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Smart home automation using AI and XMPP protocol

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ABSTRACT

Home automation is on the horizon. It is an emerging technology and also a need of today. From the last decade, a number of standards have been defined for home appliances. The main objectives of home automation are controlling, management and coordination of home appliances in a comfortable, effective and secure way. On the other hand, Artificial Intelligence is evolving as a technology for developing automatic systems that can perceive the environment, learn from the environment, and can make a decision using case-based reasoning. Using Vision capability, knowledge-based, learning an ability, decision making and reasoning the AI provides a better solution for almost all automatic systems. In this paper, we will see the types of home automation systems and then see how this system can utilize the AI tools so as to increase the effectiveness, powerfulness etc.

Keywords— Home automation, Artificial intelligence, Knowledgebase systems, Secure home

1. INTRODUCTION

One definition of an automated and networked home is “An automated and networked home is one in which every appliance can be remotely managed from anywhere on the Internet with a simple Web browser”. The general goal of the automatic-home movement is to use networking technology to integrate the devices, appliances, and services found in homes so that the entire domestic living space can be controlled centrally or remotely.

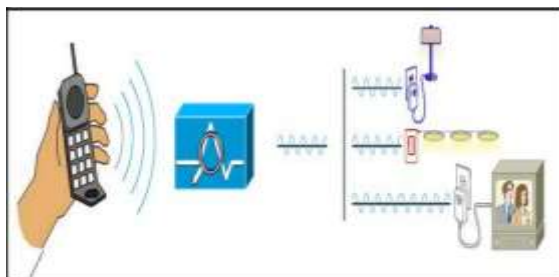


Fig. 1: Already available extra wiring for the device controlling in smart infrastructure

Home wiring, the advance home developers are installing, typically adds several thousand dollars to the cost of a new

home, and it is usually Ethernet or coaxial cable or some combination of both with other technologies in the mix. The network is being designed to make the possible remote operation of appliances connected to the network.

1.1 Services provided by the home automation system

A home automation system provides a large number of services which can broadly be classified into the following four categories:

- Efficient management of appliances
- Remote controlling of appliances
- Efficient utilization of home resources
- Enhancing home security

Comfortable management includes automatic adjustment of AC (air conditioning) setting, fan regulation setting etc. Remote controlling services include accessing devices from a remote location and setting them ON/OFF. Efficient utilization includes running the home appliances at their optimal setting (setting at which we get the required output at minimum cost). The last category of service includes all those services which are used for securing the home environment.

In this paper, we will see the implementation of all these categories of services one by one and will see the application of AI techniques in implementation.

In Section-II we will see AI techniques & Knowledge-based system very briefly. Section-III covers the issues concerned with home automation. In Section-IV, V, VI, and VII we have discussed the detailed implementation of systems for implementing the home automation system developed for services listed here.

2. ARTIFICIAL INTELLIGENCE AND KNOWLEDGE-BASED SYSTEMS (KBS)

AI is the collection of powerful and rigorous programming techniques studying the nature of intelligence by building computer systems and the application of these concepts in solving real-world problems. The growth in the areas of AI has been increased significantly from the last decade. There exist a number of AI tools that make an automation system more sophisticated but here we will discuss the knowledge-based systems only as it is used frequently.

2.1 Knowledge-Based System

A Knowledge-based system (KBS) is an AI-based system that contains a significant amount of knowledge in an explicit, declarative form. The area of KBS development has matured over the past two decades. It started with first-generation expert systems with a single flat knowledge base and a general reasoning engine, typically built in a rapid-prototyping fashion. This has now been replaced by methodological approaches that have many similarities with general software engineering practice. KBS development is best seen as software engineering for a particular class of application problems. These applications problems typically require some form of reasoning to produce the required results. In current business practice, there is an increasing need for such systems, due to the progression of information technology in our daily work. For home automation, knowledge-based systems can provide the base to store the user preferences and managing the home appliances accordingly.

3. PRELIMINARIES

If we talk home automation, there are following three main issues:

- How to connect home appliances and apparatus
- How to make two home appliances to communicate with each other
- How to control and manage home appliances

As far as the first issue is concerned, a number of standards have been developed for interconnecting the home devices and apparatus in a network so as to make their management much easier and comfortable. Summarized from [9]-[14] a following are the main networking technologies used for connecting devices in the home environment:

- Direct cable connection
- Bluetooth Connection
- Phone Line
- Ethernet
- Radio (Free) Network
- AC Network

So we can connect the entire home devices by selecting any of the above-mentioned network technologies.

