are linked together by interlinking activities (Transport, Communication, information) as shown in Figure 1.1.

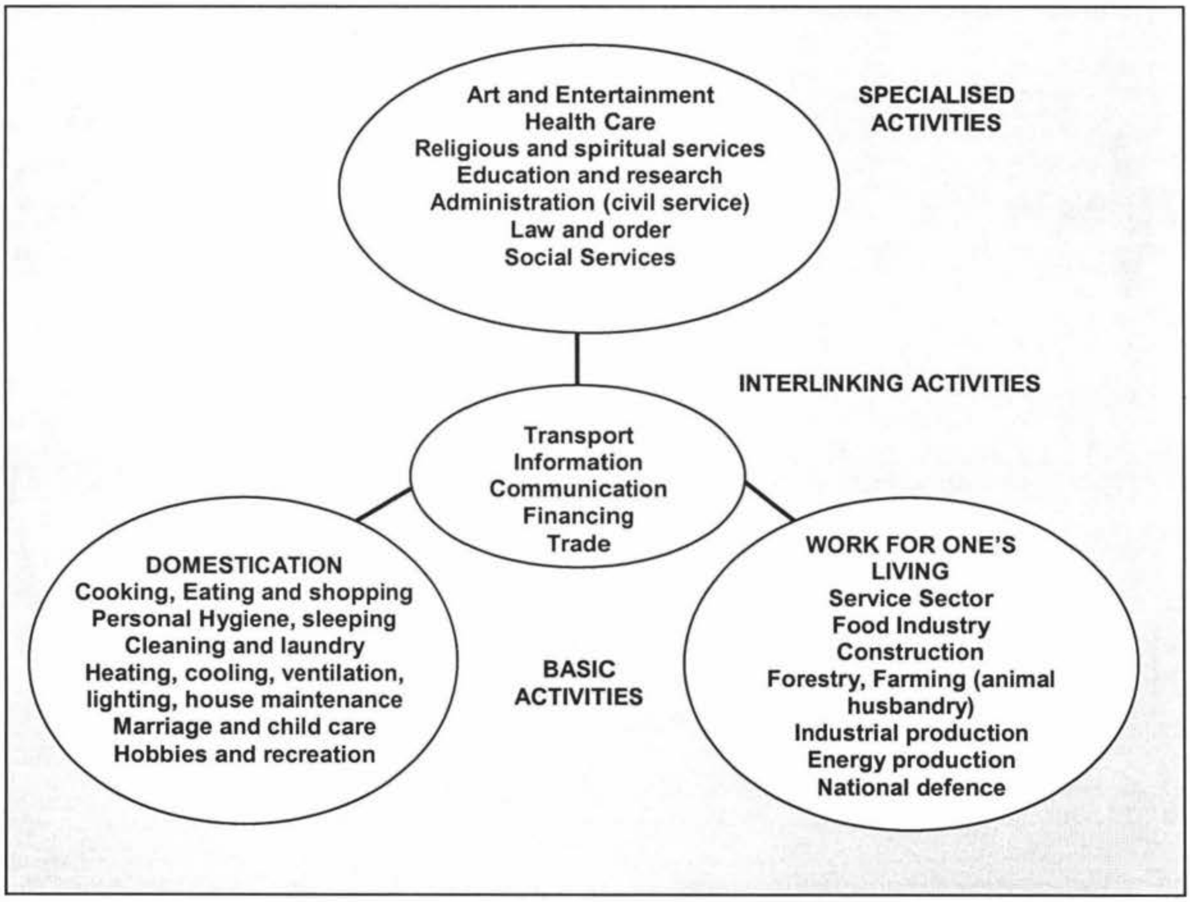


Figure 1.1 Basic Activities of a human being (Himanen & Himanen)

The working life and specialised activities (especially entertainment) are areas where we have found computers and their applications to be most useful and enjoyable. In the workplace, computers have proven to be of great importance in a wide range of fields including business and industry such as medicine, archaeology, e-marketing, mathematics, and security. Computers have also enhanced the entertainment field through various ways such as games, the Internet (through on-line groups, email, chat rooms and information on virtually every topic under the sun), and digital photography. The music and the recording industry have benefited through effects processors such as Pro Tools (Digidesign, 2004), Cakewalk (Cakewalk, 2004) and Adobe Audition (Adobe, 2003).

Now computers have found their way into the home in a new way. As computers become smaller, cheaper and more powerful, their useful applications in the home have become more diverse. Their intention is no longer limited to word processing, playing games and Internet access. They now have more functionality than ever. Sophisticated home automation systems can now be designed for house security alarms, lighting and entertainment systems.

All these systems are designed to create more convenience within the home, allowing the residents to think less about the more basic running of the home. The Massey University Smart House will be such a home. The Management System of the house will ensure that the house, if desired by the user, may do chores automatically.

Pervasive or ubiquitous computing is now an area of serious research that is truly thriving. The idea of a home that is "smart," loaded with all imaginable conveniences and able to perform a range of domestic tasks is only true in the realms of science fiction motion pictures. HAL 9000 from 2001: A Space Odyssey (Kubrick, 1968) has been the inspiration many of today's applications, including the ReBa system (Kulkarni, 2002) chatter bots (Web Hal) and digital secretaries/assistants (Ultra Hal) from Zabaware.

1.1 Smart Devices and Environments

Mark Weiser coined the term "ubiquitous computing" (Weiser, 1991). The word ubiquitous means the technology will be omnipresent or present everywhere. According to Weiser, "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." He put forward an idea – instead of the human entering the world of computers (through user interfaces such as the keyboard, mouse and monitor), computers should fit into the human environment and communicate through human interfaces such as speech and vision.

Computers will adapt to the human means of communication instead of the other way around. In the Smart House, this means that they will actively participate in the running of the home. It will be the Management System's job to do just that. It will supervise chores that need to be done within the house, as specified by the residents of the home, while keeping itself invisible.

An earlier implementation of a ubiquitous system was the Active Badge (Roy Want, Hopper, Falcao, & Gibbons, 1992), which was designed and prototyped between 1989 and

1992. This technology was worn by the users on their clothing and was created to replace pagers and tags when trying to trace people in a campus or hospital location. It was designed to be discrete in size so as not to be noticeable. When it was first developed, Active Badge transmitted a unique five-bit code every fifteen seconds to give information about the person's location. The updated device now transmits a unique infrared signal every ten seconds.

Other earlier attempts include smart clothing (Mann, 1996) as shown in Figure 1.2 (a), the wrist computer (Matias et al., 1996) in Figure 1.2 (b) and the Xerox ParcTab system (R. Want et al., 1995). All the above research required the user to wear some device in the form of Wearable Computing.

Figure 1.2(a) Smart clothing. Smart wearable devices worn include the wearable multimedia computer/personal visual assistant. The eyeglasses include a miniature computer screen and sensor array. The equipment also supports an Internet connection (Mann, 1996)

Figure 1.2(b) The wrist computer (Matias, MacKenzie, & Buxton, 1996)

More recent wearable technology include the Spot Wearable Computer (Dorsey, Gemperle, Gollum, Martin, & Siewiorek, 2002) and the wearable tactile display (Gemperle, Ota, & Siewiorek, 2001).

Ubiquitous computing has also been applied to home automation to produce intelligent environments or smart homes. The focus was to merge the technology with the ordinary life in a way that is seamless and non-intrusive. This means that the technology will be embedded into the home and be part of the daily life of the home without changing the day-to-day atmosphere of the home. The hardware of the system should be as much a part of its environment as possible. For example, wearing a lapel microphone to speak to the house might be considered an inconvenience.

Smart rooms and smart houses have been the result of adapting the computer to increase the comfort and convenience in the home. The Massey University Smart House will be such a home. The computer is invited to participate in the mundane activities of everyday. The features on offer include location tracking (you can keep track of where the children are), house modes (such as holiday mode when you are away on vacation or secure mode at night), and reactive characteristics (so the Fire Services get called automatically when the fire alarm goes off). More sophisticated systems even include conservation controls within the home. Accomplishments towards this end include the neural network house (Mozer, 1998) which automatically controls the heating and ventilation systems, MIT's Intelligent Room (Coen, 1998) and the House of the Future Project (Alves, Saur, & Marques, 2004). Internet controllable systems are also available; these include the home automation (HA) system developed at the National Taiwan University (Liang, Fu, & Wu, 2002), the Java-Based Home Automation System (Al-Ali & Al-Rousan, 2004), and the Internet Application for Home Automation (Nunes & Delgado, 2000).

Earlier developments of smart environments have been directed towards people without disabilities. Their main purpose was to increase the level of comfort and convenience within the home. Recently, there has been a drive towards using the same technology to assist those with special needs – namely the disabled and elderly. The aim is now to improve the quality of life of those who need assistance to perform basic activities in their daily lives. The Intelligent Management System will be part of this endeavour.

1.2 Pervasive Computing for the Disabled and Elderly

The World Health Organisation (WHO) has defined disability as "... any restriction or lack (resulting from impairment) of ability to perform an activity in the manner or within the range considered normal for a human being."

Disability can be further divided into physical disability (restriction of movement or loss of agility), sensory disabilities (sight and hearing disabilities), 'other' disabilities (difficulty in speaking, learning or remembering), psychiatric or psychological disabilities and mental disabilities.

One in every five people (743,800 in 2001) in New Zealand is disabled (Stewart, 2002). Among all these, physical disabilities are the most common types affecting adults. Over one-third of disabled adults living in households use some kind of special equipment, such as a voice amplifier, a computer to communicate, or a guide dog. It is also a fact that the proportion of all disabled adults using special equipment and disability increases with age (Figure 1.3).

The elderly group (or grey population) is composed of those who are sixty-five and over. It is a group that makes up a large and growing portion of New Zealand's population. At the time of the 2001 Census, they made up around twelve percent of the total usually resident population (Pink, 2004). By 2026, this figure is expected to rise to twenty percent; and increase further to twenty-five percent by 2051. There will then be 1.18 million people aged sixty-five and over by 2051, which will account for about one out of four New Zealanders.

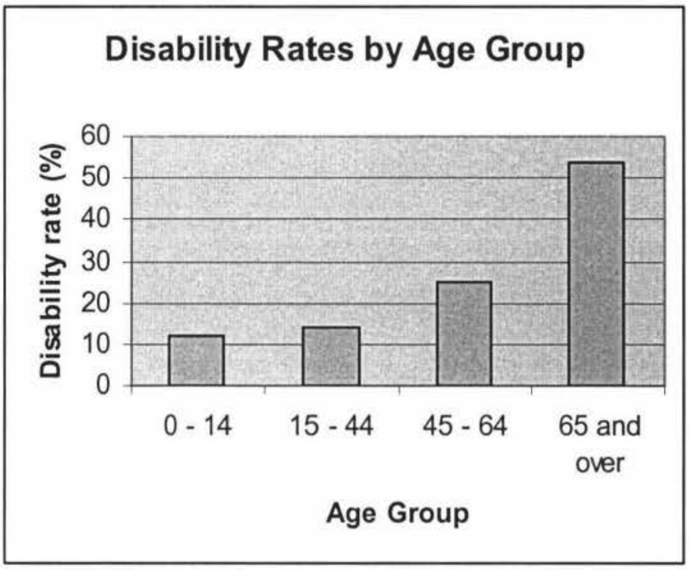


Figure 1.3 Disability Rates by Age Group (Stewart, 2002)

This growth is partially caused by the increasing life expectancy in New Zealand. This has resulted in the reduction in mortality. About eighty-nine percent of newborn girls and eighty-three percent of newborn boys are now expected to live to sixty-five years of age. For females, this means that they can expect to live for another 19.9 years on average and another 16.5 years for the males.

It is also estimated that the elderly make up thirty-six percent of all adults with disabilities. Despite their disability, eighteen percent of disabled live in one-person households (these include the elderly disabled). Among the elderly, people who are aged sixty-five years or more are expected to make up forty-seven percent of people in one-person households in 2021.

As the disabled and elderly become increasingly frail, their increasing disability will affect their ability to manage their lives by themselves. Wearable Devices have been designed with the disabled and elderly in mind. These devices will assist their users to maintain their autonomy and independence. Although physical modifications may be added to the home (such as rails to provide extra safety), they are not always enough to meet the communication needs of their users.

One of these wearable devices is the Camera Mouse (Betke, Gips, & Fleming, 2002), which is used to assist in the communication of severely disabled people such as those who are quadriplegic or non-verbal. It can track movement from the tip of the nose or the finger of the user and use these movements to communicate with the computer. The Ring sensor (Rhee, Yang, Chang, & Asada, 1998) is another example of a wearable device that provides continuous monitoring of the patient's arterial blood flow from their finger in a way that is non-intrusive and comfortable. Vivago has also developed the WristCare (Sarela, Korhonen, Lotjonen, Sola, & Myllymaki, 2003), which raises the alarm when the user has prolonged periods of immobility or passivity. Even a person's posture (Yoshida, Yonezawa, Sata, Ninomiya, & Caldwell, 2000) and postural changes (Najafi et al., 2003) such as sitting-to-lying and turning of the body in bed can be measured by a sensor. Another innovative and non-intrusive sensor is PhiloMetron's "smart Band-Aid" to monitor the healing progress of a wound. It automatically issues an alert if an infection is detected (see Figure 1.4)

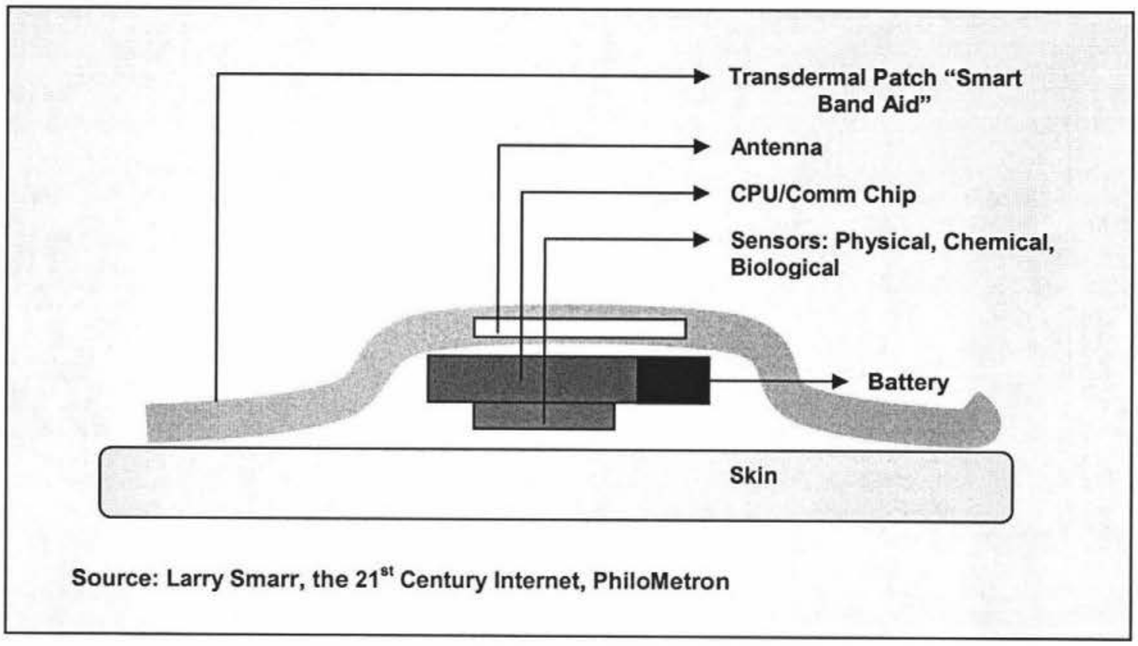


Figure 1.4 PhiloMetron's smart Band-Aid

The other kind of smart devices created for the disabled and elderly are those that are not attached to their person. These are devices that are seamlessly embedded into the environment of the user to measure its parameters. A study conducted at the Hospital Centre of Grenoble, France (Rialle, Lamy, Noury, & Bajolle, 2003) has this approach. It has a series of sensors with a movement detector, a multi-function fall sensor and recognition of help calls. Other research in this area include the Telemedicine Remote Monitoring (Celler, Ilsar, & Earnshaw, 1996), Telecare (Curry, Tinoco, & Wardle, 2003) and the Home Assurance System(P. I. Cuddihy, Ganesh, Graichen, & Weisenberg, 2003) from GE Global Research. The Home Assurance System has an activity summary (see Figure 1.5) that gives information on the user's activity patterns. Quiet times are shown as peaks that grow higher when the home is quiet. The gaps between the peaks indicate that the user is busy and the smaller peaks show periods of quiet or inactivity during the day.

