Intelligent HVAC systems for smart modern building

Harith M. Ali [1], Rashid M Aldaiyat [2]

[1] Mechanical Department, Engineering College, University of Anbar, Ramadi, Al-Anbar, Iraq
[2] Ministry of Public Works (MPW), Kuwait

ABSTRACT

The modern smart building offers software solution and sensing the surrounding environment. However, this will be allowed management easily for leaders that are providing better control and optimize heating, ventilation, and air conditioning (HVAC) ،as well as this is consider from the important topics in mechanical engineering modern application. In this paper, a new intelligent HVAC system is proposed for modern smart building. The proposed system is heavily based on one of the most efficient tools of artificial intelligence which is a support vector machine. This technique will be depended on the data set to detect the HVAC system for any building. In this case, it will save time as well as it has the ability to provide a suitable system without any delay. The HVAC system that proposed in this paper is very important issues in design modern building. According to for training and testing phases for the proposed system, we can easily notice efficiency and effectiveness for the cooling and heating systems.

Keywords:	HVAC building automation, Intelligent control of HAVC systems, HVAC Systems of Smart Building, Building management system.

Corresponding Author:

Harith M. Ali
Mechanical Department, Engineering
University of Anbar
Anbar, Iraq
eng.harith85@uoanbar.edu.iq

1. Introduction

In general, a smart building is foreseeable to be modified with alteration of occupancy requirements and also the advance of computer technology and information technology. In-office business systems, the rapid updating of microcomputer technology has dislodged the untampered implementation of computer technology. The liberalization and development of telecommunication technology have, like, the efficiency of office business systems and fostered internationalization [1]. Smart buildings are considered one of the most important modern trends in civil engineering. The persons are spent most of their time in a different building (indoor) and they aim to provide support, safety and comfort for their activities at minimum requirements of the expenses. The coinciding of computation and communication capabilities in various buildings and their subsystems is providing by the profound integration of the internet and cyber-physical technologies within these buildings and their subsystems. These technologies present tools to obtain the buildings elaborate and reality intelligent control methods [2]. In recent years, the building automation system had acquired a great amount of importance. Many studies results have been improved and the previous methods use centralized control in pneumatic actuators, the modified version of building automation system based on control distributed with direct digital equipment. More recently, these systems have depended on the artificial intelligence techniques and the network, where a hierarchical database was often utilized to detect and monitor facility malfunctioning [3], [4]. Because of the rapid growth in the information system and network technology, the working and living ways have been influenced directly and indirectly. The intelligent buildings have gradually prolonged from office building automation to residential building automation because the traditional residential buildings became not able to accommodate the impact that is made by the developing technology. The concept of smart houses in communities will be the future trend of buildings. In this paper, a prediction system is proposed for modern

build to establish smart heating and cooling systems. This system will help mechanical engineering design HVAC for a modern building. However, the basic structure of this building is shown in Figure 1.
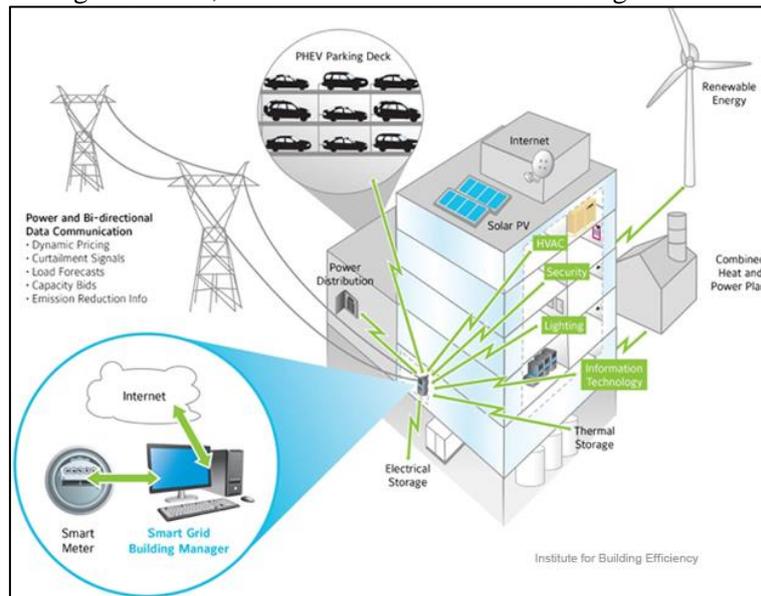

Figure 1. Basic Infrastructure of smart building [5]

This paper is organized as follow: related works present in section 2. The methodology of this system presents in section 3. Finally, the Conclusions presents in section 4.