Apart from connecting devices, the second issue regarding the home automation is “how to make two devices communicate with each other”. For handling this issue a number of standards have been developed. Summarized from the beginning, there are following leading communication technologies in the home environment:

- UPnP (Universal Plug and Play) devices
- X-10 based devices
- Infrared devices
- Bluetooth Devices
- IP based devices

All these technologies are well matured and have well-settled standards. But, in this paper, we will skip it as this is not of our concern.

Now we move toward third issue i.e. “how to manage and control the home appliances” which is the issue we are concerned with. This issue can be handled in two ways. First, by using traditional digital and microprocessor-based systems as discussed in [13], [17], and [19]. The second method for this is by using the sophisticated processing of artificially intelligent agents.

If we consider the first choice, then it is somewhat more common but at the cost of time efficiency as well as feature limitations. On the other hand, the AI-based technique provides more efficient and featured services like easy video and audio processing, easy reasoning etc.

In this paper, we will concentrate on the third issue of home automation that is management of home appliances and particularly, AI-based home appliance controlling and management.

4. MANAGING HOME APPLIANCES FOR COMFORTABILITY

As discussed in Section-I, the first service that a user expects from the home automation system is the comfortable management of devices.

Example the regulator setting of AC depends upon the temperature of the room. As the temperature increases, the AC regulation rating (hence cooling rate) also need to be increased.

Such class of services is simplest of all types’ services and has the structure as shown in figure 2.

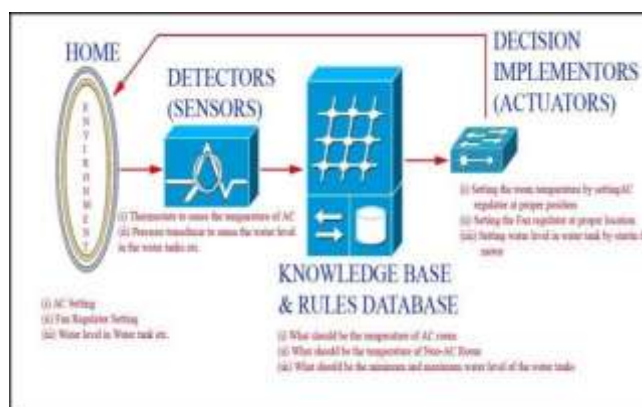


Fig. 2: The typical structure of home automation system designed for user comfortability

Some features of such systems are:

- These are closed loop systems
- Sensors are transducers and another mechanism for sensing the current proximity condition e.g. sensing the room temperature
- Actuators are simply the mechanism to change the environment according to the control signals received from the knowledge base.
- Knowledgebase (KB) is the centralized part of the system and is the main part to discuss here.

This KB system can be implemented by using simple digital circuitry as discussed in [17] or using microprocessor systems as discussed in [11] but both suffer from the problem of manual setting. In both, the system user has to decide and change the threshold setting whenever there is a change in the environment.

Example in summer AC is used to down the temperature while in winter the same are used to up the temperature. So, the user has to change the setting when the season changes because the system can't learn from its experience.

But using the KB system having learning capability, the system can adjust the threshold setting as it gets the experience in its environment. For this system, we need a KB system that can

learn from the experience that “what is comfortable temperature” for the home users and can adjust the setting of AC and fan regulator accordingly.

5. CONTROLLING HOME APPLIANCES FROM REMOTE LOCATION

The second feature provided by the home automation system is the remote access to devices and their management.

Example suppose you are going back to your home and it will take 20 minutes to reach your home. Now, you want to on

You AC so that when you reach your home you find your home with a comfortable temperature. In such a scenario you need to access your home appliances and also to control them from a remote location.

The typical structure of home automation system for this type of services is given in figure 3.