The statistics of each day are stacked behind the previous days to show a pattern of activity and highlight unusual behaviour.

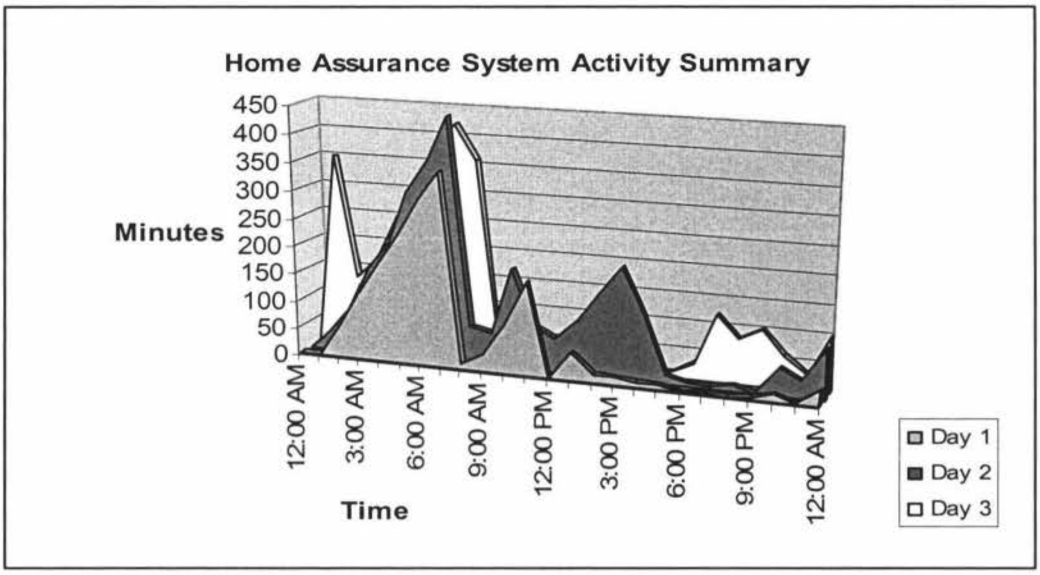


Figure 1.5 Activity summary from the Home Assurance System (P. Cuddihy et al., 2004)

Most smart houses for the disabled and elderly concentrate more on the wearable sensors and environmental sensors. Wearable sensors tend to focus on a specific area of study (cardiology, assessment of Activity of Daily Living (ADL), etc), and the environmental sensors focus on the safety and health of the user (such as temperature and fall sensors). Not much emphasis has been given in assisting the user with daily living activities (such as dishwashing and laundry) or convenience.

The focus with activity monitoring was to establish that the user was mobile and not stationary for too long (which might suggest that they have fallen somewhere and are unable to get up). The intelligent management system will attempt to integrate both the convenience found in the non-disabled smart environments and health sensors (both wearable and environmental) to get the best of both worlds and provide both assistance and comfort in the home. The Intelligent Management System will provide a means though which wearable devices and assisting the resident of the smart home with their daily activities may be merged

Georgia Tech's Aware Home (Kidd et al., 1999) is able to do just that. However, it uses the gesture pendant (Mynatt, Melenhorst, Fisk, & Rogers, 2004) to read hand movements as commands. It uses infrared illumination and a charge-coupled device (CCD) camera to recognise different gestures to dim lights, lock the doors or open the front door. It can receive commands as well as monitor the user's physical activity and request for help in the event of an emergency. They also have an application called the Digital Family Portrait (Mynatt et al., 2004) informs family members out of the house about its state (such as indoor and outdoor temperature) and the user's movement within the house.

1.3 The Massey University Smart House

In October 2002, Massey University began the Smart House Project. This venture involves the creation of a house that possesses a human-like intelligence to manage and perform daily tasks to help its occupant. It is the first New Zealand attempt in creating a home that will introduce intelligent technology into the home.

The Smart House Project is aimed primarily at the physically handicapped and the elderly. Statistics (Stewart, 2002) suggest that one in five New Zealanders will benefit from such research – those who are in need of extra help to live life comfortably, those in need of assistance to allow them to enjoy a higher degree of comfort and independence. The Smart House will allow them to improve their quality of life, deal with their physical limitations and a chance to enhance their independence and remain in their own homes for longer. It will result in a home that is safer and more enjoyable for them to live in.

The Smart House will be the test bed for all the different research projects intelligent technologies being developed. One of the technologies already developed at Massey University is the Internet controllable robotic lawnmower (see Figure 1.6). This lawnmower may also behave as a vacuum cleaner for indoors. The Smart House will integrate all these different elements together to create a functional smart home to increase its user's quality of life.

Figure 1.6 The (silent) robotic lawnmower (Restall, 2002)

1.4 Smart Technologies, the Disabled and the Elderly

An important factor of creating smart environments is the attitude of the end users toward the technology that is created for their benefit. It is all well and good to design and produce technology that will assist those who are disabled and elderly, but it would be pointless if they were uncomfortable with the technology. It is commonly believed that the elderly in particular are not open to technology. If they are not receptive, then they are less likely to use it, and consequently, cannot benefit from it. This section will give a brief overview of the social implications of smart environments for the disabled and elderly.

The elderly are not entirely hostile towards technology. In fact, they are quite adept at their use of electronic devices within the home (most dwellings nowadays are equipped with microwave ovens, television sets and security alarm systems). Wearable devices such as hearing aids and the Lifelink Medical Alarms provided by St John have been welcomed in the community. Older persons now also enjoy the Internet – they are able to perform online tasks, including online chatting and email access within the comfort of their own home (Adler, 2002; "Elderly surfers click onto net," 2004). These technologies have a positive effect in the lives of these people as they allow them to communicate and interact with others more fully.

It has been found that the potential users will welcome smart technology more if it is absolutely necessary (Carrelli, 2003; Mynatt et al., 2004). Most of the time, they prefer to forego the use of assisting devices, as they do not want to be discriminated against. This is true in the cases of both the disabled and the elderly. In New Zealand, 22 percent of disabled children aged 5-14 find it difficult to make friends and are limited from actively participating at school (Maskill, Hodges, Burns, & Carroll, 2004). Adults refuse assistive devices within the home such as raised toilets that could save them from a fall because they do not want the stigma that comes with it. This fear is very real – this discrimination and prejudice towards the elderly is called ageism (Butler, 1969). Research at York (Monk & Baxter, 2002) found that the worry "I don't want to be stereotyped or stigmatised in any way" was second only to "I want to keep my independence."

One more common cause of the elderly negativity towards assistive equipment within the home is their lack of understanding and distrust about the technology. In a case study performed (Reed, 2002), it was discovered that the education of the user during pre-installation period of the technology within the home is essential to the user's understanding of what the system does and how it works. In Sweden, the users were testing technologies after it had been developed, with no thought given to the end-user; causing irritation and distrust of new systems, delaying public acceptance of the new technology (Mekibes, Mekibes, & Thiberg, 1994).

An additional issue that was raised is the denial of privacy. Being monitored by a camera everyday in a "Big Brother" manner would be considered an intrusion of their privacy. For example, the Home Care Technologies System (Tran, 2002) does this to some degree, where cameras are activated by motion sensors and once activated, the images are automatically "pushed" to a web server and can be accessed remotely over the internet via a URL. The input is not continuous, however, and is only refreshed periodically. The person may not mind the Activity Summary (Figure 1.4) but might regard video monitoring as crossing the line.

A fear also expressed is isolation and loneliness (Mekibes et al., 1994; Monk & Baxter, 2002; Tiikkainen, Heikkinen, & Leskinen, 2004). Having a smart system and provision of comfort in the home could lead to isolation and lack of variety and contact with other human beings. Technology cannot replace personal care and social needs. A possible scenario could be the installation of an excellent alarm system that might mean that caregivers no longer call in to see if you are well. An extreme instance mentioned by Mekibes et al (1994) is a case where a woman lay dead in her apartment for a period of months. All her bill payments were taken care of by automatic banking, and her landlord was not concerned because her rent was paid on time.

The opposite side of the coin is over-reliance on the technology. The development of smart technologies for the home is aimed mainly for assistance. It is to retain the person's independence and autonomy. It is not designed to totally replace the housekeeping chores of the home. Not using your capability can negatively affect your physical condition (Dunkle, Roberts, & Haug, 2001; Tirrito, 2003). Participation in regular exercise (such as walking) and physical activity helps to prevent the physical decline of the body and retain autonomy and independence (Carlson et al., 1999; *Healthy Ageing and Physical Activity*, 1999).

1.5 Organisation of this Thesis

This thesis documents the approach I have taken in creating the Smart House Intelligent Management System. I begin by describing smart environments and linking it to the home, as well as several past and current applications of smart devices and environments. In the next chapter I discuss the Intelligent Management System problem – including the design principles and assumptions I have made in the system. The third chapter will give an overview of the Intelligent Management System. The fourth chapter will deal with some thoughts on future work for the system. Finally, I conclude with a discussion of the contributions of this thesis.

Chapter 2

The Intelligent Management System Problem

The management system of the Smart House will be responsible for providing intelligence in the overall running of the house. It will be a system that is discrete and non-intrusive to the occupants of the home. It will provide a means by which the human users will be able to communicate with the house on their terms, just as they communicate with other humans – through speech. It works towards letting computers enter the human world, instead of letting the users be bound by communication through the computer monitor, keyboard and mouse, although this type of communication is also provided for.

Intelligence will be made available through applying rules to the input received, as well as perform automated commands set by the user. In addition, the user may also speak with the house just as it would another person through a chat module. At the very least, this feature will entertain or amuse the user.

This section will explain the intelligent management system problem further, as well as elaborate on the ideas that drive it. It describes the problem and its different components as well as how they are all tied in together. These include the desired characteristics, Module Communication, and Assumptions that I have made in this project

2.1 Desired Characteristics

The Intelligent Management System has a few characteristics that are expected and explained further below. These are the concepts that will drive the development of the management system. Apart from intelligence, there are other desired features that the system will need to possess. It should be extensible, customisable and easy to use.

2.1.1 Intelligence

Humans display intelligent behaviour in a wide range of activities. It is shown by our ability to perform certain activities such as solve problems, learn and understand. In the theory of multiple intelligences (Gardner, 1983) at least seven types of intelligence have been identified. These include linguistic, musical, logical-mathematical, spatial (the ability to perceive images), bodily kinaesthetic (or movement), and the personal intelligences (how we perceive ourselves and others). Two more have been recently added: naturalistic (being aware of plants, animals, etc.) and existential (the ability to ask philosophical questions).

So for a system to be considered intelligent, it would need to display some of the attributes described above. It would need to posses the ability to "automate activities that presently require human intelligence" (C. Williams, 1983) to a certain degree.

How then would a system behave intelligently? The Society of Mind (Minsky, c1986) argues that the human mind is composed of several smaller processes called "agents."

These agents only do simple tasks that require no intelligence, but the joining of all these simple processes leads to intelligence. So a system may break a complex problem into several simpler parts that are joined together to produce intelligent behaviour. This is the approach I will use for the management system.

2.1.2 Extensible

It is important for the management system to be extensible. Just as people continually change, a house or a room within a house will not always retain its original state. New rooms or sections may be added to a home. New devices/appliances may be added into a room. As a result, it will need to be easily built upon. On the other hand, the opposite is also true; rooms and devices may also be removed from the home as time and trends change.

These changes will need to be taken into account. The management system will need to cope with extensions/contractions. The occupants should be able to modify their home as they wish and be confident that the management system will be able to absorb it without too much inconvenience on their part. Extensibility is therefore an important principle in the creation of the house management system.

2.1.3 Customisable

The users should be able to customise their home as they please. Different people have different personalities, and it follows that they would have different preferences. The uniqueness of a person is of great importance, as no one wishes to be limited or put in a box, especially in his or her own home.

For users to feel "at home" in the house, they should be given the freedom to do things as they see fit. The users should therefore be able to provide some input in terms of the rules of the house. They should not be forced to completely conform to preset rules designed by someone who is not familiar with them or the home they live in. People want to be comfortable, and when at home, do things their way. Customisability is therefore important for the management system.

2.1.4 Ease of use

It is important for the management system to be user-friendly - the end user needs to be constantly kept in mind. It needs to be designed to carefully hide the complexities that occur in the background from the user. Just as not everyone is interested in how the inner workings of a car or a stereo works, the details of the management system will not interest most users.

The user interface of the management system is an additional portion that will need ease of use. It will be where the management system and the occupant of the house will meet and communicate with each other. As a result, it is important for them to be on the same wavelength and understand each other.

Ease of use also includes the easy installation/removal of the system. Having a system that can be installed without having to renovate the whole house or rewire it from the ground up would cause less intrusion and inconvenience. Another disadvantage of this scenario is you cannot take the system with you elsewhere. It is another goal to create a system that can be easily transferred, without necessarily being tied to one particular location. People nowadays do not necessarily remain in the same house. Moving is quite common. It would be a good idea to be able to take the management system when moving.

2.2 Module Communication

The Intelligent Management System will be in communication with other applications and modules within the Smart House. It will interact with other systems, which are also currently being developed. At the moment, it will work with three different modules: the Bluetooth Enabled Watch, the Ethernet Switching System and the Speech Recognition/Generation System, which are also being developed as part of the Massey University Smart House.

The management system will be dependent on these three modules for the collection and implementation of input commands received from the user. Its main objective is to process the received command and pass it on to another module (Ethernet Switching system for implementation or the Speech Generation System to respond to the user).

2.2.1 Bluetooth Enabled Watch

The Bluetooth enabled watch is a wearable device, which will be worn by the user. It will serve as a user-tracking (and monitoring) device. Bluetooth transceiver modules will be attached to the ceiling of the house, allowing the user to be tracked within the Smart House. This feature could be useful, especially in cases where an elderly person may need to be tracked down. Once an interface of communication between the management system is developed, The Bluetooth enabled watch will be capable of informing the house who is currently at home and their exact location.

