

An Intelligent Agent based Novel Framework for Building Management System using Artificial Intelligence

Shabbab A Alhammadi

King Fahd Security College, Riyadh, Saudi Arabia,

Abstract

This paper proposes novel framework for designing of an Artificial Intelligence based Building Management System (AIBMS) with a special emphasis on intelligent agent based systems, neural networks, fuzzy logic, and genetic algorithms. The proposed methodology has the capability to perform user preferences intelligently and more adaptively which are focused on improving the comfort of user, safety and enhanced energy performance especially in the Internet of Things IoT based buildings. The proposed framework of AIBMS consists of subsystems of identifying the smart user, internal and external environment observation subsystems, an artificial intelligent decision making subsystem and also a universal infrared based communication system. Furthermore, the proposed framework is connected by a trained intelligent agent for monitoring the whole architecture. The entire system is quick installable, flexible plug and play concept for most of the residential and buildings automation applications without any change in the present infrastructure.

Key words:

Artificial Intelligence, Internet of Things (IoT), Building maintenance, Automation, Agent based Systems, Infrastructure.

1. Introduction

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction. Big Data and AI are interlinked. Data is being generated at an exponential rate. Analyzing these large sets of structured and unstructured data requires self-learning computers to recognize patterns using concepts like 'deep-learning', 'machine-learning' and 'neural networks'. Big data and AI go hand-in-hand, one will not be useful without the other and the two reinforce each other. A common use case of AI is to take significant amounts of data and distill the key inputs that a user can act on. Advanced analytics like artificial intelligence and machine learning present significant opportunities to reduce operating costs and improve outcomes for occupants. Building Management Systems (BMS) are mostly adapted in industries and large scale buildings at present and it has rarely adapted in domestic (Household) environment and existing buildings due to

flexibility issues, reliability limitations, complexities and high costs.

AI based sensors are an important derivative of semiconductor devices, initially used in automotive applications (such as airbags), and later by telecommunications and consumer products like smartphones.

Now, they stand to change the course of Internet of Things (IoT) by increasing the intelligence of sensor solutions used in:

- AI based systems for Early problem detection
- AI based systems for Building management
- AI based systems for calculating air quality
- AI based systems for calculating the vibration

In a building, energy management is a common use case. Actual energy consumption data can be compared to weather, occupancy, and other factors. AI solutions can then determine the dependencies between weather and energy. When temperatures rise by certain degrees, it's likely that energy demand will rise by its proportional kilowatts, for example. A model is built to represent these dependencies. Then, moving forward, actual or future weather data or predictions can be used to forecast energy use. More data means that a more accurate model is built, which improves the accuracy of the predictions.

The main feature in following BMS researches were based on static automation structures combining wireless remote control & monitoring systems through various communication techniques and Smart devices [3, 4, 5, 6]. Smart home implementation devices were developed using artificial intelligence focusing on creating a system which are capable of controlling home appliances based on direct and indirect users' guidelines [7]. Arduino Uno open source hardware platform based wireless home automation system was developed to control home appliances in wireless mode [8]. Voice integrated home automation security systems were developed through telephone line to control home appliances [6]. Research adapting to resident preferences in smart environments was introduced to adaptive smart home system that discovers and adapts to changes in the resident's preferences in order to generate satisfactory automation policies [9]. Atmel AVR microcontroller based temperature Monitoring and Controlling system was

introduced by using ZigBee in MATLAB [3] as a low cost wireless remote system. Internet interfaced and controlled personal computer based home automation systems were introduced with Voice control [10]. Speech recognition based Interactive home automation systems were developed to analyze, extract and characterize information from the command uttered by the human entity [11]. Smart home security systems were introduced using ANFIS [12]. Multi-user preferences model and service provision systems were introduced to learn multiple users' preferences and relationships among users as well as dependency between service and sensor observations [13]. The absence in the development of mini scale Self-controlling intelligent systems, the necessity of infrastructure modifications and the flexibility limitation in existing installations are the major barriers for using BAS in general residential applications and existing buildings. To address those, it is crucial to develop an Artificial Intelligent based Smart Building Automation Controller and this project is an endeavor towards an effective design and development of a smart building automation controller for energy efficiency improvements in existing buildings.

Even though the development of AI tools for BMS systems is more than two decades old, the performance of BMS systems controlled by AI tools has been unsatisfactory overall. Their energy savings, energy consumption, precision of heating and cooling based on load forecasting, and the predictive ability of the predictive controls, will be discussed in Section 4. Based on [5], from 1976 to 2014, the average energy savings of BMS systems by applying the scheduling control technique reached 14.07%. The maximum energy savings of BMS systems was 46.9% after applying smart sensors for smart air conditioners in 2014 [6]. However, from 1997 to 2018, the average energy savings of BMS systems using AI tools reached 14.02%. The maximum energy savings when applying Case-Based Reasoning (CBR) controlling tools for the BMS systems in an office building was only 41% in 2014. Therefore, the energy savings of BMS systems after applying AI tools was less than that of traditional energy management system controlling techniques.