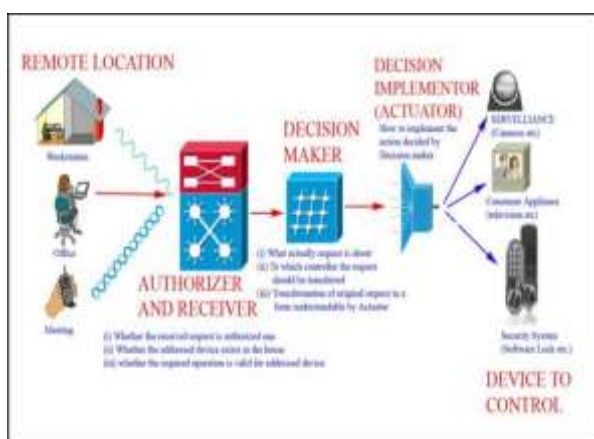


Fig. 3: The typical structure of home automation system designed for remote management of home devices

Following are the main points to consider this class of systems:

- Authorizer and Receiver is an electronic system capable to receive the control signal. As discussed in Section-II there exist a number of such systems any of them can be used for this purpose. One important thing about this system is that it requires some authorization mechanism to ensure that the request is authorized one. For this purpose, we can use some cryptographic techniques to encode and decode the request so that only authorized user can access the network.
- The decision maker system is an AI-based agent that can decide what action should be taken in response to a received query.

E.g. suppose user just put the query that the room temperature should be x0c. Now, this is the Decision Maker that will identify from its experience that the AC will maintain this temperature. And then it will determine the setting of the AC regulator corresponding to this particular temperature.

Of course, the same system can be implemented by some electronic circuitry but that will be more complex, less flexible and less featured as compared to this learning based (case-based) AI agent system.

- The third component of this system i.e. Actuator is similar to the action implementer in the previous system. So, we will not discuss anything about this here.

6. EFFICIENT UTILIZATION OF HOME APPLIANCES

This application of the home automation system is not as common as discussed two applications. But, on the other hand, if the automation system is applied in the industrial environment then it becomes the more prominent and beneficial feature of the automation system.

E.g. Suppose the AC of your office (or room) is ON but you are not in your room from last three hours. Then why the AC is still ON? This is just wastage of power. As said already, this power wastage is not much in case of home appliances but in industries, power saving is one of the major cost-cutting factors. So, for implementing this we need a system that can OFF the AC if it found that there is no person from the last significant time. We said here the word significant as the exact time can't be determined and depends upon the scenario (like for bedroom the AC should down OFF if there is no person for one hour while in the waiting room the AC should go down when there is no person from last two hours).

In such a scenario, we are supposed to have some automation system that can continuously pole the environment and can decide the appropriate action whenever needed. These systems should fast enough for responsiveness and effectiveness.

Figure 4 shows the typical structure of the system that can provide this class of services. The working of the components of the system is as follows:

The status poller continuously senses the environment conditions and forwards the sensed condition-factors to the analyzer and knowledge-based database. The Analyzer receives the current environmental condition from poller and with the help of the knowledge base database, it analyses the variation in the environment. Now, depending upon the variation Analyzer gives the instruction to Actuator.

Again here the actuator is similar to the actuator discussed in previous sections.

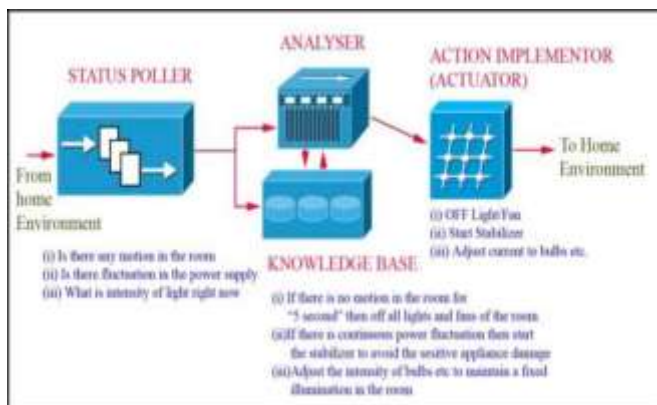


Fig. 4. The typical structure of a home automation system designed for optimizing resource utilization.

The major differentiating factor of this system from previously discussed systems is that this is sequential while previous one was atomic, because, in this system, the action to be taken depends upon the present and previous environmental conditions.