A similar piece of work done in this area of user tracking and mobility is the Cricket Location-Support System (Priyantha, Chakraborty, & Balakrishnan, 2000) which helps let static and mobile (hand-held) devices learn where they are by 'listening' to beacons spread throughout the building.

In addition to mobility and tracking, the Bluetooth enabled watch performs health-monitoring activities. It can function as a blood pressure monitoring device. Other functionality that may be included in it is checking for sugar levels for persons who are diabetic.

Personal data and preferences may also be stored within the Bluetooth enabled watch. These preferences could include their TV or stereo settings. In the case of the wheelchair-bound disabled/elderly user, this could also be a preset command to open a door when they approach one, or turn the lights on in the room that they are approaching.

2.2.2 Speech Recognition/Generation System

There are two modes of operation available to the user. They can either use the monitor, keyboard and mouse to communicate with the Intelligent System, or they can speak to it. The Speech Recognition/Generation system will be responsible for obtaining the speech commands from the user (speech to text) and converting the Intelligent System's responses (text to speech) for the user to listen to.

This system will be responsible for recognizing the speech commands. Most of the conversation that goes on in the house will be ignored. The Speech Recognition System will listen for a specific word is spoken. This could be a name for the management system, such as "Jeeves." This word will trigger the speech recognition system to listen to the words spoken after "Jeeves" and pass it on to the Intelligent Management System to process. Integration with the Smart House Management System will be described more fully in Section 3.3.1 of the following chapter.

2.2.3 Ethernet Switching System

The Ethernet Switching system is the final module and will be responsible for the implementation of the commands received by the Intelligent Management System. The Ethernet Switching System is only concerned with input regarding the devices within the house – the lights, house alarm, kitchen refrigerator and the like. Access to all these devices can only be done through the switching system.

When an input command has been received, it will be checked by the management system to ensure that it is valid. Once a command is proven valid, it is the Ethernet Switching System's job to ensure that the desired device is accessed and the appropriate command is implemented.

The relationship between the management system and the three modules above are illustrated more clearly in Figure 2.1 below.

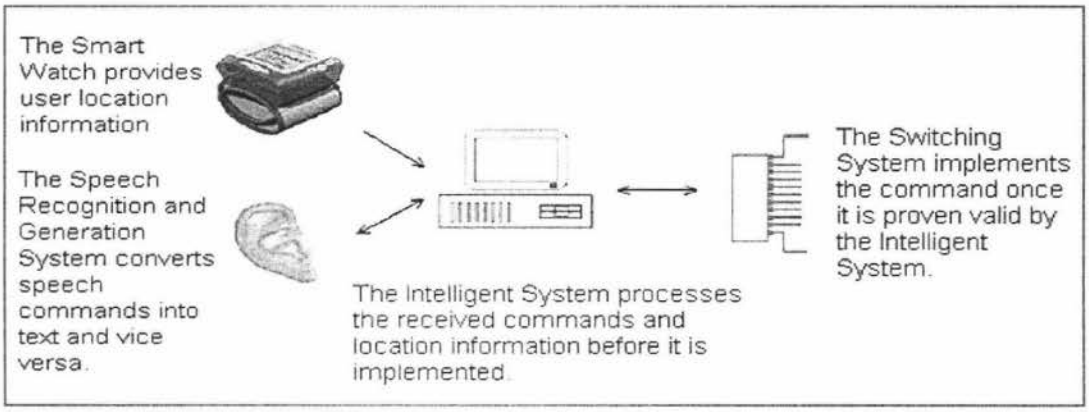


Figure 2.1 Inter-module communications in the Smart House.

2.3 Management System Assumptions and Limitations

This subsection outlines the basic assumptions I have made in the development of the management system.

2.3.1 Input received is always correct

I have developed the management system with the assumption that the speech input provided by the user will be correctly received by the Speech Recognition/Generation system before it is passed on to the management system for further processing. It will be the Speech Recognition System's responsibility to ensure correct input or ask for the speaker to repeat himself or herself if the received input is doubtful. The assumption that the responses of the management system to the user will be converted into speech accurately also applies.

It will also be assumed that the received text input through the application user-interface, (should the user opt to use the monitor, mouse and keyboard instead) will also be correct.

2.3.2 Single Person Tracking

As this is the first attempt in the creation of a management system for the Smart House, I opted to create the simplest scenario. The management system will be created on the assumption that only a single user's location will be received by the management system. This assumption is also for those disabled and elderly who live in one-person households. The management system for the Smart House will only attempt to track one person within the household through the Smart Watch.

However, in the cases where more than one person lives in a home, this does not exclude other members from communicating with the system. The commands they provide would just need to be more detailed. For example, they will have to specify their location for the management system to know where they want a command to be implemented.

2.3.3 Explicit Input

Human communication is made up of both explicit (verbal) and implicit (non-verbal) messages. Explicit messages are communicated through what we say. Implicit messages, on the other hand, are what we communicate whether or not we are verbalizing something. It is also known as "body language."

There are several ways to communicate in a non-verbal manner. These could be through body movements (eye contact, gesture, facial expressions, gaze and stance), vocal aspects (pitch and volume) and spatial relationships (body contact and proximity). Each of these may also be subdivided further. Gaze, for example, includes the length of gaze, looking while talking, looking while listening and amount of eye opening.

It is suggested that most human communication is accomplished through non-verbal means. A message is seven percent verbal, thirty eight percent vocal and 55 percent non-verbal (Mehrabian, 1968). From this breakdown, it is clear that it is important to understand the implicit portion of a message to accurately interpret the entire message. For example, a nod or a thumbs-up when a person says "yes" complements the verbal communication. In the case of a nurse, a patient's facial expression, tone of voice, paleness and even the smell of the room communicate information that are not conveyed through the person's speech.

In the Intelligent Management System, I have opted to first create the simplest scenario. As a result, the system will only deal with the received explicit commands. It will process the received speech (from the Speech Recognition/Generation System) or typed commands by the user, without taking into account the user's tone or current emotional state.

The following section will elaborate on the how the management system works and its different components. It will also explain the interactions between the different systems in more detail.

Chapter 3

Intelligent Management System Solution

This chapter presents an overview of the Intelligent Management System. This management system will be able to perform mundane tasks within the home intelligently and possess a personality that will be evident when it speaks with the user of the home at the same time. Characters of fiction that may come to mind are C-3PO and R2D2 from Star Wars (Lucas, 1977), with the management system's immobility being the main difference. So it will be the "brain" of the house in much the same way as HAL 9000 was the brain of a spacecraft – it will be an immobile robot (B. Williams & Nayak, 1996). It will be similar to an invisible, non-intrusive robot that will be embedded within the house.

The management system will be made up of two elements: the expert system and the chat module. The expert system will deal with the day-to-day maintenance of the house, taking care of the domestic side of things. This will include automated commands that are to be implemented everyday and receiving commands that the user wishes to be implemented through speech or text. This portion will also contain the extensibility and customisation tools that the occupant of the house would wish to integrate into their home.

The chat module will serve as a type of companion to the occupant. It is able to converse with the user and provide limited information retrieval functions, such as weather forecast retrieval from a database. It was incorporated in the management system to provide a type of personality for the management system and at the same time entertain the user.

3.1 Expert System

The Expert System will be the portion of the management system that is responsible for the home's smooth running. In it will be contained all the rules that will analyse the information in the home. It will be the helper within the house to assist in the mundane chores that the user will not be able to perform adequately.

Information about the home will be held in the house database, which will be the heart of the intelligent management system. This database will contain all the information about the house that will be needed for the running of the home.

3.1.1 The House Database

The house database is composed of thirteen interconnected tables. Within nine of these thirteen tables is stored all the knowledge about the house and the rules the management system needs in its administration of the smart house. These nine tables all revolve around three tables: Room, Devices and Commands. These are described in Table 3.1.

Table Name	Information Held	Description
Room	RoomID Room RoomIP	The Room Table holds all the different locations within the house such as the kitchen or the garage. Each location has a unique Room ID. The whole house itself is set as one of these locations. The Room IP is the room's IP address.
Devices	Device ID Device Device Type	The Devices table contains all the different types of devices that may be accessed. Each device has a unique Device ID. The Device Type indicates whether it is a sensor or not
Commands	CommandID Command Certainty WebCom	The commands table contains within it all the possible commands that the Intelligent System can implement within the house. Each command has a unique Command ID and a degree of Certainty. This degree of certainty may only have a value of 1 or 0 (which indicates that the command received may be unsafe or needs to be confirmed). The WebCom parameter is used to turn the device ON (1) or OFF (0).

Table 3.1 Primary Tables of the House Database Expert System

The remainder can be divided into four groups: the tables that link the primary tables above, rule tables and the tables that deal with accessing devices within the house. The house link tables hold within them the relationships between the rooms, devices and commands. This group is made up of two tables, each briefly described in Table 3.2.

Table Name	Information Held	Description
CommandsDevice	CommandID DeviceID	The CommandsDevice table links the command received to the remote device that needs to be accessed to implement the command. For example, the "lights on" command is linked to the device "lights"
RoomDevice	RoomID DeviceID DevStatus	The RoomDevice table holds information about the devices that a particular room has within it. For example, Room 1 may contain within it lights, a buzzer, a television and a stereo. The DevStatus indicates whether the particular device is ON or OFF.

Table 3.2 House Linking Tables

The device access tables contain within them the different kinds of commands: distinct, automated and compound (group) commands. Distinct commands deal with accessing only one device in the house, such as "lights on" or "stereo on," and are contained within the Commands table, described in Table 3.1

Automated commands are a type of distinct command. These are commands that the user adds into the system to be implemented automatically. It has an added parameter of time, which indicates when the management system is to implement the given command. An example of an automated command could be an alarm clock every morning. The user could program the house to turn the buzzer on in the bedroom at a specified time every morning.

It is up to the user to add or remove automated commands as he or she pleases. This allows them to easily add or remove automated commands to the house as their requirements and preferences change over time.

Group commands, on the other hand, may access several devices at the same time. One example is the command "All Lights On," which turns all the lights of the house on. The occupant may also create house modes (such as Day Mode or Night Mode) as group commands if they wish. All compound commands are to be defined by the end-user of the system. Just like the automation commands, they may be added or deleted as the user wishes.

Table Name	Information Held	Description
Automate	RoomID DeviceID CommandID Time	The RoomID, DeviceID and CommandID specify the location, device name and command to be implemented, such as "Room 1 Buzzer on." The time indicates when this command is to be implemented, such as 7:00 am.
CompoundCommand	CompoundID CommandName	The Compound Name is the name of the group command. Each group has a unique CompoundID
CompoundDefinition	CompoundID CommandID RoomID Sequence	This table defines which distinct commands make up the group command. The sequence parameter indicates the order at which each of these distinct commands is to be implemented. If order is insignificant, the sequence is 0.

Table 3.3 Device Access Tables

The last group is called the Rule Tables, and is composed of the Conflict and Dependency Tables. Conflict means a clash between devices in a certain location. Dependency, on the other hand, deals with commands that serve as triggers for other commands to be implemented. A more detailed description of how rules are applied in the house will be given in Section 3.1.3 of this chapter. The conflict tables are explained briefly in Table 3.4 below

Table Name	Information Held	Description
Conflict	DeviceID ConflictID	This table contains information about which devices are in conflict with other devices. For example, the TV and the stereo system may be programmed to be in conflict with each other.
Dependency	CommandID RoomID Dependent	This table holds information on what commands serve as triggers to other commands. For example, turning the buzzer on in Room 1 could result in the TV to be turned off in the lounge.

Table 3.4 Rule Tables

All these different tables contained in the Smart House database are dependent on each other in some way. Figure 3.1 illustrates the relationship between the different Expert System tables in the house database and how they are all interconnected with each other.

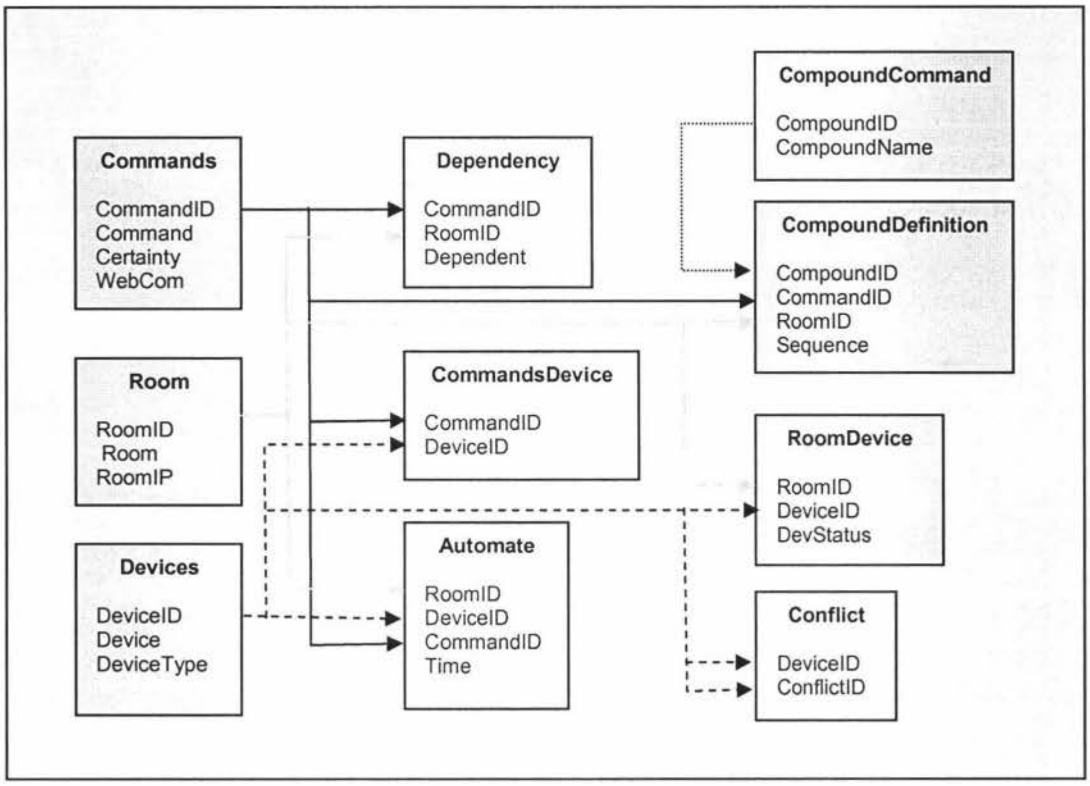


Figure 3.1 Database Table Relationships

3.1.2 Command Implementation

The Management System receives input as speech (from the Speech Recognition/Generation system) and text (through the user typing the command). The processing of these inputs is illustrated in Figure 3.2.

Each input from the user goes through the same processing each time. So each time a command is received, the slate is wiped clean, so to speak. Once it has been processed, and the system flow will repeat and apply itself to the next received input.