2. Related works

The feasibility study of HVAC is considered the main concern for engineers. For this, we are working to find an optimal solution for modern building by establishing HVAC systems. This proposed system is heavily based on machine learning. In [6], an automatic control system of air conditioner and intruder detection surveillance system for smart buildings is proposed. The proposed system has the ability to control home temperature and the detection of any unknown person entering the house. In order to improve the efficiency of energy for buildings, a software system perspective is presented in [7]. The results show that the proposed model provides fine-grained building control, maximizing its occupants' comfort and reduces energy consumption. In [5], the main motives and systems of smart buildings are identified and correlated by associating them with the beneficiaries: users, owners, and the environment. The results show eleven motives and eight systems, and these can be improved by more than one motive. The review of recent researches on the models of artificial intelligence technologies in smart buildings out of the concept of demand response programs (DRPs) and building management system (BMS) is presented in [8]. This paper presents a discussion about the open future directions and challenges of research on AI application for smart buildings. The surrogate object-communication model concept with three-layered network architecture is used [9] to develop an intelligent energy management network (IEMN). The results show that the proposed system presents many services such as the distributed intelligent management, analysis online and the ability to processing the data. In [1], a platform to manage intelligent environments behavior is presented. There are several services presented in this work, in particular, the proposed model has the ability to support the needs of the emerging workplace such as hoteling and extemporized group settings representing by users' preferences about their work environments separated from the actual configurations of the physical spaces, they occupied at a given time. Discussion about remote control system over the Internet or the telephone for the new generation air conditioner is presented [10]. The results show that the control of Internet used indoors and the phone control will be in the outdoors or on the car moving. Web-based access and the integration of BMS and FMS are two issues discussed in [11]. The two issues are addressed to integrate control networks by the Internet protocols, infrastructures access BMS remotely via the Internet and to use Internet/Intranet for building management. In [12], by depending on hybrid knowledge, a model for a building management system is presented. The proposed approach enriches management system awareness and presents better visions to the state of the system. In [13], some intelligent buildings technologies and the internet things are studied to design model for buildings intelligent based on the internet of things. This paper presents analysing of the wireless routing protocol for the buildings intelligent

based on the internet of things, wireless networking modes and wireless communication protocol. This technique has opened up new challenges in the field of building. However, our system is distinguished from others by utilising machine learning to predicate heating or cooling systems for a modern building. In addition, this system plays an important role to convert these systems for building from traditional techniques to smart.

3. Methodology

3.1 System overview

The proposed intelligent detection method comprises the main phases, which are presented in Figure 2.
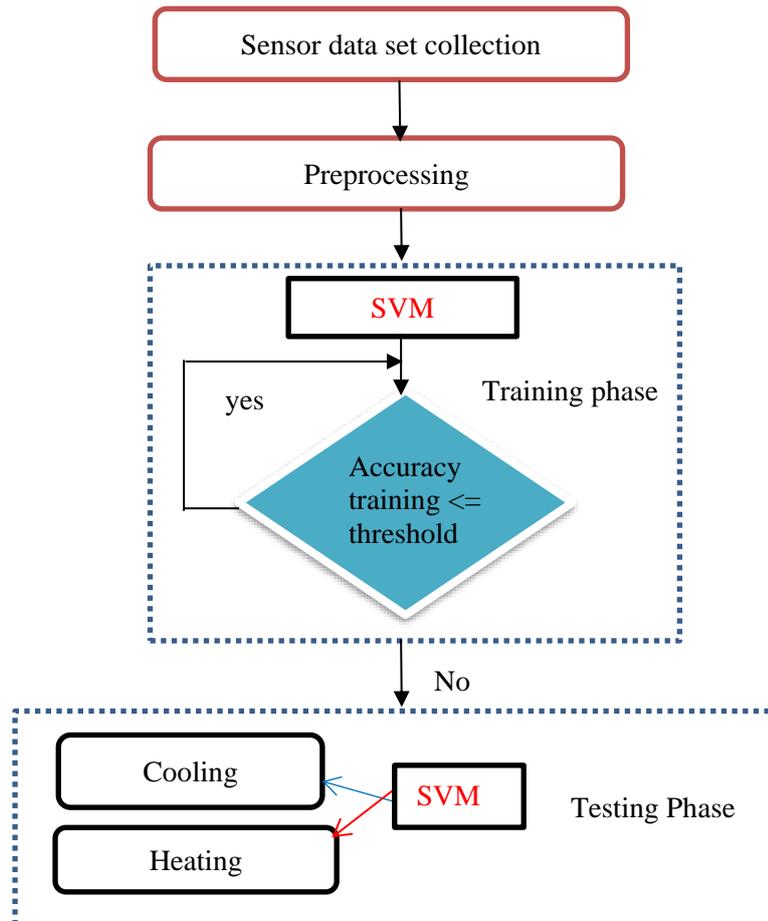