2. Motivation of the Proposed Methodology

Challenges faced by the traditional BMS techniques are as follows:

- Various methods were proposed earlier for improving the security and safety of Building management systems. Majority of the BMS systems are still in process, but with poor accuracy.
- Methods based on Artificial Intelligence (AI)

were used earlier for improving the accuracy of the BMS System. Though, it was highly scalable, but the performance was poor in terms of accuracy.

- The methods based on fuzzy systems were proposed later on for the BMS system. The errors were evaluated. The method was more efficient and robust, but resulted in poor accuracy.

3. Proposed Framework:

The proposed agent based intelligent examination system consists of three phases and four modules, which are: 1) AI based User identification system; 2) AI based decision making controller; 3) Fuzzy logic based control framework; 4) Artificial Intelligence based User Preference database. The first phase is the AI based user identification and management. In this phase, users are the one who are already registered to get access to the buildings. The second phase is the AI based decision making controller. The third phase is the Fuzzy logic based control framework. This system was designed by using intelligent agent based methods, which are applied logically to get the proposed framework. Schematic Representation of the proposed methodology is shown in Figure 1

3.1. Intelligent Agents

An agent is an autonomous computer based system which is flexible in nature that can receive input and output from the environment. There are many other advantages of the agents. For example, agents can be given knowledge to do specific task, collaborate with each other, and extendible which are very useful when developing secure systems. An agent can represent a user and do tasks on behalf of the user. Moreover, agent systems are extendible in nature. A new agent can be created instantly and added to the existing system in order to represent a new user such as a network monitoring agent, without changing the entire system. The Architecture of an agent based system is shown in figure 1.

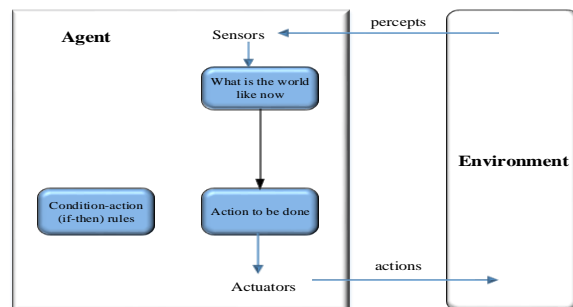


Fig. 1 Architecture of an agent based system

3.2. Artificial Intelligence

AI is the ability to adapt the system to the dynamic environments. It is the simulation of human intelligence processes by machines, especially in the computer systems. These processes include learning which is the acquisition of information and rules for using the information, logical reasoning which uses the set of rules to reach approximate or definite conclusions and self-correction. Particular applications of AI include expert systems, speech recognition and machine vision.

3.2.1. Artificial Intelligent Decision Making Controller

A controller works by using the difference between the actual value of the state of the system and the desired value of the state to obtain the error of the system. This value can be then used to make actuator adjustments. An Artificial Intelligent Decision Making Controller (AIDMC) is an intelligent based system which is powered by a 700MHz single-core ARM1176JZF-S CPU, which is a single board computer. It is an inexpensive low power consuming open source. A Fuzzy Logic controller works by using multi-valued logic, and “If-Then” statements. The algorithm for intelligent decision making is as follows
Algorithm for intelligent decision making

```
#Algorithm for intelligent decision making #
for every user D in the Decision_Set
  if( Action ∈ Action_Set ) and
    Perform= <Decision, Mode, Action>
    then,
      Decision made and performed;
    else
      Invalid Action;
  End if,
End for
```

4. Proposed Architecture

AIBMS is an AI based pre-programmable system for multiple users. It provides features to individual user preferences for various services at diverse situations. It applies intelligent agent based methods for providing control over various parameters such as maintaining the indoor air temperature, maintaining indoor air humidity level, indoor illumination level, speed of ventilation fan, sound level of audio setup, program of television set, position of Electrically operated curtain, water temperature of shower bath etc.