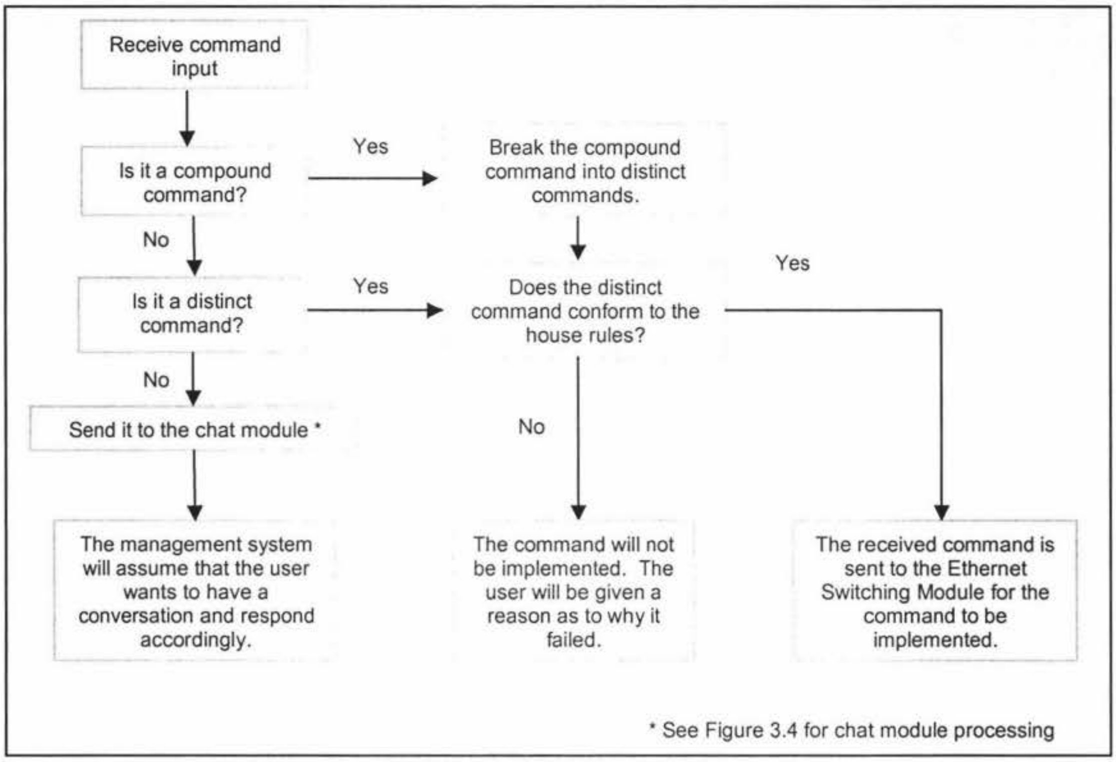


Figure 3.2 Management System Flow Diagram

The input command from the user will be checked against two groups: the compound commands and distinct commands contained by the house database. The input command from the user will first be checked against the compound commands stored within the system. If it is not recognised as a group command, it is passed to next group: distinct commands.

If it is a recognised distinct command, it is analysed to see if it is valid. How the validation of a command is established will be discussed further in section 3.1.3 of this chapter. If the command is proven valid, it is sent to the Ethernet Switching system to be implemented, otherwise, it is sent to the Chat module of the management system. Input received by the chat module will initiate a conversation between the management system and the occupant of the house. The input received will be the user's contribution to the conversation.

3.1.3 Command Validation

Command validation happens within the "Does the distinct command conform to the house rules" block from Figure 3.2. This is where the intelligence of the system exists. It is responsible for the checking of received inputs and ensuring that valid commands are implemented and invalid commands are caught by the system.

The process of validation can be further broken down into four simpler steps. Each test is to be performed consecutively, depending on the success of the preceding test. If a test should fail, then the subsequent tests need not be done. The four tests are:

1. Parameter Retrieval
2. Conflict Resolution
3. Dependent Command Implementation
4. Command validation

Parameter Retrieval is concerned with retrieving information hidden within the input command received. This portion extracts the room information (the location of the user or the room where they want the command to be implemented), device information (the device you are trying to access) and command information (whether you want to turn the device on or off). These three pieces of information are what comprise a command, and all three need to be provided to prove whether a command is valid or not.

Conflict resolution deals with device clashes that have been set by the user. For example, the user may create a conflict between the television set and the stereo, so the TV and the stereo system cannot be on at the same time. Creating conflict settings allows the home to have some sort of order in the way it deals with implementing received commands.

Also, a conflict between devices can only occur if the devices are situated in the same room. For example, having the stereo on in Room 1 should not have an adverse effect when having the kitchen stereo on. This is the approach taken by the management system in dealing with the conflicts that may occur between different devices within the house. A further breakdown of how the conflict resolution is performed is provided in Figure 3.3 below.

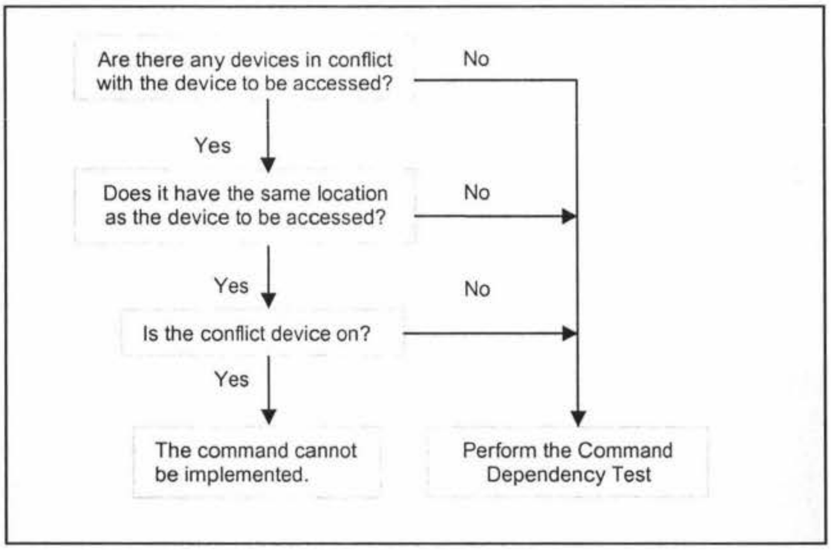


Figure 3.3 Conflict resolution

Dependent command implementation involves the execution of other commands that are tied to or dependent on the distinct command that is going to be implemented. This is a type of group command, as the command received will trigger other events in the house.

This portion provides another piece of intelligence to the management system, allowing the house to react and behave in such a way that displays some logic.

For example, when the command house alarm on is received, it could cause the porch lights to be turned on and the house to go on secure mode. Commands may be cascaded in this way, as a trigger command may implement another command, which may in turn trigger another command to be implemented and so on. When a distinct command is received and a dependent command is found, then the dependent command/s will be implemented. Otherwise, the received input is forwarded to the command validation test.

Command validation is the final portion of testing the received input from the user. This portion deals with whether the command received makes sense. For example, the user might give the command "Rumpus stereo on." The command will not mean anything if the rumpus does not have a stereo device, or if the house does not have a rumpus, or there is no stereo system in the house at all. This is the role of this test; the system needs to confirm that the command is valid and can be implemented. A command's validity is dependent on a valid location, a valid command, a valid device, and the existence of the device in the location given.

3.1.4 Extensibility and Customisation

As mentioned in Section 2.1, extensibility and the ability of the users to customise their own home is an important characteristic within the Smart House. This allows the users to set their own preferences and set up the house the way they want it. It permits them to create their own house rules and their own commands. They are given the freedom to do things within the house just as they have always done, with the exception of now having technology working on their behalf.

Extensibility and customisation is provided through four wizards within the management system application. Their purpose is to allow the user to design the management of their home the way they want it done. Initially, the expert system portion of the house database will be empty – it will be up to the user to fill it up with information concerning the house and to define their desired settings. The different wizards and their functions are described briefly in Table 3.5 below.

Wizard Name	Function
Add/Remove Room/Device	This wizard will be responsible for the addition and removal of new rooms and devices in the smart house. Devices may be added to or removed from a room as the house environment changes.
Compound Command Wizard	This wizard will be the place where the user may define a new compound command or remove one. A group command may also be altered in this wizard, i.e. distinct commands may be added or removed from a group command here.
Automation Wizard	Commands for home automation are defined and removed in this wizard. The user sets the location, device, command and time for the automation to be implemented.
Dependency Wizard	The Dependency wizard will be used to create trigger commands and response commands in the home. Receiving the trigger command will cause the response commands to be implemented as a result.

Table 3.5 Wizards in the Smart House Management System

Appendix B contains an example of how a wizard is used to add a device to a certain location within the Smart House.

3.2 Chat Module

The chat module will be a chatbot (or "chatterbot"), which will interact conversationally with the user of the Smart House. It will converse ("chat") with the disabled or elderly person in much the same way that one person converses to another through simulation. Just as a person has a personality, the chat module will also have a certain personality of its own.

In 1950, the brilliant mathematician Alan Turing replaced the question "Can machines think?" with what he called the Imitation Game (Turing, 1950). He proposed a test where a human judge would interact with two computer terminals: one controlled by a human and the other by a computer. If the judge is unable to distinguish between the computer and the human, Turing suggests that the computer must be able to "think." He predicted that within 50 years, computers would be endowed with enough processing power for a computer program to fool an average interrogator for 5 minutes for 70% of the time.

This testing of a computer program's ability to converse is now an annual event called the Loebner Prize Competition, which started in 1991. Its goal is to identify the most 'human' computer program – the one that first passes an unrestricted Turing test (Epstein, 1992). The writers of these programs are motivated by a prize money of $100,000.

One of the earliest chatbots is Eliza the Psychiatrist (Weizenbaum, 1966). She was designed to behave as a Rogerian psychotherapist – repeating several of the questions thrown at her by her "client" in a slightly different form. This is to make it seem like the program is encouraging her client to do most of the talking, thereby easing some of the client's pain. Eliza proved to be quite successful in the 1960's that it was suggested that others like her could replace therapists altogether. Users got emotionally involved with the program – Weizenbaum's secretary even wanted to be left alone with the program. Eliza became a point of reference for other chatbots that followed.

These include Parry, MegaHal (Hutchens), Mgonz (Humphrys, 1989) Alice (Wallace, 2002), which won this year's Loebner Prize in September. In fact, chatbots have now become quite sophisticated. Chatbots are able to chat with other chatbots on MIRC channels and even have the ability to learn as they continue to converse with others, both chatbots and people.

3.2.1 Stimulus – Response

Stimulus – response is an idea that represents the cause – effect link between a stimulus event and an obvious or hidden response. For example, when we get pepper up our nose, we sneeze. The pepper is the stimulus, and the sneezing is the response. Chatbots have adopted this strategy when having conversations with others.

Stimulus-response is an approach taken with chatterbots. Responses to the user's speech are generated through the identification of keywords (stimulus). All chatterbots go through this process before using different techniques to generate the optimal response. Such approaches include context discovery and transforming the input of the user (Eliza) or

MegaHal's approach of using hidden Markov chains. This is the approach used in the implementation of the management system's chat module.

3.2.2 Chat Module Implementation

Stimulus-response is implemented in the management system through the house database. Any input from the Speech Recognition system will be processed by either the Smart House's expert system or the chat module. Any invalid or unrecognisable command input from the Speech Recognition system will be sent to the chat module for processing.

Two tables in the house database are utilised by the chat module for general conversation. The first table holds the keywords that may be contained by the input from the user and the second table is used to choose a response depending on the keyword identified. The response table contains within it several responses that are available to a certain keyword. A random number is then generated to decide which response will be chosen as the response to be sent to the user.

When the management system receives input for the chat module, it searches the keyword table to check if any of the keywords can be identified. If it recognises a keyword, then it provides an appropriate random response. Otherwise, it behaves like Eliza and replies in a way that encourages the user to elaborate or provide more information. Figure 3.4 describes how input into the chat module is handled by the management system.

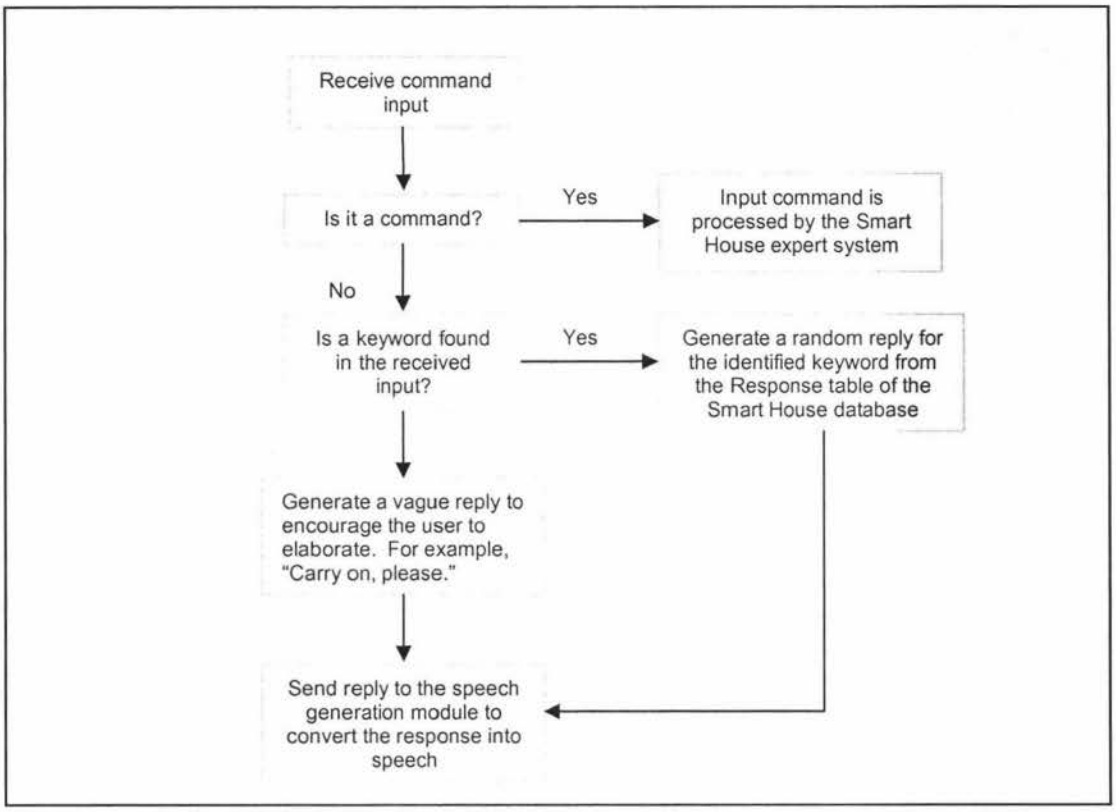


Figure 3.4 Chat Module Flow Diagram

3.2.3 Chat Module Memory

The management system's chat module is able to remember certain information through the use of tags. A tag could be any saved information about the user, such as their name, address, age, or preferences. At the moment, only one is recognised by the chat module of the management system – the user's name.

It is hoped that the management system will retrieve information from the Bluetooth watch in the future. In the Smart House, the Bluetooth watch will contain its user's personal data.