Figure 2. Overall architecture of proposed detection system

After the dataset collected by the sensor, features have involved some letters and symbols must be transferred into numbers to make the performance of the detection system more effective. in this research, SVM is trained with the dataset for generating the intelligent detection system. Moreover, the testing phase is required to detect heating and cooling states.

3.2 Dataset description

Dataset used in this research described in [15] were portion of the data set used. In this system, two sensors commercial MOX (TGS 3870-A04 and SB-500 12, presented by Figaro and FIS) were exposed to mixtures dynamic of humid synthetic air with (15–70% RH) and CO (0–20 ppm) in a gas chamber. According to the manufacturer recommendations, the heater voltage was modified with 0.2–0.9 V range. The sensor output was created at 3.5 Hz and then modified to 100 sample points. Each sensor presents a high dimensional multivariate output with dimension 100.

3.3   Experimental results

 In this paper, results are employed to measure the efficiency of the proposed detection system. In more detail, the results often tests are presented to measure system efficiency.

- Test 1

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

 Ytr= 197, C=186

Table 1. Performance metrics

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	383
Result	(2) Results in the field of (C) cooling read by heating in the field of (Ytr)

- Test 2

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

 Ytr= 194, C=185

Table 2. Performance metrics

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	379
Result	(4) results in the field of (C) cooling, read of heating in the field of (Ytr)

- Test 3

 Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

 Ytr= 198, C=185

Table 3. Performance metrics.

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	383
Result	Result: (All heating is read as heating and all cooling is read as cooling)

- Test 4

 Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

 Ytr= 197, C= 186

Table 4. Performance metrics

Total number of fields	384

errRate	0.0026
conMat = (C +Ytr)	383
Result	(2) results in the field of (C) cooling, read of heating in the field of (Ytr)

• Test 5

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 198, C=185

Table 5. Performance metrics

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	379
Result	All heating is read as heating and all cooling is read as cooling

• Test 6

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 199, C=185

Table 6. Performance metrics

Total number of fields	384
errRate	0
conMat = (C +Ytr)	384
Result	1 result in the field of (C) heating, read by Tareq in the field of (Ytr)

• Test 7

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 198, C=185

Table 7. Performance metrics.

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	383
Result	All heating is considered heating and all cooling is considered cooling

• Test 8

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 198, C= 185

Table 8. Performance metrics.

Total number of fields	384
errRate	0.0026
conMat = (C +Ytr)	383
Result	All heating is considered heating and all cooling is considered cooling

- Test 9

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 199, C= 185

Table 9. Performance metrics.

Total number of fields	384
errRate	0
conMat = (C +Ytr)	384
Result	1 result in the field of (C) heating, read by cooling in the field of (Ytr)

- Test 10

Room temperature (20 Celsius), more than (20 Celsius) gives cooling No. (1) less than or equal to (20 Celsius) give heating No. (2).

Ytr= 198, C= 186

Table 10. Performance metrics.

Total number of fields	384
errRate	0
conMat = (C +Ytr)	384
Result	1 result in the field of (C) cooling read by heating in the field of (Ytr)

- Summary

The results of ten tests are summarized in table 11 as presented below:

Table 11. Summary Results of All Tests.