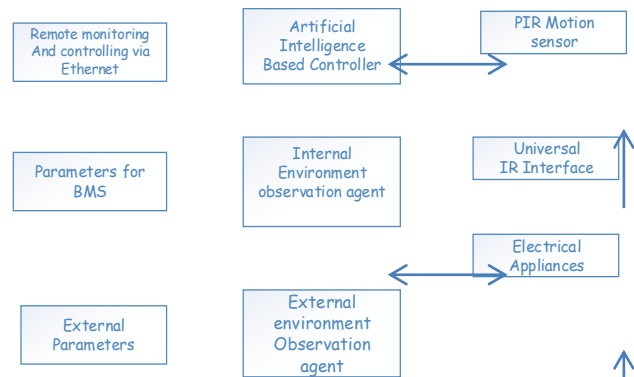


Fig. 2 Layout of the proposed system

At present many types of open source mini computer hardware platforms are available [16, 17]. Uses of single board computers instead of personal computers (PC) for building automation systems are more beneficial. Raspberry Pi model B from Raspberry Pi Foundation is a power-full single board computer which is having 700 MHz single-core ARM1176JZF-S CPU based on Broadcom BCM2835 system on a chip architecture with 512 MB of inbuilt internal random access memory shown in Fig. 3. Pre-installed Linux based operating system on SD card (Secure Digital) operates in the computer platform. Further Raspberry Pi model B comes with USB 2.0 dual ports, single 15-pin MIPI camera interface, HDMI multimedia port, Analog audio port, 100 Mbit/s Ethernet port and 8 General purpose Input Output which is having interface of UART (Universal asynchronous receiver/transmitter), I²C bus (Inter-Integrated Circuit), SPI bus (Serial Peripheral Interface), I²S audio (Inter-IC Sound). Equipped with these specifications Raspberry Pi model B computer runs with 5V DC power supply with a maximum power consumption of 3.5W.

In the stage of working, the proposed framework identifies the users in application area E.g. users, designers, engineers etc. Then user interface agent identifies the users and categorizes them to priority levels which are pre-defined. It also identifies the preferences for individual users from the inbuilt internal data base. Based on the priority of user preferences, the proposed methodology selects the proper service configurations automatically and communicates to respective appliances. The AI based system also senses the real-time internal and external climatic conditions and physical conditions such as temperatures, Humidity, illumination, Noise levels and motion detection. Based on these observations, the AI based controller changes the automation guide lines for maximum energy enhancement and optimum user comfort. Integration of those features avoids unnecessary energy usages and provides lighting and other services to be more

energy efficient, comfortable and safety focused environment.

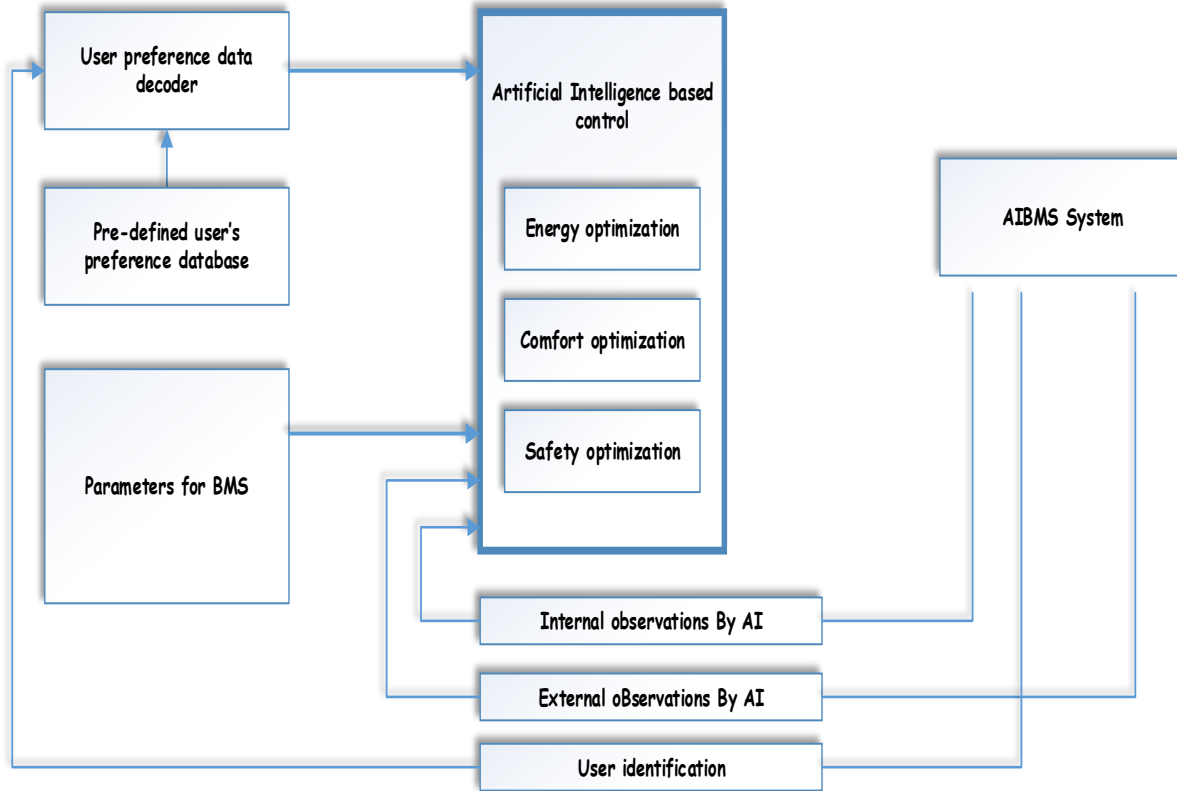


Figure 3. Schematic Representation of the proposed methodology

The main advantage of the proposed intelligent agent based methodology is the usage of ultra-low power consumption embedded single board computer. This results in more energy efficient and precise automation process compared to the use of personal computer based automation systems.