When it is fully integrated with the Smart House management system, the chat module will be able to retrieve personal information from the wearable device and associate certain tags within the chat tables to this information. Examples of possible tags that could be used would be their name, location and health information such as their blood pressure level.

3.2.4 Information Retrieval

Information retrieval will also be a function that will be performed by the chat module. Examples of this could be gaining information about the house locations and devices, such as whether the appliances within a room are turned on or not. Other kinds of possible information could be the daily news or weather reports. At the moment, the chat module is able to retrieve weather forecast information from the Weather table of the house database.

An example of a conversation of a user with the chat module of the management system is shown in Figure 3.5 below. The input from the user is preceded by "--" and the management system's response is on the line below it.

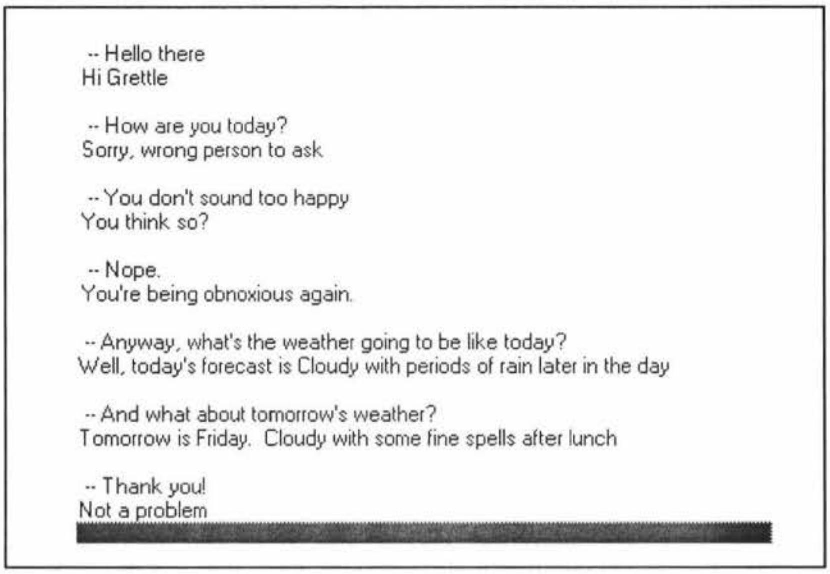


Figure 3.5 A conversation with the Chat Module

3.3 Inter-System Integration

As mentioned in Section 2.2, the Smart House Management System will not work on its own. It will be dependent on other systems being developed to ensure the smooth running of the Smart House. This section will describe the interactions that the Smart House Management System will have with the Speech Recognition/Generation System and the Ethernet Switching System. Although work has been done towards the creation of the Bluetooth Enabled Watch, no effort to integrate it with the Smart House Management System has yet been accomplished.

3.3.1 Integration with the Speech Recognition/Generation System.

There are two ways for the user to communicate with the Smart House Management System. They may use the keyboard or speak to the Smart House. The Speech Recognition/Generation System will be used if the user selects the latter choice.

The Smart House Management System and the Speech Recognition/Generation System will communicate with each other through Transmission Control Protocol/Internet Protocol (TCP/IP). The Speech Recognition portion of the system will convert the speech of the user into text for the Management System to process, and the Speech Generation portion will convert the text response of the Management System into the speech for the user to listen to.

The Speech Recognition System will be triggered by a particular word, such as "Jeeves." This word serves as a switch that turns the Speech Recognition system on. The recognition system will then listen to whatever the user says after "Jeeves" and sends it to the Management System for processing. Input into the Management System from the Speech Recognition System will include commands that are to be implemented as well as the user's side of the conversation when he is chatting to the Smart House.

Once the text input from the Speech Recognition is received, the Management system processes this input as described in Section 3.1.2. If it is a command, the Management system assesses its validity. If the user is having a conversation or wanting some information, the chat module will retrieve the appropriate response. This text response is then sent to the Speech Generation System to be converted into speech.

The Speech Generation System expects the text to be in a certain format. The text received will contain the expected response from the user. For example, there will be cases when a received command will be double-checked to ensure that the user wants to go through with the command. The instruction "Kitchen Refrigerator off" may be one of these. The Management System will confirm that the user wants to go through with the command and provide expected replies (see Figure 3.6).

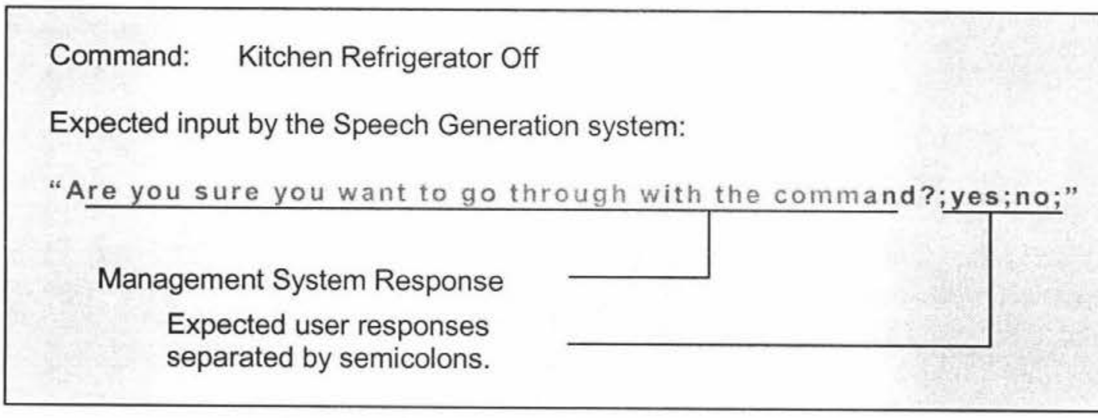


Figure 3.6 Management System response format

For cases when no set user responses are expected (such as in a conversation with the chat module), only the Management System response portion is sent directly to the speech Generation System.

3.3.2 Integration with the Ethernet Switching System

Communication with the Ethernet Switching System will be done when a command has been successfully put through the rule checks and command validations performed by the expert system as described in Section 3.1.3. It is the final stage in the process of the user communicating their wishes to a particular device within the Smart House. Once proven valid, the management system of the Smart House will send the command information to the Ethernet Switching system to be implemented.

The Ethernet Switching system is Internet-based. So the management system will contact the different devices and implement commands through the Internet. Access to a particular device will be done through calling a uniform resource locator (URL), which is directly linked to both the room where the device to be accessed is located and the device itself. This URL will be of a specific form. For example, the Command "Please turn the lights on in Room 1" will be converted into a URL (see Figure 3.7), which will pass information to the Switching system about the room where the command is to be implemented (Room 1), the device to be accessed (lights) and the desired device status (ON).

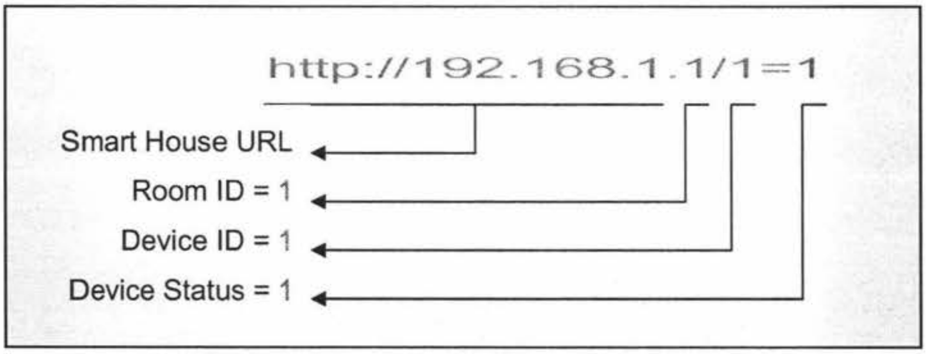


Figure 3.7 A Distinct Command Example

Calling the appropriate URL passes the command from the Smart House management system to the Ethernet Switching System. The switching system will access the device, implement the desired command and update the information about the device accessed.

Information from the Ethernet Switching System will also be retrieved through the Internet. The data about all the different Smart House locations, devices and their status will be stored in an XML file.

This file is the XML version of the RoomDevice table of the Smart House database for each room – i.e. it contains information on each room, its devices and the status of these devices. For example, the XML file in Figure 3.8 will represent Room 1 of the Smart House. The Ethernet Switching System will update this file when a command is implemented.

```
<?xml version="1.0" ?>
- <Room>
    <RoomID>1</RoomID>
  - <Device>

        <DeviceID>1</DeviceID>
      <Status>1</Status>
    </Device>
  - <Device>

        <DeviceID>2</DeviceID>
      <Status>1</Status>
    </Device>
  - <Device>

        <DeviceID>3</DeviceID>
      <Status>1</Status>
    </Device>
  </Room>
```

Figure 3.8 Ethernet Switching System Status for Room 1.

Once a command is passed to the Ethernet Switching System, it will be the Intelligent Management System's responsibility to update its database to contain the most recent information about the Smart House and its devices. The database will be updated each time a command is implemented by the Ethernet Switching System. When a command is passed, the Ethernet Switching System updates the concerned location's XML file, which is in turn parsed by the Intelligent Management System to extract the information embedded within. The extracted information is used to update the Smart House database to ensure that it contains the latest changes.

In the cases where the Smart House device is a sensor, having the sensor triggered (sensor status is ON) will cause the Management System to alert other users of the house by issuing a verbal warning (through the Speech Generation system) to the other users of the house that the sensor has been triggered. The location of the sensor is also given in the message sent. This warning will be given every minute until the triggered sensor's status is set to OFF in the House Database. Figure 3.9 shows an example of such a warning and the message received by the Speech Recognition/Generation system when the Fall Sensor in Room 1 is triggered.

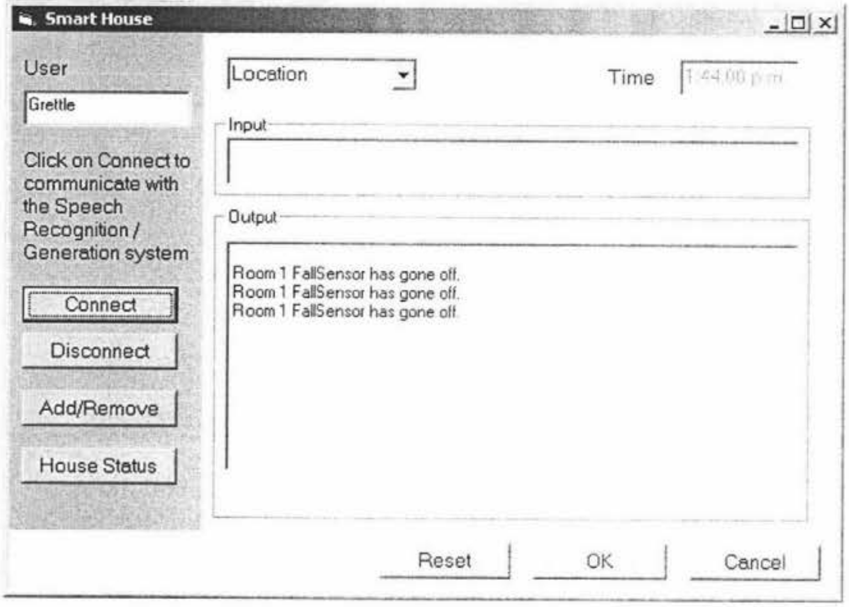


Figure 3.9(a) Sending a sensor warning in the Smart House Management System's graphical user interface

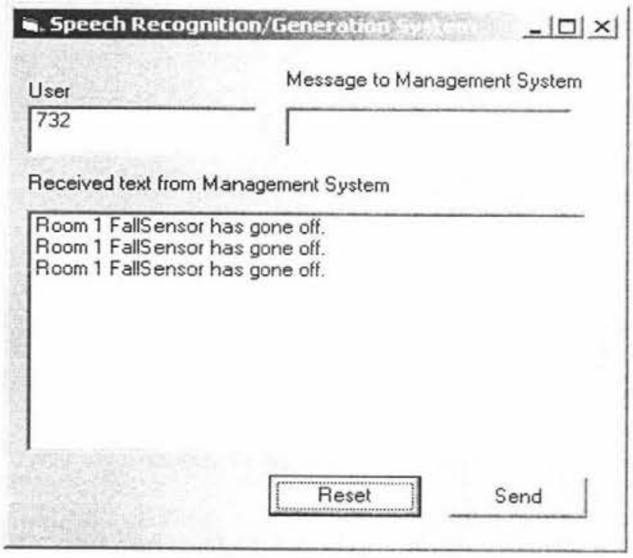


Figure 3.9 (b) Received sensor warnings from the Smart House Management System to be converted to speech by the Speech Generation System

Figure 3.9 Sensor warning messages

The following chapter will discuss the Smart House Management System's current status as well as future work still to be done for this portion of the Smart House.

Chapter 4

Discussion

The first portion of this chapter will discuss the current state of the Smart House Management System. Future work and possible improvements will be elaborated on in the second part of this chapter.

4.1 The Current Management System

The Smart House Management System is at present comprised of an Expert System and a chat module that converses with the user of the Smart House. Input into the Management System is received through speech (via the Speech Recognition System) or as typed text in the graphical user interface. The Ethernet Switching system receives and implements the commands once they are processed and proven to be valid. The Speech Generation System converts speech responses and warnings for the users of the house from text to speech.

The Management System's present status and limitations is discussed in the following sections.

4.1.1 The Expert System

Section 2.1 discussed the desired characteristics that have guided the development of the Smart House Management system. These are intelligence, extensibility, customisability and ease of use.

Intelligence is displayed in the Management system by the processing of the inputs received from the user. It is able to break each input into several simpler portions that are joined together to produce intelligent behaviour. The application of rules displays the system's ability to ensure that the commands received are processed properly. These rules are conflict resolution and command dependency.

Conflict resolution will deal with clashes between devices within a certain location of the Smart House. For example, clashes between two devices that both emit sound in the same location will not be allowed. Command dependency is concerned with creating a cause – effect link between commands received within the house, where the implementation of a certain command triggers other commands to be executed as well.

Intelligence is also displayed by the system's ability to check certain commands with the user when a command may need to be confirmed. An example of this is making sure that the user wants to turn the refrigerator off. Allowing the refrigerator to defrost accidentally may cause water to spill onto the floor, becoming a hazard to the Smart House's resident.

Extensibility and *Customisation* are provided for in the Smart House through the four wizards (see Table 3.5):

- Add/Remove a Room or Device
- Compound Command Wizard
- Automation Wizard
- Dependency Wizard

These wizards give the user freedom to define their home. It also takes into consideration constant changes that may take place in the Smart House as time goes on, such as the addition of more devices, or changes in the user's desired automated commands. Initially, the expert system portion of the house database will be empty – it will be up to the user to define their desired settings.

Ease of use is provided through two user interfaces – speech and the Management System graphical user interface (GUI). Although the latter means of communication is provided, speech is expected to be the primary approach used by the occupant of the Smart House. This type of communication allows the user to be free from being tied to a certain location or device. It allows the user to give commands naturally without the need for him to be in front of a computer.

The Management System GUI was also created with simplicity in mind. It was designed to hide as much of the complexity of the Management System from the user as possible. An overview of the Management System GUI is given in Appendix A.