7. SECURE HOMES

The last major application provided by the home automation system is to provide home security. This is the most complex home automation system and the structure is given in figure 5.

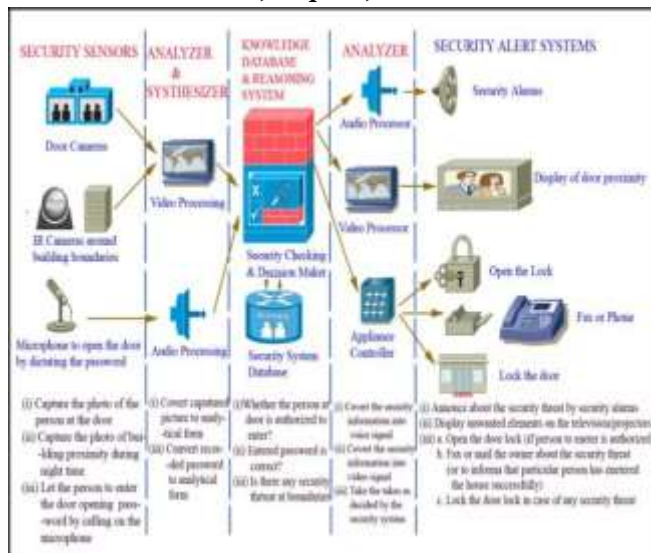


Fig. 5: The typical structure of the AI-based secure home

The description of how the system works is as follows:

- Security sensors sense the environment for a security threat.
- The analyzer and synthesizer analyses the data received from the sensors and filter out any security threat. If it found any security threat, then it sends the sufficient information to reasoning system.
- The Reasoning system applies the reasoning for detecting whether the security threat is really a threat, if yes then it fires the security alert system for alerting the user about this security threat by the analyzer.
- This analyzer is the same as used at the second stage but opposite in nature. The previous converts the physical information into digital form while later one converts the digital information back to physical form to alert the user.

8. APPLICATION OF AI IN HOME AUTOMATION

So in Section-4, 5, 6, and 7 we have discussed the home automation taken one class of services at the time. Now, in this Section, we will concentrate on the application of AI in all the four forms of home automation system one by one.

8.1 Use of AI in Comfortable Systems

In these systems the application of AI is limited as most of the part can be easily implemented using some electronic circuitry. Here the only part where the AI is effective is the knowledge based database which should be learnable (as discussed previously) for system to be truly comfortable. Since AI tools are little bit costly it will increase the cost of the system but will make the system more comfortable, flexible, easy updatable etc.

8.2 Use of AI in remote controlling systems

In these systems AI can be applied in the *authorizer* as well *decision maker* stage. Applying AI at the authorizer will increase the responsiveness and security and is more applicable when the environment under consideration is an industry where security is a major concern (e.g. Banks). On the other hand, Decision making part can utilize the case based reasoning of AI for effective and efficient management as it has to decide that which of the target device is corresponding to this particular instruction.

8.3 Use of AI in optimizing the resource performance

In this system, AI can be used to implement knowledge base as discuss for previous systems and for Analyzer as it makes it more efficient in deciding the particular action. Moreover, if the analyzer is learnable from its experience then it will make the system more optimized.

8.4 Use of AI in secure systems

The biggest use of AI is in these systems. Here we can apply the following tools of AI for various applications:

- Video Processing for security threat analysis.
- Image Processing for security threat analysis.
- Audio processing for security threat analysis.
- Knowledge base system for Security system database.
- Case-based reasoning for analyzer and synthesizer.
- Decision making in security checking and decision making.

So these systems use the AI exhaustibly. Presently, even though, different technologies are used for implementing these systems but in the near future, AI will be the only implementation technique behind these systems as it is proved to be more sophisticated and effective tool for listed applications.

9. CONCLUSION

In this paper, we started our discussion with the home automation system by defining four major applications of these systems which are comfortability, remote control, optimal resource utilization, and security. After that, we see the detailed structure of home automation for implementing these services one by one explaining the working of each system and the use of heuristic-based tools in these systems. At the last, we discuss the applications of AI tools in all four types of home automation systems.

From this discussion, it is clear that AI is emerging as a very useful and applicable technology for Home automation. On the other hand, home automation systems provide AI with a vast range of Application.

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