TEST	errRate	conMat Field:C	conMat Field:Ytr	C+Ytr	Data Reading	Results
TEST 1	0.0026	186	197	383	384	Result: (2 results in the field of (C) cooling read by heating in the Ytr field
TEST 2	0.0026	185	194	379	384	Result: (4 results in the field of (C) cooling, read of heating in the field of (Ytr))
TEST 3	0.0026	185	198	383	384	Result: (All heating is read as heating and all cooling is read as cooling)
TEST 4	0.0026	186	197	383	384	Result: (2 results in the field of (C) cooling, read of heating in the field of (Ytr))

TEST 5	0.0026	185	198	383	384	Result: (All heating is read as heating and all cooling is read as cooling)
TEST 6	0	185	199	384	384	Result: (1 result in the field of (C) heating, read by cooling in the field of (Ytr))
TEST 7	0.0026	185	198	383	384	Result: (All heating is read as heating and all cooling is read as cooling)
TEST 8	0.0026	185	198	383	384	Result: (All heating is read as heating and all cooling is read as cooling)
TEST 9	0	185	199	384	384	Result: (1 result in the field of (C) heating, read by cooling in the field of (Ytr))
TEST 10	0	186	198	384	384	Result: (1 result in the field of (C) cooling read by heating in the field of (Ytr))

4. Conclusion

Mechanical Engineering is a hot topic for modern applications. One of these areas is heating and cooling system at design modern building. Therefore, engineering spends money and time to configure HVAC system with all of these efforts still build suffer from a shortage of services. For this, we design a modern system that has the ability to predicate heating and cooling system for any building. However, this will arrange this HVAC system automatically without any human interaction. On the other side, machine learning makes the proposed more efficient by sensing all surrounding environment. In this case, the building will provide by HVAC automatically. According to the testing/ evaluating system of the proposed system, we can easily notice that intelligent HVAC can adopt with modern building with acceptance results.

In future directions, this proposed system will be tested with other data set to confirm its efficacy. Hence, this dataset will be employed with other artificial tools, such as deep learning, neural networks and k nearest neighbor.

5. References

[1] PDF and S. Y. P. C. D. Wong, "Managing behavior of intelligent environments," *Proc. First IEEE Int. Conf. Pervasive Comput. Commun. 2003. (PerCom 2003)*, 2003.

[2] and D. R. R. Minerva, A. Biru, "Towards a definition of the Internet of Things (IoT)," *IEEE Internet Initiat.*, no. 1, 2015.

[3] A. C. W. W. and A. T. P., "Building automation in the 21st century," *Proc. 4th Int. Conf. Adv. Power Syst. Control. Oper. Manag.*, pp. 819–824, 1997.

[4] P. C. Y. S. M. Tsai, S. S. Wu, S. S. Sun, "Integrate home service network on intelligent intranet," *IEEE Trans. Consum. Electron*, vol. 46, pp. 499–504, 2000.

[5] M. M. Froufe, C. K. Chinelli, A. L. A. Guedes, A. N. Haddad, A. W. A. Hammad, and C. A. P. Soares, "Smart buildings: Systems and drivers," *Buildings*, vol. 10, no. 9, pp. 1–20, 2020.

[6] R. K. U. R. V. N. P. K. S. S. Radha, "IoT Based Intelligent Control System for Smart Building," *2020 Int. Conf. Innov. Intell. Informatics, Comput. Technol.*, 2020.

[7] H. Chen, P. Chou, S. Duri, H. Lei, and J. Reason, "The design and implementation of a smart building control system," *Proc. - IEEE Int. Conf. E-bus. Eng. ICEBE 2009; IEEE Int. Work. - AiR 2009; SOAIC 2009; SOKMBI 2009; ASOC 2009*, no. January, pp. 255–262, 2009.

[8] H. Farzaneh, L. Malehmirchegini, A. Bejan, T. Afolabi, A. Mulumba, and P. P. Daka, "Artificial intelligence evolution in smart buildings for energy efficiency," *Appl. Sci.*, vol. 11, no. 2, pp. 1–26, 2021.

[9] H. Y. Huang, J. Y. Yen, S. L. Chen, and F. C. Ou, "Development of an intelligent energy management network for building automation," *IEEE Trans. Autom. Sci. Eng.*, vol. 1, no. 1, pp. 14–25, 2004.

[10] I. G. Park, "The remote control system for the next generation air conditioners," *IEEE Trans. Consum. Electron.*, vol. 47, no. 1, pp. 168–178, 2001.

[11] S. Wang and J. Xie, "Integrating Building Management System and facilities management on the Internet," *Autom. Constr.*, vol. 11, no. 6, pp. 707–715, 2002.

[12] I. Szilagyi and P. Wira, "An intelligent system for smart buildings using machine learning and semantic technologies: A hybrid data-knowledge approach," *Proc. - 2018 IEEE Ind. Cyber-Physical Syst. ICPS 2018*, pp. 20–25, 2018.

[13] L. Wan and R. Xu, "Study of intelligent building system based on the internet of things," *AIP Conf. Proc.*, vol. 1820, no. March, 2017.