Ease of use is also shown by the system's portability. The Management System may be easily transferred from one location to another. All previous data may also be removed so the user may start from scratch again if required. It also does not need the house to be renovated or rewired from the ground up before it can be activated.

4.1.2 The Chat Module

The chat module of the management system functions purely through stimulus – response. It searches the speaker's input for a keyword, and responds with a random programmed response. There are currently sixty-eight keywords arranged in order of importance in the keyword table. This is small compared to the 24,000 categories of Alice (Wallace, 2001). Each keyword has several programmed replies stored in the keywords table of the house database. When a keyword is identified, a random reply is chosen out of these programmed replies and sent to the user.

The chat module is also able to perform limited information retrieval. At the moment, it is able to get weather forecast information from the weather table of the house database.

Figure 4.1 below shows a test to check the length of time that the chat module takes to respond to a command. The first half demonstrates the typical response times of the Management System chat module (in this case, 60ms and 40 ms respectively). In comparison, online chatbots Alice (Wallace, 2004) and Alan (*Alan*, 2001) have a response time that is largely dependent on the type of connection to the Internet. Both Alice and Alan have a response time of around 2 seconds on a 56 kbps dial-up connection to the

Internet and less than 1 second on a 100Mbps connection (exact measurements of their response times could not be obtained from conversing with either chatbot on the Internet).

The current Chat module is computer-based so the matter of Internet or network connection is not a concern. Also, the chat module database is still relatively small so the response time is also short. As the database continues to grow, the response time will also be expected to increase proportionally. Other means of querying the database may need to be used to have a quicker response time.

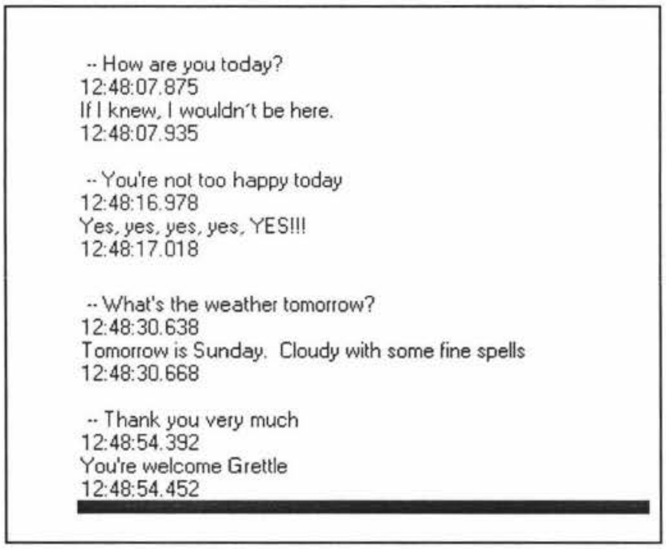


Figure 4.1 Checking Response Times of the Chat Module

The second half of Figure 4.1 demonstrates the information retrieval response time to get the forecast from the Weather database of the Smart House. The amount of time to obtain this information is approximately the same as it is to respond to something the user says when having a conversation with the chat module.

4.1.3 Module Communication

The Smart House Management System is currently able to communicate with two of the other three modules currently being developed for the Smart House. It is able to exchange information with the Speech Recognition/Generation System as well as the Ethernet Switching System. No work has yet been done towards integration with the Bluetooth Smart Watch.

Although full integration with both the Speech Recognition/Generation System and the Ethernet Switching system has not been accomplished yet, the Management System has followed the required specifications for integration as described in Section 3.3.

A separate test application was created to check the communication between the Speech Recognition/Generation System and the Management system. The exchange of data was accomplished through TCP/IP. Since the data to be exchanged between the two systems was text, the idea was to successfully send and receive data from the test application. Figure 4.2 illustrates communication between the test application and the Management System, where the input to the Management System comes from the test application.

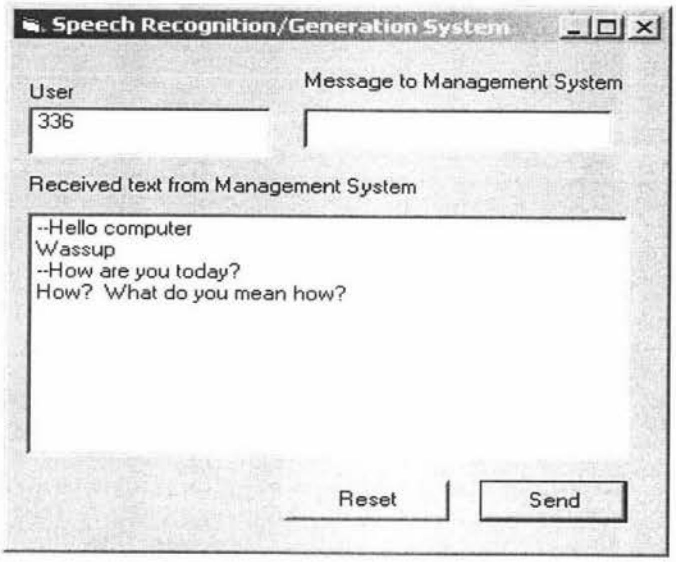


Figure 4.2(a) Integration Test between the Management System and the Speech Recognition/Generation System. Test Speech Recognition/Generation Application side.

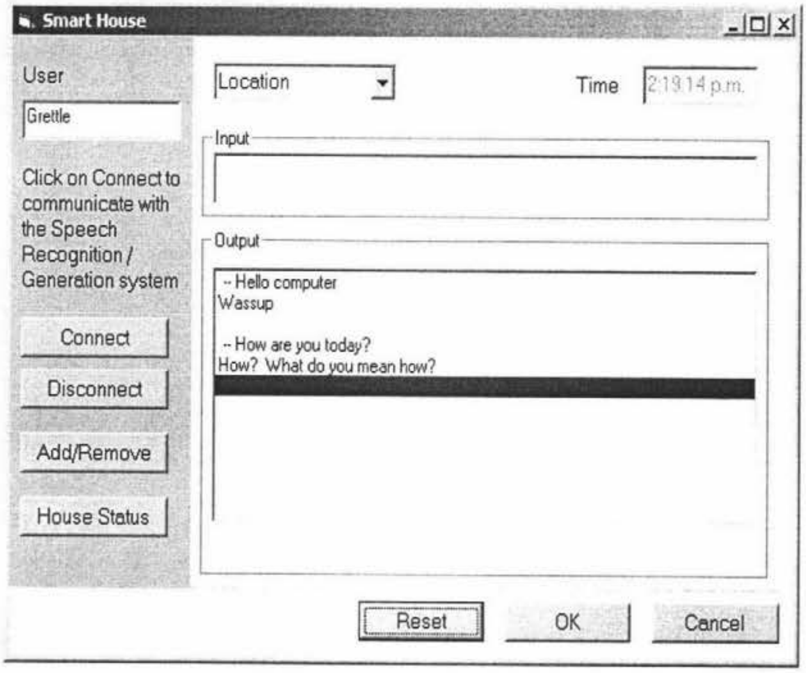


Figure 4.2(b) Integration Test between the Management System and the Speech Recognition/Generation System. Smart House Management System GUI side

Figure 4.2 Integration Test between the Management System and the Speech Recognition/Generation System

The Management System was able to successfully send and receive messages from the test Speech Recognition/Generation application as shown above. It is therefore expected that integration with the actual Speech Recognition/Generation System should not cause a major difficulty.

Communication with the *Ethernet Switching System* was accomplished through creating and calling a specific URL (to implement a command) and successfully reading an online XML file to update the house database so that it contains the most current information. For example, to implement the command "Room 1 lights on, please", a certain URL of a specific format should be called (see Section 3.3.2) to implement the command successfully. Figure 4.3 illustrates successfully creating and calling the correct URL format to implement the command "Room 1 lights on, please."

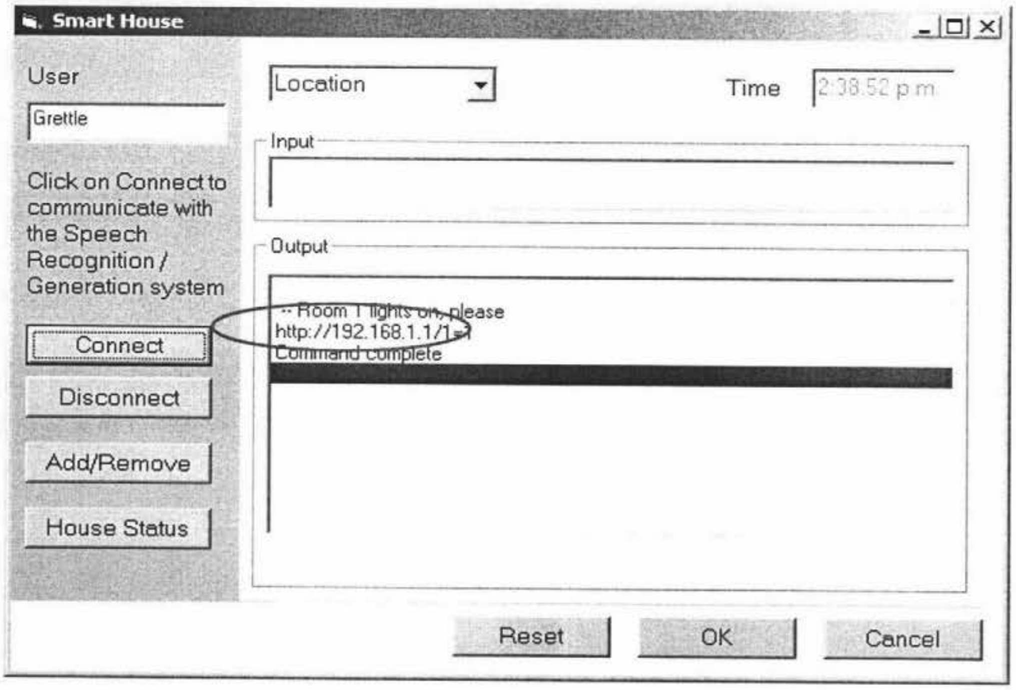
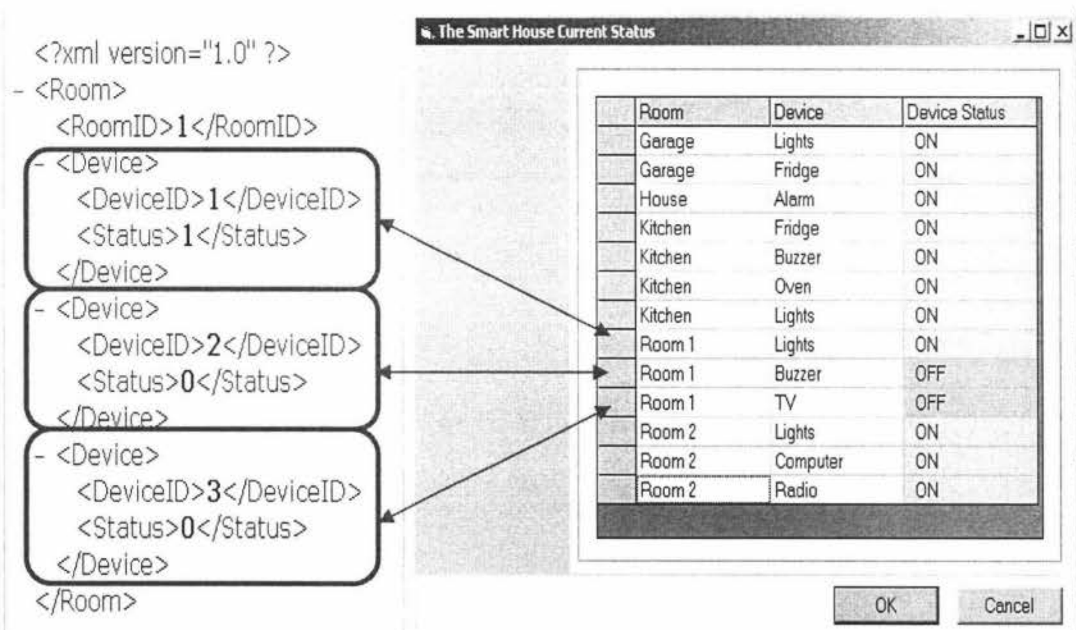


Figure 4.3 Implementing a command through the Ethernet Switching System

Once the correct URL has been accessed, it will be up to the Ethernet Switching System to access the correct device and implement the received command from the user. Once the command has been implemented, the Management System's next responsibility is to update the Smart House database so that it reflects the actual status of the Smart House. It does this by reading an XML file and extracting the latest information and then it updates the Smart House database.

Since each XML file contains the information for one room only, the above command would read Room 1's XML file. Figure 4.4 below shows that the online XML file and the Smart House Database contain the same information, and that the Smart House database has been successfully updated.



(a) Room 1's XML file

(b) The House Database's Current Status

Figure 4.4 Updating the Management System's Database

4.1.4 Limitations of the Expert System

The current Management System is by no means complete. This section will discuss the limitations of the current Expert System portion of the Management System.

Limited Input Commands

The Management System is only able to implement one discrete command at a time. These include commands such as "May I have the kitchen buzzer on, please," where the location "kitchen" and command "buzzer on" may be found in the Smart House Database. Discrete commands such as "Could you please turn on the buzzer in the kitchen" will not be considered valid because although the location "kitchen" will be found, the command "turn on the buzzer" will not.

Simply simply inserting the phrase "turn on the buzzer" in the Smart House database will solve the problem above. Other ways of putting the phrases may also inserted to maximise the possibility of a command being recognised and implemented. The Add Device Wizard will also need to be altered to allow for this change. At the moment, when a new device is added to the Smart House, it creates the commands "Device ON" and "Device OFF" and inserts them into the Commands table of the house database. All the other possibilities of saying the command will also be added in when a device is added into the house (and they will also all need to be removed when that same device is completely removed from the Smart House).

Although group commands are accepted, they are implemented successfully because within each group command is a group of complete discrete commands. For example, the compound command "Movie mode on" is made up of the following discrete commands: "Room 1 lights off", "Room 1 buzzer on" and "Room 1 TV on." Cases where the user says "Turn the lights on and the computer on in Room 2 please" results in the implementation of the command "Turn the lights on in Room 2." It only acknowledges the first recognised command and implements it, while the other command ("computer on") is ignored altogether.

This problem is not as easily solved as the earlier difficulty of anticipating different ways of saying a command. In this case, the instruction will need to be processed further. For the case above where two commands are to be implemented in one location, a possibility of solving it would be separating the commands and the locations and splitting the received instruction into two. So the input would become two commands instead: "Room 2 lights on" and "Room 2 Computer on." This approach should also handle cases where there is one command to be implemented in multiple locations, such as "Lights on in Room 1 and Room 2 please." However, multiple commands in multiple locations (like "Could you please turn the lights on in Room 2 and Room 1 and turn the stereo off in the Kitchen") will need another approach.

Spelling Errors

Although the Management System expects input from the Speech Recognition System to be correct, spelling errors when the user chooses the Management system GUI cannot be completely avoided. The current Management System is unable to deal with spelling errors. When having a conversation with the Chat Module, spelling errors are not of great importance, as the Chat Module will simply ask the user to keep on speaking until it recognizes a keyword.