4.1. Fuzzy logic based control framework

The proposed AIBMS is introduced as an intelligent device with wider information collecting system and multiple appliances control interface. Based on these multi information such as climatic conditions, multiple user preferences and time varying inputs the decision making process is complex compared to the Single Input Single Output (SISO) control system model [14, 15]. Fuzzy logic is a problem-solving control technique which is can be implementing on a microprocessor. It provides decisions for multiple control nodes based on multiple inputs. The control model of AIBMS is based on a fuzzy logic controlled closed loop control system as shown in Fig. 3. Observed information from sensor network and externally entered or pre-programmable time varying parameters are

the inputs of the system. The fuzzy model of AIBSBAC continuously executes these multiple inputs for the optimum solutions.

4.2. Agent based User Identification System

The intelligent agent based user identification system is based on agent based module which is connected with a single board computer. This module continuously searches for another agent based systems in application range. If any agent based system is connected within the identification range, CPU will identify the device and verify with the pre-defined identification keys to identify the specific users. Internally Integrated PIR motion sensors are used for further confirmation of user's location. Algorithm for user identification

```

#Algorithm for User Authentication#
for every user U in the User_Set
  if( User ∈ User_Set ) and
    Access = <User, Mode, Action>
    then,
      Access Granted;
  
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else
  Invalid User;
End if,
End for
    
```

4.3. Prototype Development

The prototype of the proposed system is shown in Fig. 4. Various sensors such as the Temperature sensor, Motion sensor Humidity sensor, Resistors, etc. are connected in the arduino board. Future work of this research includes testing and verification of the proposed system in a real time scenario.

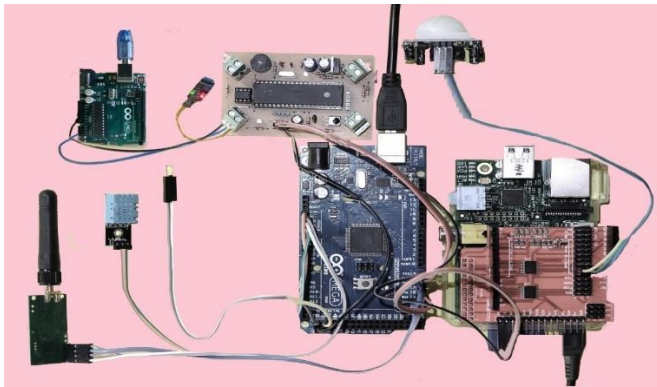


Figure 4 Hardware Implementation of the proposed system

4.3. Artificial Intelligence based User Preference database

The intelligent agent used in this methodology stores and maintains a database for the user and their preferred data for illumination and living temperature. When the user is identified by the system, the AI based agent defines the user preferred values so that it can be optimal for the users. The proposed system will decide the best temperature settings for the user based on the identified users and corresponding user preferences as shown in Table 1.

Table 1: Database of User Preferences

User No	Mode	Category	Values
User 1	Idle	Temperature	22
User 2	Working	Temperature	20
User 3	Presentation	Illumination Level	23
User 4	General	Heat	41
User 5	Night	Moderate heat	33

4.4. Findings of this Research

- The proposed methodology based on AI based systems can provide effective services for Building management.
- This framework is controlled by the intelligent AI based systems which is considered a major part

of the proposed system.

- Various types of hardware’s, intelligent agent and fuzzy logic make systems easy-to-use, effective communication between users and the proposed system

The proposed system can be connected through a website or a mobile based application so that it will be easy to handle for the users.

5. Conclusion and Future Enhancements

Many researchers have been done earlier in the building management systems as shown in the literature review section. Most of the methods are based on remote monitoring and controlling of home appliances, rather than focusing on efficient energy utilization aspects. In this research the proposed system is designed based on the combination if AI and fuzzy logic as a plug and play device to automate commercial buildings and residential buildings. Automation of the proposed is based on AI with smart user identifications and observations of environment conditions as inputs to achieve improvement of user comfort and maximum saving of energy. In development of the proposed system AI based system creates wireless communication links between the hardware and electrical appliances without any manual intervention.

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