In the case of receiving commands, spelling errors are of more importance because commands may not be implemented. When a group or discrete command is not spelt correctly, the command is not recognized and sent to the chat module. In cases where the location is not recognised, the error message "Error! There is an inconsistency in the command received" is displayed or sent to the user.

Limited Error Definitions

The current Management System also does not provide the user with detailed feedback when an error occurs. An example is the case above where a location for the command is not provided. Sending the device "Computer on" with no location will result in the Management System responding with the error message "Error! There is an inconsistency in the command received," which does not really tell the user where the error in the command received was. Ideally, it could say, "Where do you want the computer to be turned on?"

4.1.5 Limitations of the Chat Module

Limitations in the current Chat Module of the Management System include its limited ability to sustain a meaningful conversation and restricted information retrieval capability.

Limited conversation

The Chat Module of the Smart House Management System is able to hold a limited conversation with the user of the Smart House. Although a conversation may be sustained as long as the user still talks to the Chat Module, he will eventually get bored with the system, and in time, decide not to use it altogether. The reason for this is the number of keywords that are stored within the House database limits the Chat Module. The more the keywords and the more programmed responses there are, the more interesting the conversations with the occupant of the Smart House will be.

Limited Information Retrieval

The Chat Module of the Management System is able to perform some information retrieval. Its ability is limited to retrieving weather forecasts that are stored within the Smart House Database. This feature may be improved on in the future by extracting the information from an online weather database, such as MET SERVICE (MetService, 2005) or Television New Zealand (TVNZ, 2005). This would involve parsing the source code of the webpage to search for a particular tag that contains the weather information. A couple of weaknesses in this approach could be found. First, the changing of the specific tag's name in the future would mean that the information would no longer be available. Also, if there is no way for the user to specify which city or country they would like the weather for, the received information would be limited to one city (which is hidden in the Management System's code).

It is also able to as associate certain tags within the Chat Module's Response table to specific information, such as the user's name. More tags may be added in the future, such as personal information like the user's age, address and information extracted from the Bluetooth Smart Watch when integration is complete.

4.2 Future Work for the Smart House Management System

The Massey University Smart House will be a test bed for more groundbreaking technology in the future. This requires a management system that can absorb all these improvements that will be added to the Smart House as time goes on. So the possibilities for further work towards a smarter management system span a broad area of technologies. This section will focus on more immediate improvements to the Management System that will contribute more intelligence, extensibility, customisability and ease of use for the Smart House user. These improvements will be divided into three sections: the future work for the Expert System, Chat Module and Inter-module integration.

4.2.1 Expert System

The current Expert System, although able to process commands and apply rules to validate commands, still falls short of human intelligence. We as human beings are created with our five senses of vision, smell, hearing, taste and touch. Along with it is the ability to process input from these five senses and react accordingly.

The long – term goal for the Smart House Management System is to give it intelligence that gets as close to human intelligence as we can. This is a very big and challenging task. The current system is equipped with limited hearing and processing. I have divided further improvements to the expert system into six parts: user interface, multiple users and command processing, implicit input recognition, multiple device states, multiple device functions and Management System help.

User Interface

The addition of other means of user interfaces for the Expert System would allow the Management System to be more "sensitive" to its environment. At the moment, the only user interfaces are speech and the Management System GUI. There will be instances when neither of the two will be appropriate for communication with the users of the house.

Such a scenario would be informing the user of the house that an automated command has been successfully implemented through the Speech Generation System when the user is watching a movie. Although the same confirmation may be displayed through the GUI, the user may not be in front of his computer. This highlights the need for the addition of alternative means of communicating with the user. A projector installed into a wall of the room where the user is in may display this message as text, or the user may receive an SMS message on his mobile phone. These alternative communication interfaces will also allow the Management System of the house to decide on which method would be most appropriate for the current situation. So in the case where the user is watching a movie, the Management System may conclude that issuing a verbal confirmation would conflict with the television's sound and decide to SMS the user instead.

An improvement on the Management System GUI is also making it Internet-based instead of computer-based to make the application more accessible. This allows the Smart House to be accessible to the user even when they are away from the Smart House. They are given the option of checking up on the Smart House's status even while they are away on holiday. It can also provide a utility for a concerned relative to check up on the user once in a while just to make sure that things are going well.

Another way for the Smart House to adjust to a human interface is the addition of a vision system. This will give the Management System the ability to "see" ongoing activities in the house, as opposed to just listening to speech commands. A possible application for vision could be the recognition of users within the Smart Home, as well as reading their gestures and other body language when receiving commands.

Implicit Input Recognition

Implicit input is currently not recognised by the Smart House Management System. It only receives speech as text, with none of the other hidden information that may be received as pitch or volume. Since 55 percent of a message is non-verbal (Mehrabian, 1968), more than half of the message is missed. An example of work toward this area is the Affect-Sensitive Human-Robot Cooperation (Rani, Sarkar, & Smith, 2003).

Processing the visual input from the Vision system mentioned above as well as the received speech to extract non-verbal information (Billinghurst & Savage, 1996) would result in an expert system that is more sensitive and more attentive to what the user is actually saying. The end result would be a sort of emotion sensor that can extract information about how the user feels and take this into account when processing input.

Multiple Users and Commands

The current management system was designed to only keep track of a single user within the Smart House. A future improvement on this system is to add multiple-user tracking to know where the residents of the house may be.

The further processing of multiple commands within the received input is also an improvement in sight for the future. This means allowing the Management System to process the received input in such a way that it "understands" what the user is saying as opposed to searching for fixed keywords. So the Management System will know that the command "Please turn the computer and the lights on in Room 2" is made up of two commands and that "Please turn on the computer in Room 2" and "Room 2 computer on" mean exactly the same thing.

Multiple Device States

The Management System only recognises two possible states for the devices housed within the Smart House – ON or OFF. Not all home devices are limited to these two states. Devices such as light dimmers, for example, are not merely ON or OFF. They have several levels of brightness.

Multiple Device Functions

Multiple device functions deals with fully integrating devices in the house with the Smart House Management System. This means giving it the ability to access not just the ON/OFF switch of the TV or the radio, but adjust its volume and change its channel. This could mean the creation of a layer of abstraction that serves as a common interface between the

Smart House Management System and devices contained within the Smart House that would allow them to communicate with each other.

Management System Help

A helper or assistant within the Management System could also be a useful tool to assist the user (particularly when they are just new to using it) to perform tasks within the Smart House. This could be particularly helpful when adding information to the House Database through the wizards.

A logging system could also be created to record recent activities within the Smart House for future reference. It may be useful if in the future there is a need to study the user's behaviour pattern throughout the day or over a certain period of time, particularly in the cases of users who are disabled or elderly.

4.2.2 Chat Module

Future work for the Smart House Management System's Chat Module includes more advanced information retrieval and learning.

Information Retrieval

Other useful information for the Management System to retrieve would include the current states of devices contained within the Smart House. This allows the user to query about certain devices and their states. Although the current state of each of the devices housed within the home may be viewed through the GUI, receiving information about a particular device is useful. Examples of when this could be helpful would be checking to see if we left the stove or the clothes iron on.

Other information that may useful to retrieve would be the last command that the user asked the Management system to do. Or it could be designed to search and retrieve specific information from the World Wide Web, such as the latest news or the current exchange rate.

Chatbot Learning

Further improvement on the Chat Module would be giving it the ability to learn from the user as it converses with him. Examples of chatbots that learn include MegaHal (Hutchens), jabberwacky (Carpenter, 2004) and Zero (Hope, 2004). This ability would make the Chat Module's function much more entertaining for the user. It would also mean that the longer the user and the Management System converse with each other, the Chat Module would learn to reply with a wider, more varied vocabulary.

4.2.3 Inter-module Integration

The next step in terms of inter-module integration would be to put together the Bluetooth Smart Watch and the Smart House Management System. As the Bluetooth Watch has not yet been developed, specifications for communication and integration with this particular module of the Smart House has not been taken into account in this thesis.

Inter-module integration would also include the Management System's absorption of other possible human-friendly user interfaces that may be added to the Smart House in the future. Possible human interfaces are a vision system, the use of projectors and SMS messages to relay text messages when the use of speech messages may be inappropriate.

This chapter described the current status of the Smart House Management System and further work still to be accomplished. This project is ongoing. As the Smart House and technology continues to advance, the Management System will need to adapt in order to absorb the different changes that are still to be applied.

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Appendix A

The Smart House Management System Graphical User Interface

The graphical user interface of the Smart House Management System is a means through which the user and the management system can communicate with each other (see Figure A-1). Aside from speech, this is the only alternative currently available to the Smart House user. It was designed to be simple and hide as much of the background activity from the user as possible.

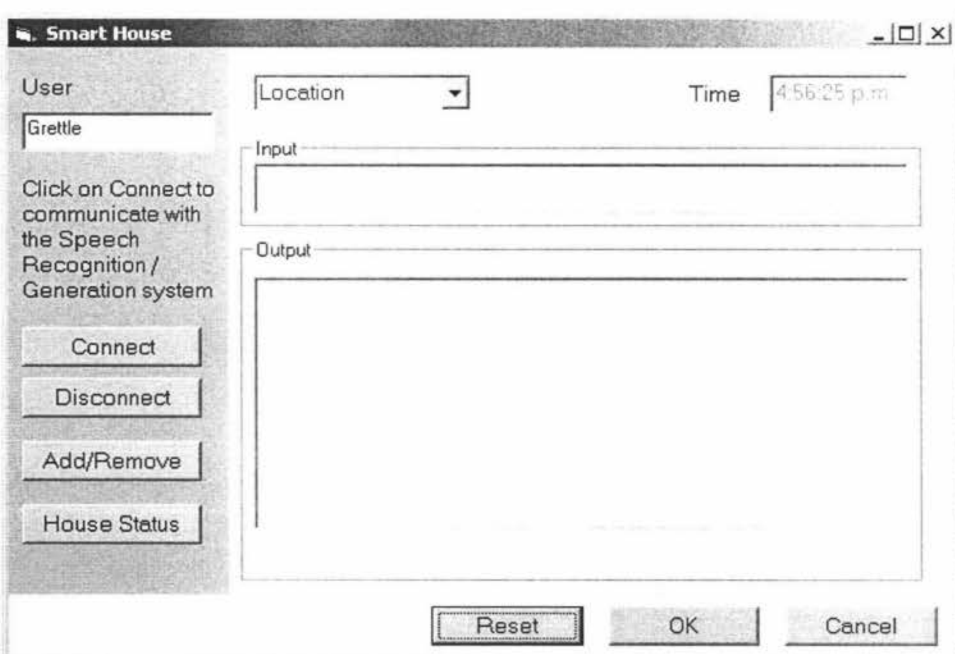


Figure A-1 The Smart House Management System GUI

Although the Speech Recognition/Generation system is able to receive commands for processing and speech for the conversation module, a speech interface for adding locations or devices in the Smart House is still unavailable. For example, the user will need to utilise the graphical user interface when adding information concerning the Smart House to the house database. Table A-1 will briefly describe what each of the different components of the Smart House Management System GUI does.

Management System GUI component	Description
User Textbox	The User textbox contains the name of the user of the Smart House. In the future, when the Bluetooth Smart Watch is integrated with the Management System, this information will be extracted from the Smart Watch.
Location Listbox	The Location listbox contains the current location of the user within the Smart House. This information will also be extracted from the Smart Watch after integration is completed.
Time Textbox	Displays the current time
Input Textbox	This is where the user will type their text input.
Output Listbox	Displays interactions between the user and the Smart House Management System.
Connect Button	Connects the Smart House Management System to the Speech Recognition/Generation System
Disconnect Button	Disconnects the Smart House Management System from the Speech Recognition/Generation System.
Add/Remove Button	This button is used to call the wizards when adding or removing a location, device, group command or command dependency to the house database (see Appendix B).
House Status Button	This button displays the current status of the house devices
Reset Button	The Reset button clears the Output listbox
OK Button	The OK button retrieves input from the input textbox and processes it through command validation or sends it to the Chat module.
Cancel Button	The Cancel button terminates the application.

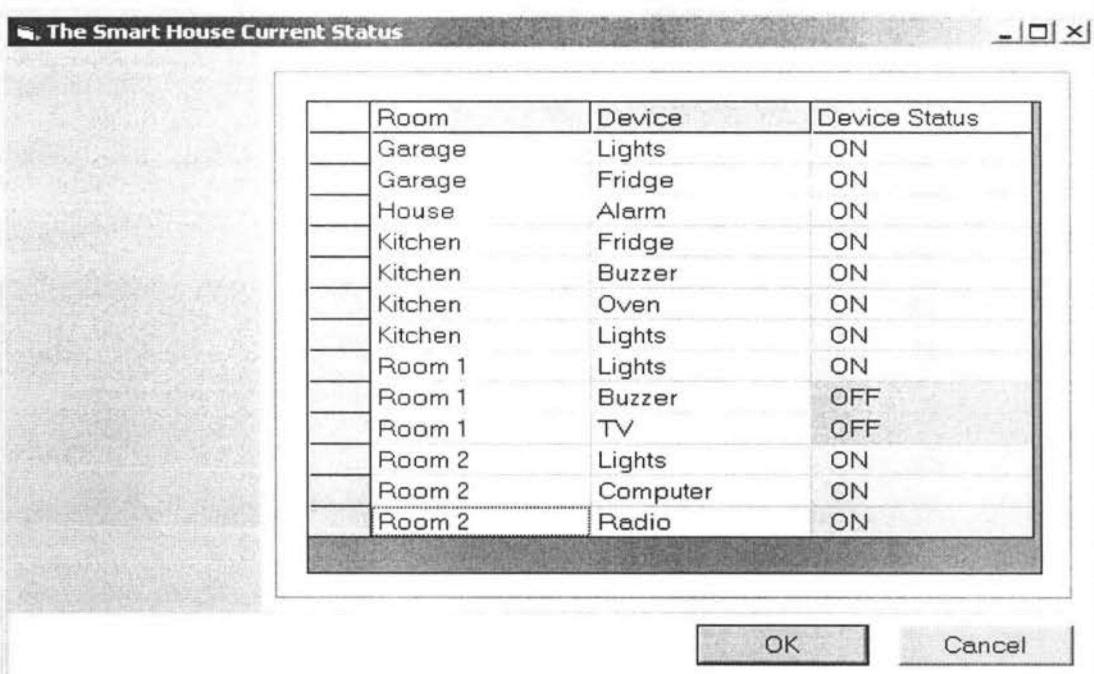
Table A-1 Management System GUI Component Overview

The Smart House Current Status

The status of the smart house will hold information about all the devices within the Smart House. It can be accessed through the House Status (see Figure A-1) button of the management system graphical user interface.

Figure A-2 shows the current status of the Smart House. Information in this figure is based on the RoomDevice table of the Management System database, which holds information about the different locations within the Smart House, the devices each particular location contains, as well as their current status – ON or OFF.

This information is updated regularly as well as each time a command is implemented successfully to give the user accurate information about the current status of the Smart House.



Room	Device	Device Status
Garage	Lights	ON
Garage	Fridge	ON
House	Alarm	ON
Kitchen	Fridge	ON
Kitchen	Buzzer	ON
Kitchen	Oven	ON
Kitchen	Lights	ON
Room 1	Lights	ON
Room 1	Buzzer	OFF
Room 1	TV	OFF
Room 2	Lights	ON
Room 2	Computer	ON
Room 2	Radio	ON

Figure A-2 Current Status of the House

Appendix B

Wizards: Extensibility and Customisation in the Smart House Management System

Extensibility and Customisation in the Smart House management system are provided through the means of wizards. When the management system will be first received, it will be blank – it will not know anything about the house. It will be up to the user to provide the management system with the various locations and devices within the house. It is also their responsibility to define the rules that they want applied in their home.

Altogether, there are four wizards, which have been described briefly in Table 4.1 (Chapter 4). Although speech may be used as an interface when receiving commands to be implemented in the house, imparting knowledge about the house to the house database cannot be done in this way. For the house database to be filled, the user will have to fill up the database in the traditional way: through the monitor, keyboard and the mouse. This appendix will go through one of these wizards as an example – the Add/Remove Location/Device wizard. The other wizards operate in a similar way.

The user will be initially faced with the management system's graphical user interface (see Figure B-1). All the different wizards can be accessed through the Add/Remove button, located on the lower left hand corner.

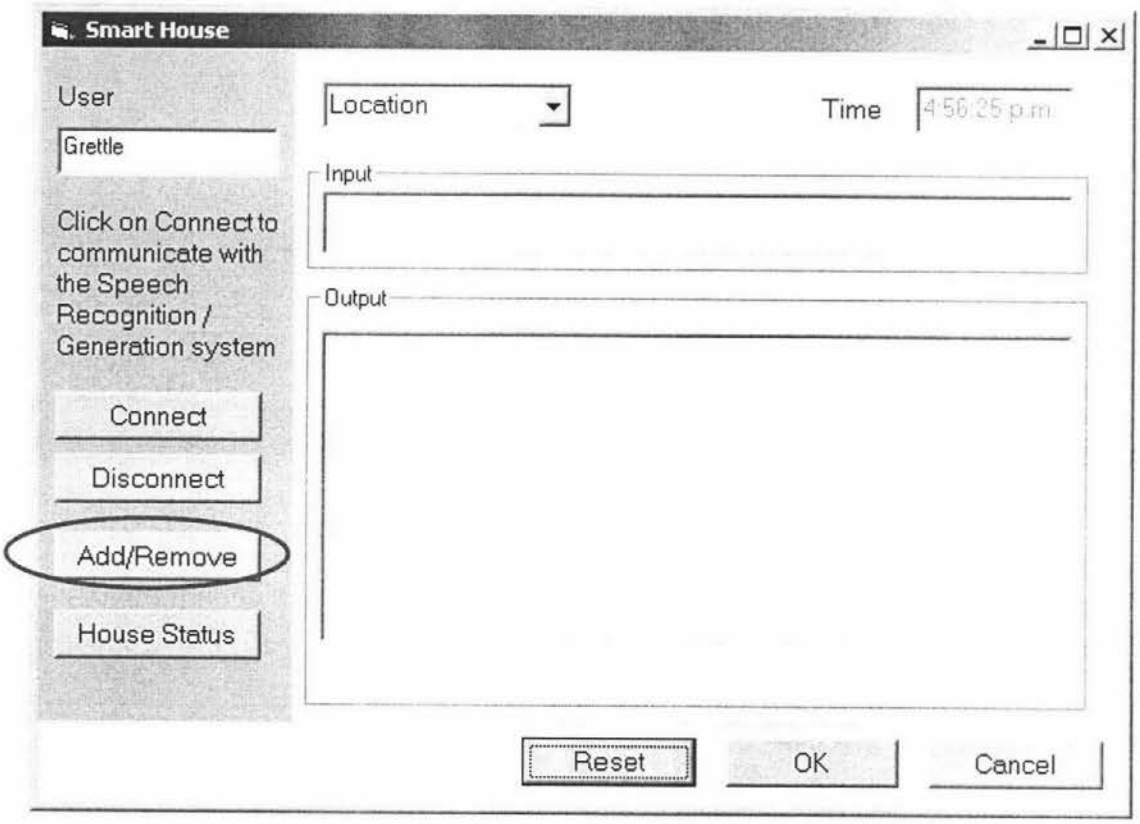


Figure B-1 The Management System GUI

When pressed, another window opens, which allows the user to choose which operation, they wish to perform (See Figure B-2). The first two belong to the Add/Remove Location/Device Wizard and the following wizards are the Compound Command, Automation and Command Dependency wizards.

Figure B-2 Choice of operations

The user is only allowed to perform one operation at a time. Selecting a specific choice disables all the other choices. This was done as a safety precaution to keep the updating of the house database tidy.

Once the choice has been selected, pressing the Next button takes the user to the appropriate window to do the selected operation. In this case, the user will be adding a microwave device into the house (see Figure B-3).

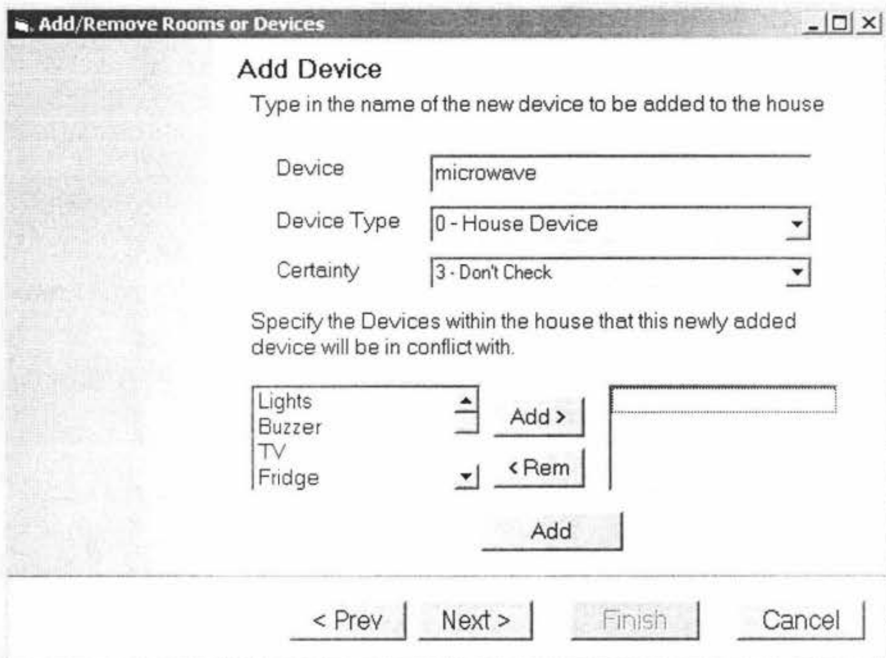


Figure B-3 Add Device Window

The user will specify the name of the device (in this case, microwave) and choose the device type. There are two choices of device type: house or sensor device. A house device will be devices which may be turned on and off at will. These devices will be addressable through speech. Sensor devices, on the other hand, will not be accessible in the same way. These will be devices such as smoke alarms or fall sensors which, when triggered, may indicate that the user may be in need of help, or there is something wrong in the house. When a sensor is triggered, the Management System will alert other people within the house that a sensor has been set off.

Certainty refers to double checking a command when it is received from the user. Some commands that may be received will need to be re-checked to confirm that the user does want to implement it. An example would be "Turn the kitchen fridge off." In cases such as this, the house will ask the user if they really want to implement the command before carrying on. The choices in command certainty are given in Table B-1.

Certainty	Meaning
0	Check before turning on AND off
1	Check before turning the device ON
2	Check before turning the device OFF
3	Don't check.

Table B-1 Command Certainty

The next action is to specify which other existing devices within the home will be in conflict with this newly added device. For example, if a radio is added to the house, it may be in conflict with the buzzer. In the case of the microwave, there will be no other devices to clash with, so the user may leave the conflict section blank.

A device may also be permanently removed from the house through the window shown in Figure B-4 below. The list of all the devices contained within the house is given, so the user may easily choose the device they wish to permanently remove and at the press of a button, remove it completely from the Smart House.

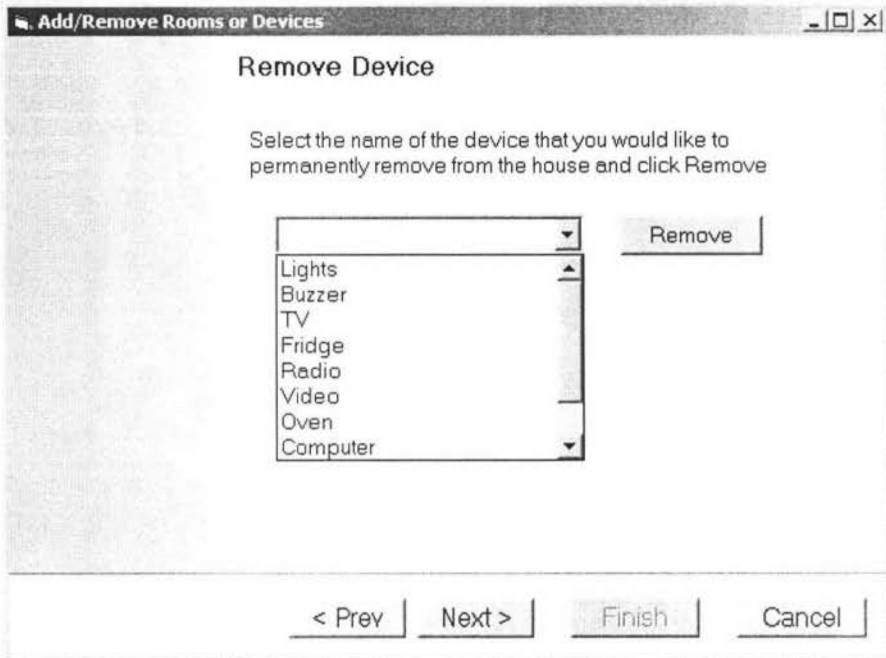


Figure B-4 Permanent Device Removal

Once the device has been added to the house, the device will need to be placed in a particular location. The management system will need to know where it is located. For example, a new device, radio, will be placed in the kitchen (see Figure B-5).

This process will also be responsible for the placement of multiple devices within the house. For example, there may be more than one radio in the house. It should not be necessary for the second radio to have a unique name, as long as both the radios are not located in the same place. However, this process is limited. Only one device may be added to a location at a time.

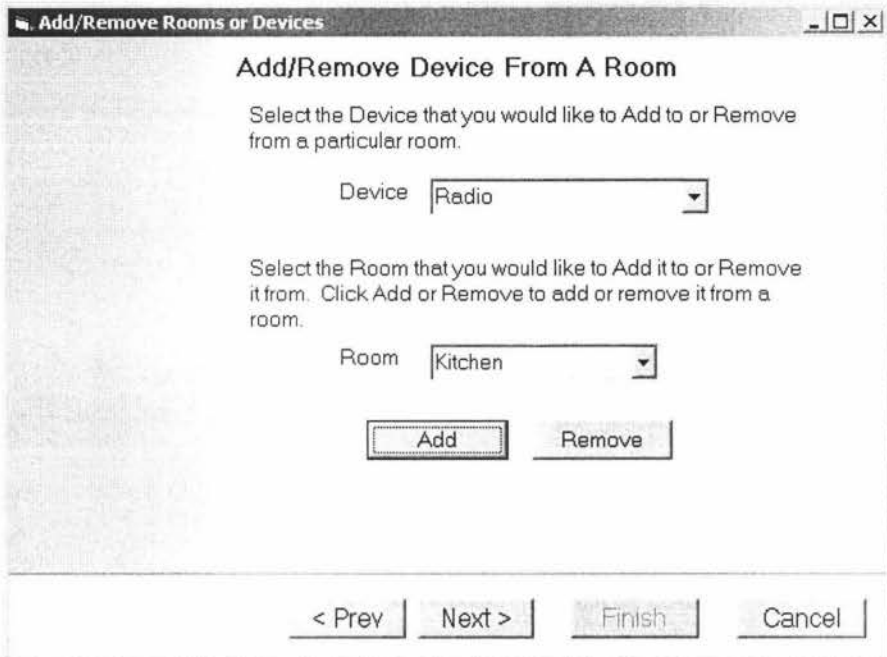


Figure B-5 Device Addition to a Location

The same window is used for removing a device from a room. Again, in the case of multiple devices of the same kind within the home, there will be cases when one device will be removed from a room, but the other devices stay where they are. In such cases, it is not right to remove the device permanently from the house. This is the step that provides a way out for such times.

The last window in the wizard is the Summary (Figure B-6). This is a way for the user to check the changes that they wish to implement before the database is updated. This gives them a chance to go back and change things to the way they want them if they are not happy before the change is permanently stored into the Smart House database.

In it is shown a summary of the changes that the user wishes to add to the Smart House database. In this case, this change is the addition of a new device to the Smart House called microwave and the addition of a radio to the kitchen.

Pressing the Finish button will complete the procedure and update the house database. The management system is now aware of the new microwave device and the existence of the radio in the kitchen.

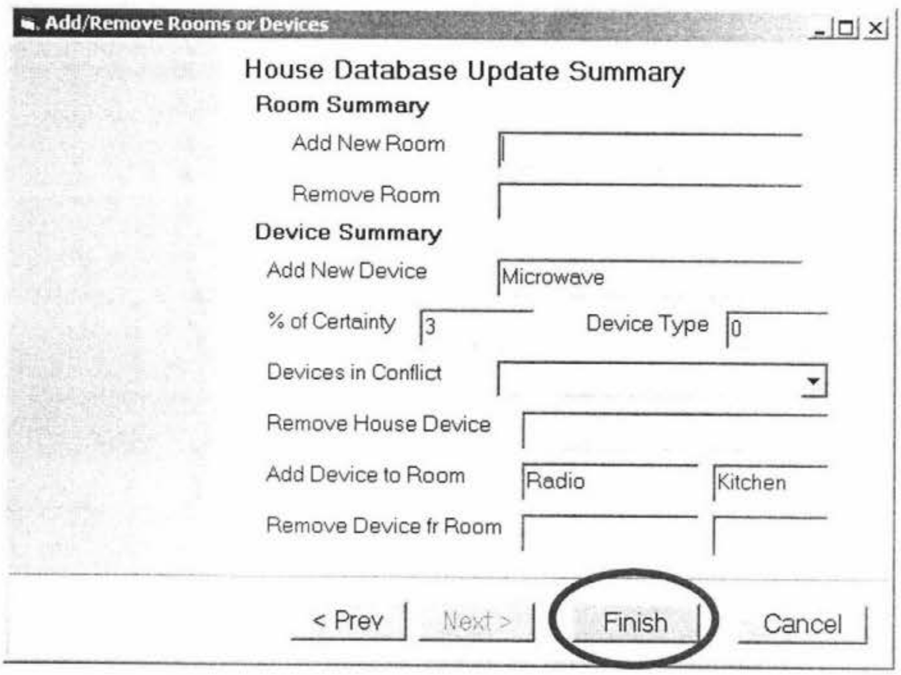


Figure B-6 Wizard Summary

The other three wizards in the Smart House Management System follow the same procedure when updating or changing the Smart House database.